EOS ECOLOGY

Styx Mill Aquatic Ecology Annual Monitoring 2016

EOS Ecology Report No. CHR01-16018-01 | March 2016

AQUATIC SCIENCE & VISUAL COMMUNICATION

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REPORT

Prepared for
Christchurch City Council

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EXECUTIVE SUMMARY

The Styx Stormwater Management Plan resource consent (CRC131249) requires annual aquatic ecological monitoring at a single site on the Styx River within the Styx Mill Conservation Reserve. EOS Ecology undertook the latest round of monitoring in February 2016. The purpose was to assess compliance against the surface water quality objectives of the consent. Comparisons were also made with data from previous years (2008, 2013, 2014, and 2015).

The table below compares the relevant 2016 results with the surface water quality objectives of Consent CRC 131249 (cells are shaded where objectives are not met). The only consent objective not met was QMCI, where the mean score of 4.4 was just below the prescribed minimum of 4.5.

Parameter	Surface water quality objectives from Consent CRC131249	Results from 11 February 2016 survey
Quantitative macroinvertebrate community index (QMCI)	Minimum score of 4.5	4.4
Fine sediment cover (<2 mm diameter)	Maximum of 40%	20%
Total macrophyte cover	Maximum of 50%	41%
Filamentous algae cover (>20 mm long)	Maximum of 30%	0%

Habitat conditions have remained broadly similar over time. The site has a stony substratum dominated by pebble-sized rocks (16–64 mm diameter), moderate centre-channel water velocities (mean = 0.5 m/s) and depths (mean = 0.3 m), low canopy cover, and a riparian zone of unmanaged grass and herbs with some shrubs and trees. Thin algal mats covered much of the substratum and no filamentous algae were observed. Macrophytes consisted of mostly exotic species commonly found in spring-fed lowland waterways, with *Ranunculus trichophyllus* (water buttercup) being dominant in 2016.

The macroinvertebrate community appears to have undergone a shift in some of the dominant taxa between 2014 and 2015 with this being maintained in 2016. In 2015 and 2016 the three dominant taxa in order of relative abundance were *Potamopyrgus* snails, *Pycnocentrodes* cased caddisflies, and *Deleatidium* mayflies. The presence of two EPT taxa, including *Deleatidium* (now absent from the more urbanised Ōtākaro/Avon River and Ōpāwaho/Heathcote River catchments) among the most abundant taxa at this site is encouraging and implies stormwater discharges may not be having an adverse effect on macroinvertebrates (as measured by semi-quantitative sampling). However, the current monitoring programme is not well designed to determine the true impacts of stormwater discharges on the Styx River catchment, and thus recommendations to address this are provided.

1 PURPOSE

As part of Christchurch City Council's (CCC) resource consent for the Styx Stormwater Management Plan (SMP) (CRC131249), annual aquatic ecological monitoring is required from a single site on the Styx River within the Styx Mill Conservation Reserve. This is the third year of monitoring under this consent (see James, 2014; Blakely, 2015), although this site had been monitored prior to the Styx SMP becoming operative, as part of the CCC's long-term monitoring programme (see McMurtrie & Greenwood, 2008; James, 2013). The purpose of the current monitoring is to assess compliance against the surface water quality objectives of the consent (Table 1).

Table 1 Styx Stormwater Management Plan (CRC131249) surface water quality objectives for the Styx River at Styx Mill Conservation Reserve site.

Minimum QMCI	Maximum Fine Sediment (<2 mm diameter) Cover	Maximum Total Macrophyte Cover of Streambed	Maximum Filamentous Algae Cover of Streambed
4.5	40%	50%	30%

2 METHODS

2.1 Site

The site sampled was within the Styx Mill Conservation Reserve (location coordinates: E2478252 N5749370) (Figure 1). This site was chosen by the CCC for annual sampling because of its high ecological and community values. Representative site photos are shown in Appendix 8.1. This site was previously sampled on 13 March 2008 (McMurtrie & Greenwood, 2008) and 27 February 2013 (James, 2013) as part of the CCC's long-term monitoring of aquatic invertebrates and fish where it was designated as "Site 14". Under the Styx Stormwater Management Plan (CRC131249) it was sampled on 21 February 2014 (James, 2014) and 10 February 2015 (Blakely, 2015) for the first two years of Styx SMP monitoring. The results of these previous surveys are detailed in each respective report however, relevant data from those surveys are provided for comparison with the 2016 data in this report.

Figure 1 Location of the Styx River sampling site within the Styx Mill Conservation Reserve.

2.2 Sampling

The site was sampled on 11 February 2016 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. Some physico-chemical parameters were also assessed on a reach-scale.

2.2.1 Instream and Riparian Habitat Conditions

Instream habitat variables were quantified at five 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 five points on each of the three transects included wetted width, depths (water, macrophyte and fine sediment), embeddedness, substrate composition (silt/sand: 0.01–2 mm; gravel: 2–16 mm; pebble: 16–64 mm; small cobble: 64–128 mm; large cobble: 128–256 mm; boulder >256 mm), and presence and type of organic material (i.e., macrophytes, algae, moss/liverworts, fine/coarse detritus, and terrestrial vegetation). Macrophyte and periphyton (algae) measurements are further described below. Water velocity was measured (using a Sontek ADV meter) at three points across each of the three transects (25%, 50%, and 75% of channel width). As per standard convention, velocity was measured at 0.4 × the water depth, and was measured over a 30 second interval.

General bank attributes, including bank material composition, lower and upper bank height (cm) and slope, riparian vegetation (composition and % cover), canopy cover (%), horizontal bank undercut (cm), and overhanging vegetation (cm), groundcover vegetation (%), and bank erosion (%) were measured for each bank at each transect.

Across the entire reach, flow habitat composition (i.e., riffle, run, pool %) was estimated. Substrate composition (%) was also estimated across the entire reach, specifically to determine fine sediment (<2 mm) cover for assessing compliance with the objectives of the Styx Stormwater Management Plan (CRC131249) as this site-wide measure was used in previous monitoring reports (James, 2014; Blakely, 2015).

2.2.2 Water Quality

Spot measures of dissolved oxygen, conductivity, pH, and temperature were taken from the mid-channel with calibrated handheld field meters. Dissolved oxygen and temperature were measured with an YSI ProODO, conductivity with a Eutech TDScan 3, and pH with a Eutech pHTestr 30.

2.2.3 Macrophytes and Periphyton

Macrophyte cover, composition, and species was assessed at the five points across each of the three transects. This involved visual estimation of streambed cover (%), identification of the dominant species present, and identification of the type present (emergent or submerged). The percentage streambed cover by macrophytes, macrophytes type (emergent or submerged), and the dominant species were also assessed within a 1-m band at across each of the three transects.

Periphyton cover (%) and composition was visually estimated at the five points across each transect following the Biggs & Kilroy (2000) algal classifications of 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)

Because macrophyte and periphyton 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 and periphyton cover was also undertaken over the entire site. Site-wide measurements were also used to test for compliance with the objectives in the Styx SMP (CRC131249) as had been done in previous monitoring reports (James, 2014; Blakely, 2015).

Channel maintenance involving macrophyte removal occurs periodically at this site. Based on information in the project Request for Quotation document (Christchurch City Council, 2016), it is assumed no such macrophyte removal was undertaken in the months prior to sampling.

2.2.4 Aquatic Macroinvertebrates

Aquatic benthic invertebrates were collected at each transect by following the semi-quantitative C1 (hard-bottomed) kick net protocol of Stark *et al.* (2001). 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 following the P3 (full count with subsampling) protocol of Stark *et al.* (2001). All invertebrates were counted and identified to the same level of classification as the 2015 data provided by CCC.

2.3 Data Analysis

For those parameters measured across each of the transects, mean values for each transect were calculated. For wetted width (measured at each transect) a single site mean was calculated.

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

Substrate index = [(0.03 x %sand/silt) + (0.04 x %gravel) + (0.05 x %pebble) + (0.06 x (%small cobble + %large cobble)) + (0.07 x %boulder)

Where derived values for the substrate index range from 3 (i.e., a substrate of 100% sand/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.

Invertebrate data were summarised by taxa richness, total abundance, and abundance of the five most common taxa, and non-metric multidimensional scaling ordination (NMS). 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.

» NMS is an ordination of data that is often used to examine how communities composed of many different taxa differs between sites. It can graphically describe communities by representing each site as a point (an ordination score) on an x–y plot. The location of each point/site reflects its community composition, as well as its similarity to communities in other sites/points. Thus points situated close together indicate sites with similar macroinvertebrate communities, whereas points with little similarity are situated further away. Habitat variables can also be associated with the different axes, indicating whether the macroinvertebrate communities are responding to habitat differences.

» 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%. To indicate significant differences between means (ANOVA) or medians (Kruskal-Wallis), the Holm-Sidak (ANOVA) or Dunn's (Kruskal-Wallis) were used.

3 RESULTS

3.1 Physical Habitat

Spot measures of temperature, pH, conductivity, and dissolved oxygen (DO) were similar to those recorded in 2015 (Table 2). Temperatures were well below the Canterbury Land & Water Regional Plan (CLWRP) maximum of 20°C and DO was above the CLWRP minimum saturation of 70% for "Spring-fed –plains" and "Spring-fed –plains Urban" waterways (Environment Canterbury, 2015). It is important to note that spot water quality measures of temperature, pH, and DO are not particularly useful at characterising these parameters as they all vary over a 24 hour cycle, hence any interpretation must be done with caution. For example, minimum dissolved oxygen levels generally occur at night thus continuous measurement over a 24 hour period would be required to truly determine minimum DO saturation. Conductivity was relatively low indicating relative few dissolved ions in the water, while pH was circum-neutral (Table 2).

Table 2 Water quality and habitat attributes from the Styx Mill Conservation Reserve site from surveys undertaken in March 2008, February 2013, 2014, 2015, and 2016.

Sampling Date		**13 March 2008[1]**	**27 February 2013[2]**	**21 February 2014[3]**	**10 February 2015[4]**	**11 February 2016**
Spot temperature (°C)		Not measured	Not measured	Not measured	13.6	13.8
Spot pH		Not measured	Not measured	Not measured	6.90	7.37
Spot conductivity (µS/cm)		Not measured	Not measured	Not measured	137	110
Dissolved oxygen (%)		Not measured	Not measured	Not measured	86	79.2
Substrate composition (dominant substrate is in bold)	Large cobble	2%	0%	1%	1%	0%
	Small cobble	5%	0%	5%	16%	1%
	Pebbles	0%	40%	**70%**	**37%**	**74%**
	Gravel	**60%**	15%	5%	15%	5%
	Sand/Silt	33%	**45%**	21%	31%	20%
Surrounding land use		100% park/reserve	100% park/reserve	100% park/reserve	Park/reserve, with some residential on true left and farming on true right	100% park/reserve
Habitat type (% riffle:run:pool)		0:100:0	0:100:0	0:100:0	0:100:0	0:100:0
Bank material composition		Earth (minor wood)	Earth	Earth	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.	Grasses, cabbage trees, flax lancewoods, *Carex* sedges, willow, toe toe	Grass/herb mix, *Carex* sedges, flax, toe toe, cabbage trees, willows
Canopy cover (% Stream shade)		5–25%	<5%	5–25%	<5%	5–25%
Substrate embeddedness		50–75%	25–50%	25–50%	25–50%	5–25%

[1]From McMurtrie & Greenwood (2008); [2]From James (2013); [3]From James (2014); [4]From Blakely (2015)

Pebble-sized stones (16–64 mm diameter) have been the most common substrate class for the last three years, followed by sand/silt (<2 mm diameter) (Table 2). Since the site is within a CCC-managed conservation reserve the surrounding land use, bank material, and riparian vegetation have changed little (Table 2). Water depth and fine sediment depth both showed statistically significant differences over the five years of data (Figure 2; Table 3). Water depths were greater in 2013 and 2014, while they have been similar over the last two years. Fine sediment depth was relatively high in 2014, but has been consistently low (<5 cm) over the last two years (Figure 2). Water velocity (as measured in the centre of the channel), wetted width, and water velocity have be relatively similar over time and showed no statistically significant differences (Figure 2; Table 3).

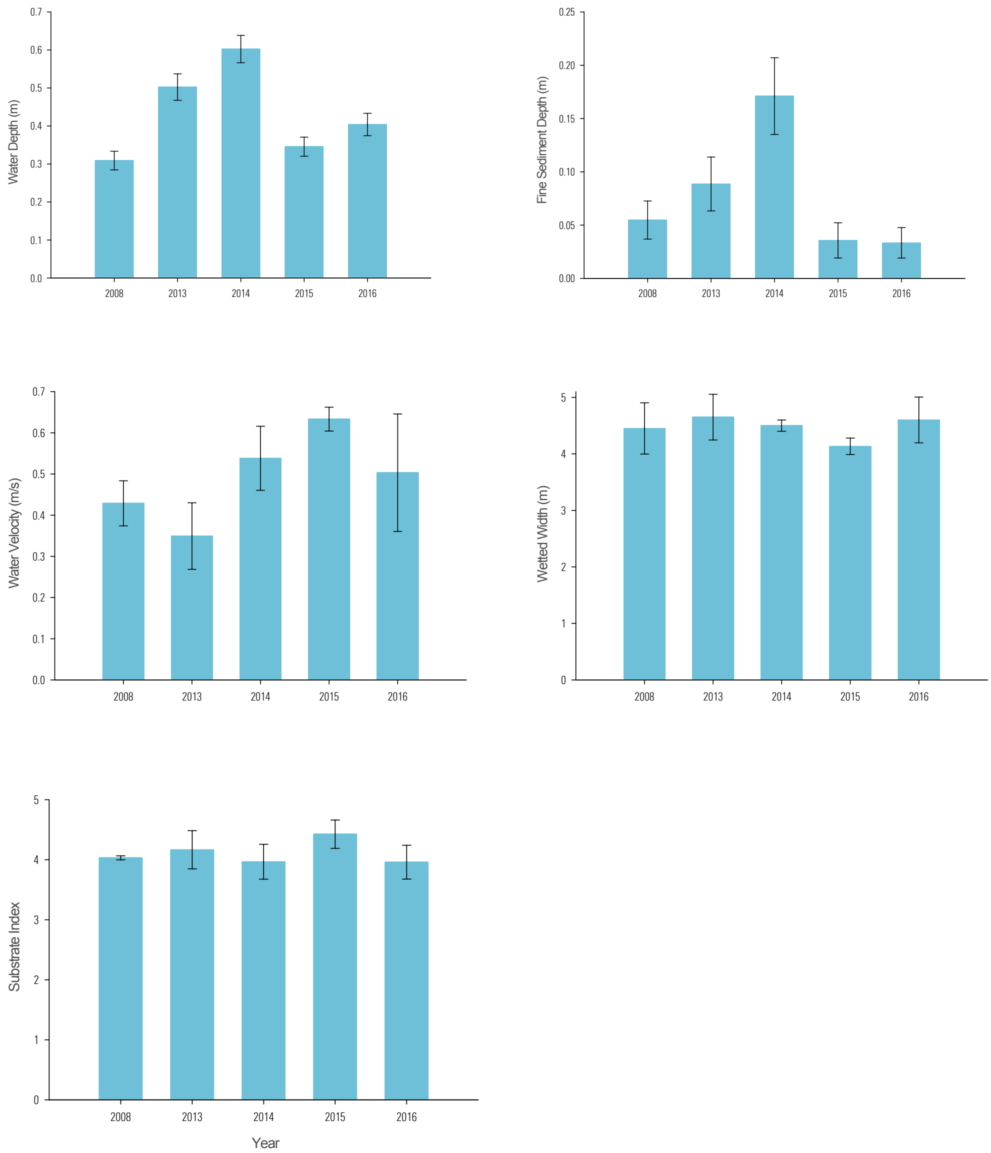

Figure 2 Mean (+/- 1 SE) aquatic habitat attributes of the survey site on 13 March 2008, 27 February 2013, 21 February 2014, 10 February 2015, and 11 February 2016.

Table 3 Results of one-way analysis of variance (ANOVA) on aquatic habitat attributes from the survey site on 13 March 2008, 27 February 2013, 21 February 2014, 10 February 2015, and 11 February 2016. The non-parametric Kruskal-Wallis test was used where the assumptions of ANOVA could not be met even after data transformation. The Holm-Sidak (ANOVA) or Dunn's (Kruskal-Wallis) multiple comparison procedure was used to indicate significant differences among means or medians.

Parameter	Statistic	N	H or F value	*p*	Significant Difference?	Multiple Comparison
Water depth	Kruskal-Wallis	2008, 2013, 2014: 36 2015, 2016: 15	H=48.53	<0.001	Yes	2008=2015=2016<2013=2014
Fine sediment depth	Kruskal-Wallis		H=9.66	0.047	Yes	Difference too weak for Dunn's Test to determine which medians differed.
Water velocity (centre-channel)	ANOVA	3	$F_{4,10}$=1.58	0.25	No	2008=2013=2014=2015=2016
Substrate Index	Kruskal-Wallis	2008, 2013, 2014: 3 2015, 2016: 15	H=3.44	0.49	No	2008=2013=2014=2015=2016
Wetted width	ANOVA	3	$F_{4,10}$=0.36	0.83	No	2008=2013=2014=2015=2016

3.2 Macrophytes and Periphyton

The macrophyte community has shown some variation over time, but is generally dominated by a few exotic species (Table 4). A notable exception was 2014 when the native *Myriophyllum triphyllum* was dominant. In 2016 *Ranunculus trichophyllus* (water buttercup) was the dominant macrophyte while thin algal mats covered much of the substratum (Table 4). Total cover of macrophytes as measured across the three transects were similar between 2015 and 2016 (Figure 3; Table 5), while that estimated across the whole reach (and used for assessing compliance with the objectives of the Styx SMP consent) was lower in 2016 compared to 2014 and 2015 (Table 4). Macrophyte depth was significantly different over time with 2014 having higher values than other years (Figure 3; Table 5). This corresponds with the relatively high bed coverage of *M. triphyllum* (70%) observed in that year (Table 4). No filamentous algae were observed in 2016 (Table 4).

Table 4 Organic matter attributes (including macrophyte and periphyton) from the Styx Mill Conservation Reserve site from surveys undertaken in March 2008 (McMurtrie & Greenwood, 2008), February 2013 (James, 2013), February 2014 (James, 2014), February 2015 (Blakely, 2015), and February 2016. 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 subsequent years the categories of Biggs & Kilroy (2000) were used. The 2015 data did not include site wide estimates of the coverage of each algae or organic matter category or macrophyte species; hence no percentages are shown for that column.

Sampling Date	13 March 2008[1]	27 February 2013[2]	21 February 2014[3]	10 February 2015[4]	11 February 2016
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%**	*M. guttatus* (monkey musk)	Algal mats (thin): 55%
	Algal mats: 5%	***Ranunculus trichophyllus* (water buttercup): 15%**	*E. canadensis* (Canadian pondweed): 15%	*Rorippa* (watercress)	***Ranunculus trichophyllus* (water buttercup): 20%**
	***Elodea canadensis* (Canadian pondweed): 5%**	*P. crispus* (curly pondweed): 10%	*Rorippa* (watercress): 5%	*Glyceria* (sweetgrass)	*E. canadensis* (Canadian pondweed): 5%
	***Potamogeton crispus* (curly pondweed): 5%**	*E. canadensis* (Canadian pondweed): 5%	*Glyceria* (sweetgrass): 1%	*Ranunculus trichophyllus* (water buttercup)	*Glyceria* (sweetgrass): 5%
	Fine detritus (leaf litter): 5%	*Rorippa* (watercress): 5%	*M. guttatus* (monkey musk): 1%	Coarse woody debris and leaves	*Rorippa* (watercress): 5%
	Glyceria (sweetgrass): 3%	Terrestrial roots/vegetation: 5%	Terrestrial roots/vegetation: 1%	Moss	*M. guttatus* (monkey musk): 4%
	Rorippa (watercress): 1%	*Azolla*: 1%			*Ranunculus repens* (creeping buttercup: (1%)
		Woody debris: 1%			Terrestrial roots/vegetation: 2%
		Lemna minor (duckweed): 1%			Large woody debris: 2%
		Mimulus guttatus (monkey musk): 1%			Moss/liverworts: 0.5%
		Moss/liverworts: 1%			*Azolla filiculoides* (Pacific azolla): 0.5%
Emergent macrophyte cover	4%	8%	6%	?	11%
Total macrophyte cover (includes submerged and emergent macrophytes)	14%	38%	92%	70%	41%
Filamentous algal cover	0%	0%	0%	9%	0%

[1]From McMurtrie & Greenwood (2008); [2]From James (2013); [3]From James (2014); [4]From Blakely (2015)

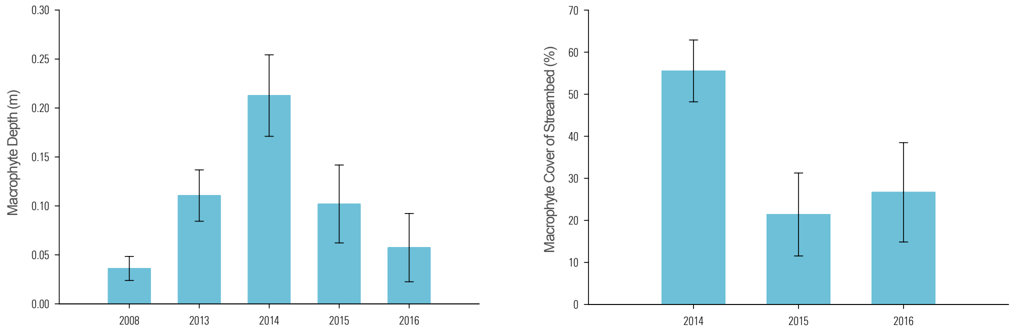

Figure 3 Mean (+/- 1 SE) macrophyte depth (March 2008, February 2013–2016) and macrophyte cover (February 2014–2016) as measured across the three transects of the Styx River at Styx Mill Conservation Reserve survey site.

Table 5 Results of one-way analysis of variance (ANOVA) on macrophyte depth (March 2008, February 2013–2016) and macrophyte cover (February 2014–2016) as measured across the three transects of the Styx River at Styx Mill Conservation Reserve survey site. The non-parametric Kruskal-Wallis test was used where the assumptions of ANOVA could not be met even after data transformation. The Dunn's 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	2008, 2013, 2014: 36 2015, 2016: 15	H=12.93	0.012	Yes	Difference too weak for Dunn's Test to determine which medians differed
Macrophyte cover	Kruskal-Wallis	2014: 3 2015, 2016: 15	H=3.03	0.220	No	2014=2015=2016

3.3 Aquatic Macroinvertebrates

A total of 26 taxa were found at the Styx River SMP monitoring site in 2016; the same number as in 2015. The most diverse groups were caddisflies (Trichoptera: 9 taxa), two-winged flies (Diptera: 6 taxa), molluscs (Mollusca: 5 taxa), and crustaceans (Crustacea: 2 taxa). Coleoptera (beetles), Ephemeroptera (mayflies), worms (Oligochaeta), and flatworms (Platyhelminthes) were each represented by one taxon. Both 2015 and 2016 had the same three dominant taxa with the snail *Potamopyrgus antipodarum* being the dominant taxa, and accounting for 70% of all invertebrates sampled in 2016 (Table 6). Three of the five most abundant taxa in 2015 and 2016 were EPT "cleanwater" taxa (the mayfly *Deleatidium* and cased caddisflies *Pycnocentrodes* and *Pycnocentria*) (Table 6).

Table 6 Percentage abundance of the five most abundant aquatic macroinvertebrate taxa from the Styx River at Styx Mill Conservation Reserve survey site in March 2008 and February 2013–2016. EPT taxa are highlighted in bold.

Sampling Date	13 March 2008[1]	27 Feb 2013[2]	21 Feb 2014[3]	10 Feb 2015[4]	11 Feb 2016
Five most abundant taxa (% relative abundance)	*Paracalliope fluviatilis* (amphipod crustacean): 37%	*Paracalliope fluviatilis* (amphipod crustacean): 33%	*Paracalliope fluviatilis* (amphipod crustacean): 63%	*Potamopyrgus antipodarum* (snail): 34%	*Potamopyrgus antipodarum* (snail): 70%
	Potamopyrgus antipodarum (snail): 27%	*Potamopyrgus antipodarum* (snail): 15%	*Potamopyrgus antipodarum* (snail): 13%	***Pycnocentrodes* (cased caddisfly): 19%**	***Pycnocentrodes* (cased caddisfly): 11%**
	Ostracoda (seed shrimp crustacean): 12%	Ostracoda (seed shrimp crustacean): 12%	Ostracoda (seed shrimp crustacean): 10%	***Deleatidium* (mayfly): 12%**	***Deleatidium* (mayfly): 6%**
	Orthocladiinae (midge larvae): 7%)	***Pycnocentria* (cased caddisfly): 9%**	***Deleatidium* (mayfly): 2%**	Oligochatea (oligochaete worm): 10%	Ostracoda (seed shrimp crustacean): 4%
	***Pycnocentrodes* (cased caddisfly): 4%**	***Deleatidium* (mayfly): 6%**	***Hudsonema amabile* (cased caddisfly): 2%**	***Pycnocentria* (cased caddisfly): 5%**	***Pycnocentria* (cased caddisfly): 2%**

[1]From McMurtrie & Greenwood (2008); [2]From James (2013); [3]From James (2014); [4]From Blakely (2015)

Total abundance and taxa richness were lower in 2016 compared to previous years, however these differences were not statistically significant (Figure 4; Table 7). There were also no statistically significant differences in EPT richness or %EPT, with %EPT being particularly variable over the years (Figure 4; Table 7). MCI-hb and QMCI-hb have shown little variation over time and always being in the "fair" water quality interpretation category of Stark & Maxted (2007) (Figure 4; Table 7). UCI and QUCI scores have remained positive over time, which is indicative of an invertebrate community that prefers a hard substrate and faster flowing water (Figure 4). There have been no statistically significant differences in QUCI over time, while UCI was the only metric to have a significant difference (Table 7). However, this difference was too weak for the multiple comparison tests to indicate which mean(s) differed from the others, although from Figure 4 it appears UCI scores in 2013 and 2014 where lower than those of 2008, 2015, and 2016. Given all the scores are positive, it is unlikely there is any ecological significance of this result.

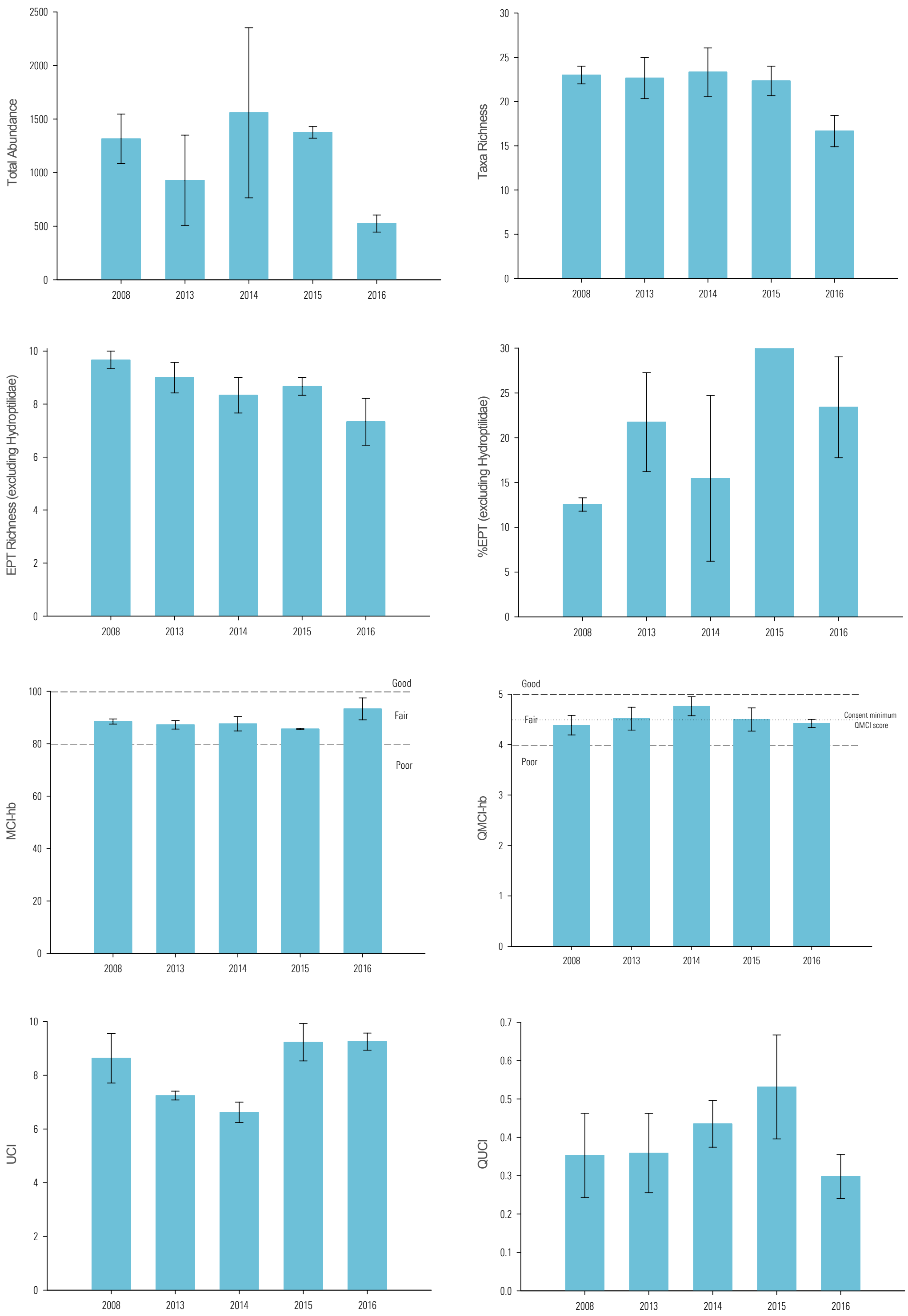

Figure 4 Mean (+/- 1 SE) macroinvertebrate community metrics of the Styx River at Styx Mill Conservation Reserve survey site on 13 March 2008, 27 February 2013, 21 February 2014, 10 February 2015, and 11 February 2016. N=3. Note that hydroptilid caddisflies were excluded from the EPT metrics, as they 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 dotted line on the QMCI-hb graph shows the minimum QMCI score of Consent CRC131249.

Table 7 Results of one-way analysis of variance (ANOVA) on macroinvertebrate community metrics from the Styx River at Styx Mill Conservation Reserve survey site on 13 March 2008, 27 February 2013, 21 February 2014, 10 February 2015, and 11 February 2016. The Holm-Sidak 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	$F_{4,10}$=0.98	0.46	No	2008=2013=2014=2015=2016
Taxa richness	ANOVA	3	$F_{4,10}$=1.96	0.18	No	2008=2013=2014=2015=2016
EPT richness	ANOVA	3	$F_{4,10}$=2.09	0.16	No	2008=2013=2014=2015=2016
% EPT	ANOVA	3	$F_{4,10}$=2.51	0.11	No	2008=2013=2014=2015=2016
MCI-hb	ANOVA	3	$F_{4,10}$=1.47	0.28	No	2008=2013=2014=2015=2016
QMCI-hb	ANOVA	3	$F_{4,10}$=0.60	0.67	No	2008=2013=2014=2015=2016
UCI	ANOVA	3	$F_{4,10}$=4.49	0.03	Yes	Difference too weak for Holm-Sidak procedure to identify
QUCI	ANOVA	3	$F_{4,10}$=0.85	0.52	No	2008=2013=2014=2015=2016

NMS ordination shows some separation of the macroinvertebrate communities of 2008, 2013, and 2014 with those from 2015 and 2016 along Axis 1 (Figure 5). This is driven primarily by the abundance of the snail *Potamopyrgus* and the cased-caddisfly *Pycnocentrodes* in 2015 and 2016 while 2008, 2013, and 2014 samples are associated with *Paracalliope* amphipods and *Hydrobiosis* caddisflies (Figure 5). These results align with the shift in dominant taxa between these two groups of years (i.e., 2008, 2013, 2014 and 2015, 2016) as shown on Table 6. In terms of habitat variables, the 2008, 2013, and 2014 were associated with greater water depths and fine sediment depths.

In summary, the macroinvertebrate community has changed between 2014 and 2015 from being dominated by *Paracalliope* (along with *Potamopyrgus* and Ostracoda) to one dominated numerically be *Potamopyrgus* along with two EPT taxa, *Pycnocentrodes* and *Deleatidium*, which have persisted into 2016. It is unclear what has caused the decline in *Paracalliope* and rise in *Pycnocentrodes* and *Deleatidium* at this site. Whatever the case, the increase in these EPT species (especially *Deleatidium*) could be interpreted that stormwater is not having an adverse affect at this site (as measured by semi-quantitative biomonitoring), given the greater sensitivity of EPT taxa to pollution compared to other taxa.

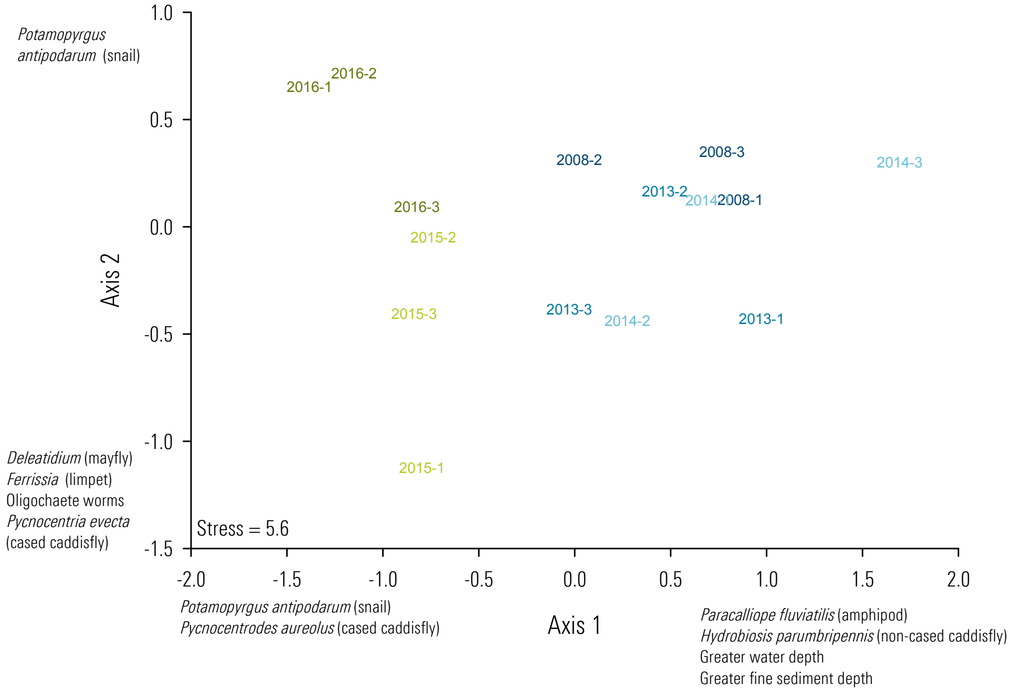

Figure 5 Non-metric multidimensional scaling (NMS) ordination plot of macroinvertebrate data from the Styx River at Styx Conservation Reserve monitoring site. Each point represents one of the three kick net samples taken in that respective year. Macroinvertebrates and habitat variables that are significantly associated with each axis are shown. The low stress value of 5.6 indicates the ordination is good with no real risk of drawing false inferences.

4 STYX RIVER SMP WATER QUALITY OBJECTIVES COMPARISON

Of the surface quality objectives from Consent CRC131249 only QMCI was breached on 11 February 2016 with the mean score of 4.4 being just below the “minimum score of 4.5” objective (Table 8).

Compared against the Canterbury Land and Water Regional Plan (Environment Canterbury, 2015) “freshwater outcomes”, emergent macrophyte cover, total macrophyte cover, and filamentous algae cover were below the maximum percentages for “spring-fed plains” and “spring-fed plains urban” waterways (Table 9). Fine sediment cover was at the maximum for “spring-fed plains” waterways and below that for “spring-fed plains urban” waterways (Table 9). QMCI was below the minimum score for “spring-fed plains” waterways and well above that for “spring-fed plains urban” waterways (Table 9).

Table 8 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 (11 February 2016). Parameters that breach the objectives are shaded.

Parameter	Surface water quality objectives from Consent CRC131249	Results from 2016 survey
Quantitative macroinvertebrate community index (QMCI)	Minimum score of 4.5	4.4
Fine sediment cover (<2 mm diameter)	Maximum of 40%	20%
Total macrophyte cover	Maximum of 50%	41%
Filamentous algae cover (>20 mm long)	Maximum of 30%	0%

Table 9 Comparison of selected "Freshwater outcomes for Canterbury Rivers" from Table 1a of the Canterbury Land and Water Regional Plan (Environment Canterbury, 2015) with measurements taken during the most recent survey at the Styx Mill Conservation Reserve site (11 February 2016).

Parameter	Canterbury Land & Water Regional Plan		Results from February 2016 survey
	Spring-fed –plains	Spring-fed –plains Urban	
Quantitative macroinvertebrate community index (QMCI)	Minimum of 5	Minimum of 3.5	4.4
Fine sediment (<2 mm diameter) cover	Maximum cover of 20%	Maximum cover of 30%	20%
Emergent macrophyte cover	Maximum cover of 30%	Maximum cover of 30%	11%
Total macrophyte cover	Maximum cover of 50%	Maximum cover of 60%	41%
Filamentous algae cover (>20 mm long)	Maximum cover of 30%	Maximum cover of 30%	0%

5 ASSESSMENT OF STORMWATER EFFECTS

It is difficult to determine if stormwater discharges are having any impact on the receiving environment based on standard habitat and biomonitoring data collection at a single site. What can be said is that the macroinvertebrate community was relatively stable from 2008–2014, while there was a shift in dominant taxa in 2015 with EPT taxa (*Pycnocentrodes* and *Deleatidium*) accounting for a greater proportion of the invertebrates captured. This change was maintained in 2016; hence these EPT taxa seem to be doing well at this site. The high relative abundance of the mayfly *Deleatidium* was encouraging and since this taxon is now absent from the more urbanised Ōtākaro/Avon River and Ōpāwaho/Heathcote River catchments, it could be interpreted that stormwater (and the other impacts associated with urbanisation) is not having an adverse affect at this site (as measured by semi-quantitative biomonitoring). However, the current monitoring methodology does limit how much can be concluded in regards to the impacts of a stormwater discharge on the receiving environment.

6 RECOMMENDATIONS

A full list of recommendations was given in James (2014) and they are still relevant now. In summary, a monitoring programme that is more effective at detecting stormwater discharge effects on aquatic ecology would include:

- 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 stormwater is more likely to be discharging, rather than collecting only dry weather samples.
- More than one biological monitoring site, including reference sites that receive no or minimal stormwater discharges, so as to separate out natural stochasticity from any stormwater/urban-related impacts.

Finally, macrophyte growth in the Styx River is more to do with a lack of canopy cover, stable flows, nutrient levels of the groundwater at the various springheads, and the CCC's channel maintenance programme rather than stormwater discharges. Thus compliance with the discharge consent objective relating to macrophyte cover would not be as relevant as some of the other consent conditions.

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8 APPENDIX

8.1 Site Photos – Looking downstream from upstream survey boundary


2015
Photo by Boffa Miskell


2016

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