EOS ECOLOGY

Styx Mill Aquatic Ecology Annual Monitoring 2017

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AQUATIC SCIENCE & VISUAL COMMUNICATION

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Prepared for Christchurch City Council

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EXECUTIVE SUMMARY

Under the Styx Stormwater Management Plan resource consent (CRC131249), annual ecological monitoring is required at a single site within the Styx Mill Conservation Reserve in order to assess compliance against surface water quality objectives. EOS Ecology carried out the most recent round of monitoring on 23 February 2017. The results of this monitoring round were compared against the consent objectives as well as the results of previous monitoring at the Styx Mill Conservation Reserve site.

The table below provides a comparison of the 2017 monitoring results with the objectives as set out in the Consent (CRC131249). Cells are highlighted to indicate where the consent criteria were not met; the objectives not met were quantitative macroinvertebrate community index (QMCI) and total macrophyte cover.

Parameter	Surface water quality objectives from Consent CRC131249	Results from 2017 survey
Quantitative macroinvertebrate community index (QMCI)	Minimum score of 4.5	4.0
Fine sediment cover (<2 mm diameter)	Maximum of 40%	20%
Total macrophyte cover	Maximum of 50%	69.5%
Filamentous algae cover (>20 mm long)	Maximum of 30%	0%

Spot water quality measurements and habitat attributes have not changed substantially over the course of monitoring at this site. The site is characterised by a hard gravel (2–16 mm) and pebble (16–64 mm) substrate, moderate water velocity (centre-channel mean: 0.45 m/s), low stream shading, and surrounding land use of park/reserve with a mix of native and exotic riparian plants. Macrophyte cover at this site in February 2017 was above the maximum consent value for percentage cover, and was dominated by the exotic species *Ranunculus trichophyllus* (water buttercup).

Over the six years of monitoring data at this site, the macroinvertebrate community has undergone several shifts in the three most abundant taxa from *Paracalliope*, *Potamopyrgus* and Ostracoda (2008, 2013, 2014) to *Potamopyrgus*, *Pycnocentrodes,* and *Deleatidium* (2015, 2016), and most recently Ostracoda, *Potamopyrgus*, and *Pycnocentrodes* (2017). MCI and QMCI declined slightly from 2016 to 2017 (not statistically significant), and trend analysis indicates that total abundance of macroinvertebrates and the richness of EPT taxa are also declining. However, three of the five most abundant taxa recorded were EPT taxa (*Pycnocentrodes*, *Deleatidium*, *Pycnocentria*), suggesting the site still has a relatively high aquatic ecological value (in terms of the macroinvertebrate community) compared to more urbanised catchments within Christchurch. Interpretation of the survey results with regards to the impact of stormwater discharge on the Styx River is limited by the methodology of the current sampling programme, and therefore recommendations are provided to address these limitations.

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 fourth year of monitoring under this consent (see James, 2014; Blakely, 2015; James, 2016), although previous monitoring was carried out at this site 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), although consideration is also given to compliance against relevant thresholds in the Environment Canterbury Land and Water Regional Plan (Table 2).

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

Minimum Quantitative macroinvertebrate community index (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%

Table 2 Relevant "Freshwater outcomes for Canterbury Rivers" from Table 1a of the Canterbury Land and Water Regional Plan (Environment Canterbury, 2015). Indicator values for "spring-fed –plains" and "spring-fed – plains Urban" are included as the Styx River falls within both categories.

	Minimum Quantitative macroinvertebrate community index (QMCI)	Minimum dissolved oxygen saturation	Maximum temperature	Maximum fine sediment (<2 mm diameter) cover	Maximum emergent macrophyte cover	Maximum total macrophyte cover	Maximum filamentous algae cover (>20 mm long)
Spring-fed – plains	5	70%	20°C	20%	30%	50%	30%
Spring-fed – plains Urban	3.5	70%	20°C	30%	30%	60%	30%

2 METHODS

2.1 Site

The site sampled was within the Styx Mill Conservation Reserve (location coordinates: E2478252 N5749370) (Figure 1). The CCC chose this site 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), 10 February 2015 (Blakely, 2015) and 23 February 2016 (James, 2016) for the first three years of the 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 2017 data in this report.

2.2 Sampling

The site was sampled on 23 February 2017 while the river was at base flow. At each site, three transects were placed across the stream at 10m 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 at the reach scale to allow assessment against the Styx Stormwater Management Plan (CRC131249) objectives.

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 (percentage), substrate composition (silt/sand: <2 mm; gravel: 2–16 mm; pebble: 16–64 mm; small cobble: 64–128 mm; large cobble: 128–256 mm; boulder: 256-4000 mm; bedrock/concrete/artificial hard surfaces: >4000mm), 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 surrounding land use, bank material composition, lower and upper bank height (cm) and slope, riparian vegetation (composition and % cover), canopy cover (%), horizontal bank undercut (cm), overhanging vegetation (cm), groundcover vegetation (%), and bank erosion (%) were measured for each bank at each transect, for a 5 metre bank width.

Flow habitat composition across the entire reach (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 SMP (CRC131249) as this site-wide measure was used in previous monitoring reports (James, 2014; Blakely, 2015; James, 2016).

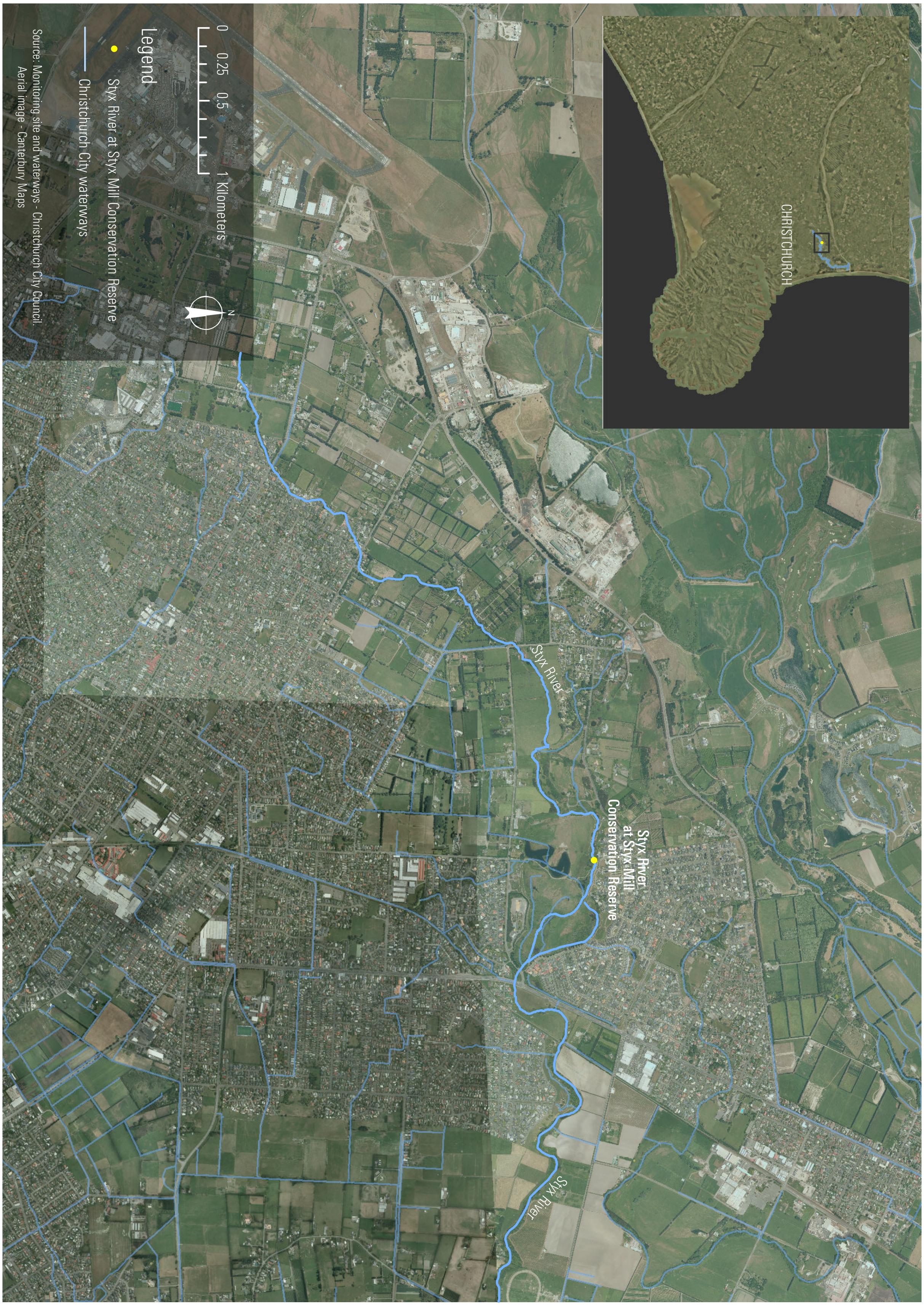

Figure 1 Location of the Styx River at Styx Mill Conservation Reserve survey site

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, percentage cover of each macrophyte type (emergent or submerged), and the dominant species were also assessed within a 1 m band 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; James, 2016).

Channel maintenance involving macrophyte removal occurs periodically at this site. It was confirmed that no macrophyte removal that could compromise the survey results had occurred recently prior to the sampling date.

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 2016 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 centre-channel value for velocity was used as this was the only velocity measure taken for each transect in 2015.

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 is a useful community metric related to habitat diversity, with sites with more diverse habitats often having greater richness. However, there are numerous aquatic invertebrate taxa that prefer or tolerate degraded instream conditions such that taxa richness on its own should not be used to infer stream health.

» NMS is an ordination of data that is often used to examine how communities composed of many different taxa differ 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 is the hydroptilid caddisflies (e.g. Trichoptera: Hydroptilidae: *Oxyethira, Paroxyethira*), which are algal piercers and often found in high numbers in nutrient enriched and degraded waters 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 indices used in this report.

» 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 six years were evident. Where there were multiple measures across a transect, these were averaged prior to ANOVA. 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. Temporal trends in macroinvertebrate community metrics were examined using the Mann-Kendall trend test in Time Trends version 5.

3 RESULTS

3.1 Physical Habitat

Spot measurements of the water quality parameters (temperature, pH, conductivity, and dissolved oxygen) were similar to those measured in 2016, although dissolved oxygen was slightly lower (Table 3). Temperature and dissolved oxygen are ecological health indicators in the Canterbury Land & Water Regional Plan (CLWRP); the temperature and dissolved oxygen recorded at the Styx Mill site on 23 February 2017 are within the established levels for "spring-fed –plains" and "spring-fed –plains Urban" (Table 2). The pH was near neutral, and the conductivity (indicating the level of dissolved ions) was relatively low. While these spot measurements taken on 23 February 2017 appear to indicate reasonably good water quality, it is important to note that these physical and chemical properties can change rapidly and individual measurements should therefore be interpreted cautiously. In particular, temperature, pH, and dissolved oxygen vary over a 24 hour period, with temperature and dissolved oxygen both at their lowest at night. As such, the spot measurements taken during the day do not represent the minimum values for these parameters.

Gravel (2-16 mm) was the dominant substrate class in 2017. Pebble-sized stones (16-64 mm), the dominant substrate class for 2014, 2015, and 2016, were the second most common substrate class for 2017 (Table 3). Fine sediment (silt/sand, <2 mm) covered 20% of the total streambed within the site; this falls within the Styx SMP water quality objectives, as well as the health indicators of the CLWRP (Table 1; Table 2). As a function of the moderate to low cover of fine sediment, embeddedness was also low (Table 3). The land surrounding the survey site is within CCC-managed reserve, and as a result the surrounding land use type, the riparian vegetation, stream shade, and bank composition have not changed markedly over the six years of monitoring (Table 3).

Water depths were significantly greater in 2013 and 2014 than in the subsequent three years of sampling (Figure 2, Table 4). Water velocity (centre-channel), fine sediment depth, wetted width and substrate index (an indicator of the overall coarseness of substrate) showed no statistically significant differences among the six years of monitoring (Figure 2, Table 4).

Table 3 Water quality and habitat attributes from the Styx River at the Styx Mill Conservation Reserve survey site from surveys undertaken in March 2008, and February 2013-2017.

Sampling Date		13 March 2008[1]	27 February 2013[2]	21 February 2014[3]	10 February 2015[4]	11 February 2016[5]	23 February 2017
Spot temperature (°C)		Not measured	Not measured	Not measured	13.6	13.8	13.8
Spot pH		Not measured	Not measured	Not measured	6.90	7.37	7.70
Spot conductivity (μS/cm)		Not measured	Not measured	Not measured	137	110	110
Dissolved oxygen (%)		Not measured	Not measured	Not measured	86	79.2	73
Substrate composition (dominant substrate is in bold)	Boulder	0%	0%	0%	0%	0%	1%
	Large cobble	2%	0%	1%	1%	0%	0%
	Small cobble	5%	0%	5%	16%	1%	1%
	Pebbles	0%	40%	**70%**	**37%**	**74%**	28%
	Gravel	**60%**	15%	5%	15%	5%	**50%**
	Sand/Silt	33%	**45%**	21%	31%	20%	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	100% park/reserve
Habitat type (% riffle:run:pool)		0:100:0	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	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	Grass/herb mix, *Carex* sedges, flax, toe toe, cabbage trees, broadleaf, lancewood, willows
Canopy cover (% Stream shade)		5–25%	<5%	5–25%	<5%	5–25%	5–25%
Substrate embeddedness		50–75%	25–50%	25–50%	25–50%	5–25%	5–25%

[1]From McMurtrie & Greenwood (2008); [2]From James (2013); [3]From James (2014); [4]From Blakely (2015), [5]From James (2016)

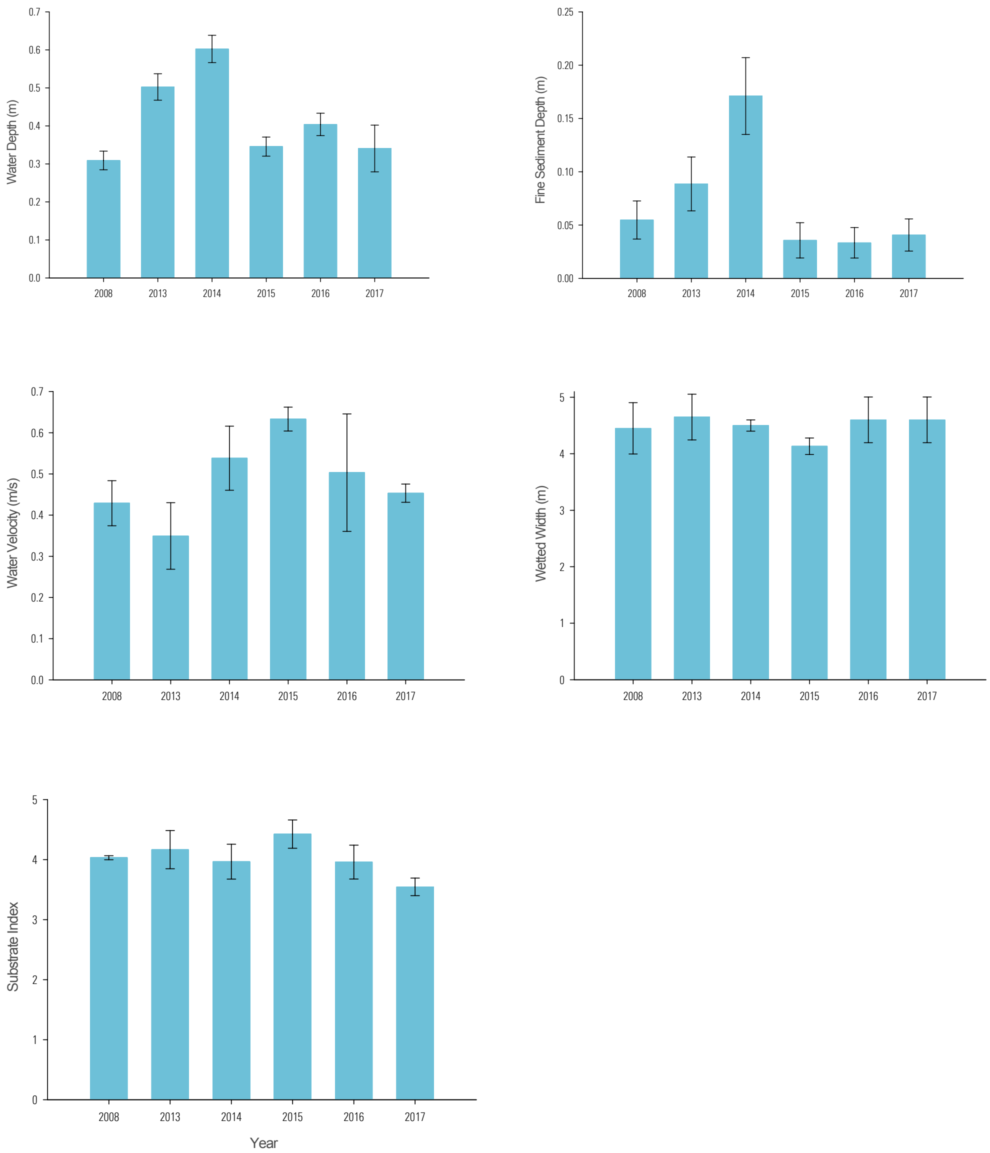

Figure 2 Mean (+/- 1 SE) aquatic habitat attributes of the Styx River at the Styx Mill Conservation Reserve survey site on 13 March 2008, 27 February 2013, 21 February 2014, 10 February 2015, 11 February 2016, and 23 February 2017.

Table 4 **Results of one-way analysis of variance (ANOVA) on aquatic habitat attributes from the Styx River at the Styx Mill Conservation Reserve survey site on 13 March 2008, 27 February 2013, 21 February 2014, 10 February 2015, 11 February 2016, and 23 February 2017. 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, 2017: 15	H=49.069	<0.001	Yes	2008=2015=2016=2017<2013=2014
Fine sediment depth	Kruskal-Wallis		H=10.213	0.069	No	2008=2013=2014=2015=2016=2017
Water velocity (centre-channel)	ANOVA	3	$F_{4,10}$=1.536	0.25	No	2008=2013=2014=2015=2016=2017
Substrate Index	Kruskal-Wallis	2008, 2013, 2014: 3 2015, 2016, 2017: 15	H=9.310	0.097	No	2008=2013=2014=2015=2016=2017
Wetted width	Kruskal-Wallis	3	H=1.763	0.881	No	2008=2013=2014=2015=2016=2017

3.2 Macrophytes and Periphyton

Ranunculus tricophyllus (water buttercup), an exotic macrophyte, was the dominant aquatic vegetation in 2017 (Table 5). Exotic macrophytes (*Ranunculus tricophyllus* in 2013, 2016, 2017; *Elodea canadensis* in 2008) are usually dominant at this site, although in 2014 a native macrophyte (*Myriophyllum triphyllum*) was dominant (Table 5). Short algal filaments (<20 mm) had the second greatest coverage of any aquatic vegetation in 2017, and were primarily found growing on top of submerged macrophyte beds (Table 5). The percentage cover of filamentous algae was notably higher than in 2016. However, as the filamentous algae present were short (<20 mm), they are excluded under the consent objective for maximum filamentous algae cover of streambed. All macrophyte types recorded in 2017 were also recorded in the previous year. Total macrophyte cover was not significantly different over the six years of sampling, although macrophyte depth was significantly higher in 2014 (Figure 3, Table 6). This difference in macrophyte depth is likely the result of the dominance of *Myriophyllum triphyllum* in 2014, which was absent in the other years sampled (Table 5).

Table 5 Organic matter attributes (including macrophyte and periphyton) from the Styx Mill Conservation Reserve survey site from surveys undertaken in March 2008 and February 2013-2017. 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, 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[5]	23 February 2017
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%	***R. trichophyllus* (water buttercup): 60%**
	Algal mats: 5%	***Ranunculus trichophyllus* (water buttercup): 15%**	*E. canadensis* (Canadian pondweed): 15%	*Rorippa* (watercress)	***R. trichophyllus* (water buttercup): 20%**	Algal filaments (short): 35%
	***Elodea canadensis* (Canadian pondweed): 5%**	*P. crispus* (curly pondweed): 10%	*Rorippa* (watercress): 5%	*Glyceria* (sweetgrass)	*E. canadensis* (Canadian pondweed): 5%	Algal mats (thin): 20%
	***Potamogeton crispus* (curly pondweed): 5%**	*E. canadensis* (Canadian pondweed): 5%	*Glyceria* (sweetgrass): 1%	*R. trichophyllus* (water buttercup)	*Glyceria* (sweetgrass): 5%	Terrestrial roots/vegetation: 5%
	Fine detritus (leaf litter): 5%	*Rorippa* (watercress): 5%	*M. guttatus* (monkey musk): 1%	Coarse woody debris and leaves	*Rorippa* (watercress): 5%	*E. canadensis* (Canadian pondweed): 5%
	Glyceria (sweetgrass): 3%	Terrestrial roots/vegetation: 5%	Terrestrial roots/vegetation: 1%	Moss	*M. guttatus* (monkey musk): 4%	*M. guttatus* (monkey musk): 2%
	Rorippa (watercress): 1%	*Azolla*: 1%			*Ranunculus repens* (creeping buttercup: (1%)	*Glyceria* (sweetgrass): 2%
		Woody debris: 1%			Terrestrial roots/vegetation: 2%	Fine detritus (leaf litter): 1%
		Lemna minor (duckweed): 1%			Large woody debris: 2%	Small woody debris: 1%
		Mimulus guttatus (monkey musk): 1%			Moss/liverworts: 0.5%	Large woody debris: 1%
		Moss/liverworts: 1%			*Azolla filiculoides* (Pacific azolla): 0.5%	*A. filiculoides* (Pacific azolla): 0.5%
Emergent macrophyte cover	4%	8%	6%	?	11%	5%
Total macrophyte cover (submerged and emergent macrophytes)	14%	38%	92%	70%	41%	69.5%
Filamentous algal cover	0%	0%	0%	9%	0%	35%

[1]From McMurtrie & Greenwood (2008); [2]From James (2013); [3]From James (2014); [4]From Blakely (2015), [5]From James (2016)

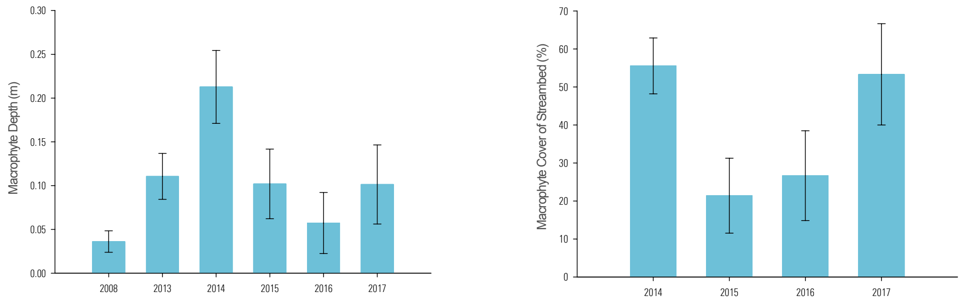

Figure 3 Mean (+/- 1 SE) macrophyte depth (March 2008, February 2013–2017) and macrophyte cover (February 2014–2017) as measured across the three transects of the Styx River at the Styx Mill Conservation Reserve survey site.

Table 6 Results of one-way analysis of variance (ANOVA) on macrophyte depth (March 2008, February 2013–2017) and macrophyte cover (February 2014–2017) 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 medians.

Parameter	Statistic	N	H value	*p*	Significant difference?	Multiple comparison
Macrophyte depth	Kruskal-Wallis	2008, 2013, 2014: 36 2015, 2016, 2017: 15	H=13.064	0.023	Yes	Difference too weak for Dunn's Test to determine which medians differed
Macrophyte cover	Kruskal-Wallis	2014: 3 2015, 2016, 2017: 15	H=4.013	0.260	No	2014=2015=2016=2017

3.3 Aquatic Macroinvertebrates

A total of 28 taxa were found at the Styx River monitoring site in 2017; this was greater than the total number of taxa (26) found in 2016. These taxa included (by group, in decreasing order of diversity): caddisflies (Trichoptera: 10 taxa), two-winged flies (Diptera: 7 taxa), molluscs (Mollusca: 4 taxa), crustaceans (Crustacea: 3 taxa), mayflies (Ephemeroptera: 1 taxon), nematodes (Nematoda: 1 taxon), worms (Oligochaeta: 1 taxon), and flatworms (Platyhelminthes: 1 taxon). The five most abundant taxa were the same between 2016 and 2017 although the dominant taxon was different, with *Potamopyrgus antipodarum* dominant in 2016, and Ostracoda dominant in 2017 (Table 7). As in 2015 and 2016, three of the five dominant taxa were "cleanwater" EPT taxa (Table 7).

Table 7 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 2013–2017. Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa are highlighted in bold.

Sampling Date	13 March 2008[1]	27 February 2013[2]	21 February 2014[3]	10 February 2015[4]	11 February 2016[5]	23 February 2017
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%	Ostracoda (seed shrimp crustacean): 31%
	Potamopyrgus antipodarum (snail): 27%	*Potamopyrgus antipodarum* (snail): 15%	*Potamopyrgus antipodarum* (snail): 13%	***Pycnocentrodes* (cased caddisfly): 19%**	***Pycnocentrodes* (cased caddisfly): 11%**	*Potamopyrgus antipodarum* (snail): 27%
	Ostracoda (seed shrimp crustacean): 12%	Ostracoda (seed shrimp crustacean): 12%	Ostracoda (seed shrimp crustacean): 10%	***Deleatidium* (mayfly): 12%**	***Deleatidium* (mayfly): 6%**	***Pycnocentrodes* (cased caddisfly): 7%**
	Orthocladiinae (midge larvae): 7%)	***Pycnocentria* (cased caddisfly): 9%**	***Deleatidium* (mayfly): 2%**	Oligochaeta (oligochaete worm): 10%	Ostracoda (seed shrimp crustacean): 4%	***Deleatidium* (mayfly): 5%**
	***Pycnocentrodes* (cased caddisfly): 4%**	***Deleatidium* (mayfly): 6%**	***Hudsonema amabile* (cased caddisfly): 2%**	***Pycnocentria* (cased caddisfly): 5%**	***Pycnocentria* (cased caddisfly): 2%**	***Pycnocentria* (cased caddisfly): 4%**

[1]From McMurtrie & Greenwood (2008); [2]From James (2013); [3]From James (2014); [4]From Blakely (2015), [5]From James (2016)

Total abundance of macroinvertebrates was lower in 2017 than in previous years, but this difference was not statistically significant (Figure 4, Table 8). Taxa richness was higher in 2017 than in 2016, but again this difference was not statistically significant (Figure 4, Table 8). Likewise, EPT richness and %EPT were not statistically significantly different between years. MCI-hb and QMCI-hb were lower in 2017 than previously, although this difference was not statistically significant. MCI-hb has remained within the "fair" classification of Stark & Maxted (2007); the QMCI-hb has fallen to the boundary of the "fair" and "poor" classification.

As in previous years, UCI and QUCI were positive in 2017 (although only marginally so for QUCI) (Figure 4). Positive UCI and QUCI scores are indicative of an invertebrate community characterised by taxa with a preference for fast-flowing water and stony substrate. Both UCI and QUCI were significantly lower in 2017 than in previous years at this site, however given that these scores are still positive it is likely that the ecological significance of these declines may be minimal (Figure 4, Table 8). In particular, the decline in QUCI may be the result of the high macrophyte cover at this site during sampling in 2017.

Trend analysis of the macroinvertebrate community metrics across the six years of sampling indicates a 12.04% annual decline in total abundance of macroinvertebrates, and a 3.70% annual decline in EPT richness (Table 9). No other metrics showed a significant trend (Table 9). It would be unwise to read too much into this decline in total abundance given the semi-quantitative kick net sampling methodology.

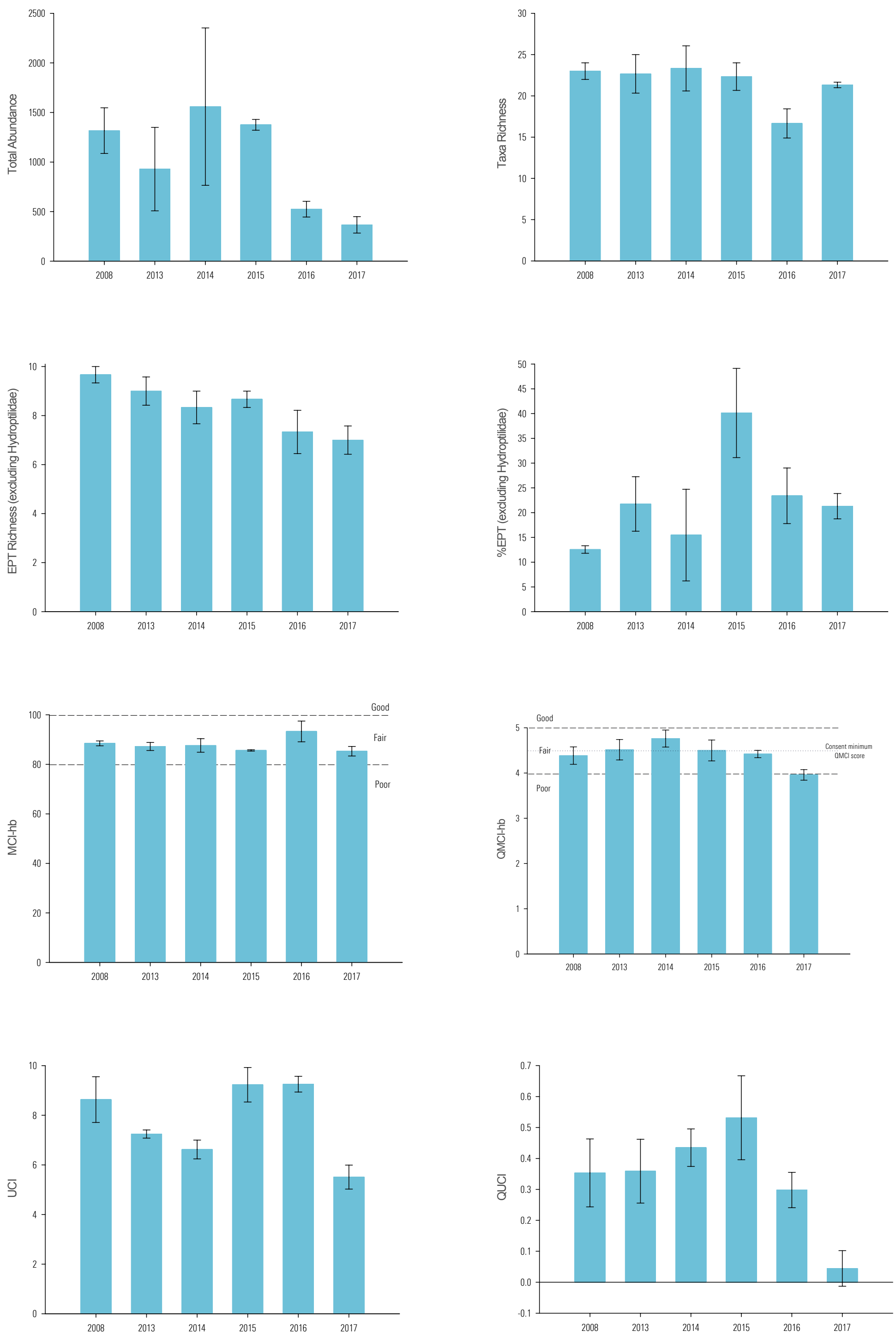

Figure 4 Mean (+/- 1 SE) macroinvertebrate community metrics of the Styx River at the Styx Mill Conservation Reserve survey site on 13 March 2008, 27 February 2013, 21 February 2014, 10 February 2015, 11 February 2016, and 23 February 2017. N=3. Note that hydroptilid caddisflies were excluded from the 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 8 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, 11 February 2016 and 23 February 2017. 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	$F_{4,10}$=2.22	0.12	No	2008=2013=2014=2015=2016=2017
Taxa richness	ANOVA	3	$F_{4,10}$=2.10	0.18	No	2008=2013=2014=2015=2016=2017
EPT richness	ANOVA	3	$F_{4,10}$=2.78	0.07	No	2008=2013=2014=2015=2016=2017
% EPT	ANOVA	3	$F_{4,10}$=2.22	0.12	No	2008=2013=2014=2015=2016=2017
MCI-hb	ANOVA	3	$F_{4,10}$=1.55	0.25	No	2008=2013=2014=2015=2016=2017
QMCI-hb	ANOVA	3	$F_{4,10}$=2.11	0.13	No	2008=2013=2014=2015=2016=2017
UCI	ANOVA	3	$F_{4,10}$=9.00	<0.001	Yes	2017<2008=2013=2014=2015=2016
QUCI	ANOVA	3	$F_{4,10}$=3.31	0.05	Yes	2017<2008=2013=2014=2015=2016

Table 9 Results of Mann-Kendall trend analysis for macroinvertebrate community metrics collected from 2008 and 2013–2017. Where a significant trend was determined the direction and annual change is indicated.

Macroinvertebrate community metric	Trend
Total abundance	12.04% annual decrease (*P*=0.045)
Taxa richness	No trend (*P*=0.199)
EPT richness	3.70% annual decrease (*P*=0.002)
% EPT	No trend (*P*=0.281)
MCI-hb	No trend (*P*=0.643)
QMCI-hb	No trend (*P*=0.083)
UCI	No trend (*P*=0.488)
QUCI	No trend (*P*=0.077)

NMS ordination shows some separation of the macroinvertebrate communities of 2008, 2013, and 2014 with those from 2015, 2016, and 2017 along Axis 1 (Figure 5). This is driven primarily by the abundance of the mayfly *Deleatidium*, the snail *Potamopyrgus,* and the cased caddisfly *Pycnocentrodes* in 2015, 2016, and 2017 while 2008, 2013, and 2014 samples are associated with *Paracalliope* amphipods and Tanytarsini midge larvae (Figure 5). This shift in dominant taxa between 2014 and 2015 can be seen in Table 7. The NMS ordination also shows some separation between the macroinvertebrate communities of 2016 and 2017, largely driven by the abundance of *Potamopyrgus* snails in 2016 and the abundance of *Deleatidium* mayflies, *Physa* snails, Sphaeriidae pea clams, Ostracoda seed shrimp, *Pycnocentria* cased caddisflies, and *Oxyethira* purse-cased caddisflies in 2017. The 2008, 2013, and 2014 macroinvertebrate communities were associated with greater water depths and fine sediment depths than those of 2015, 2016, and 2017.

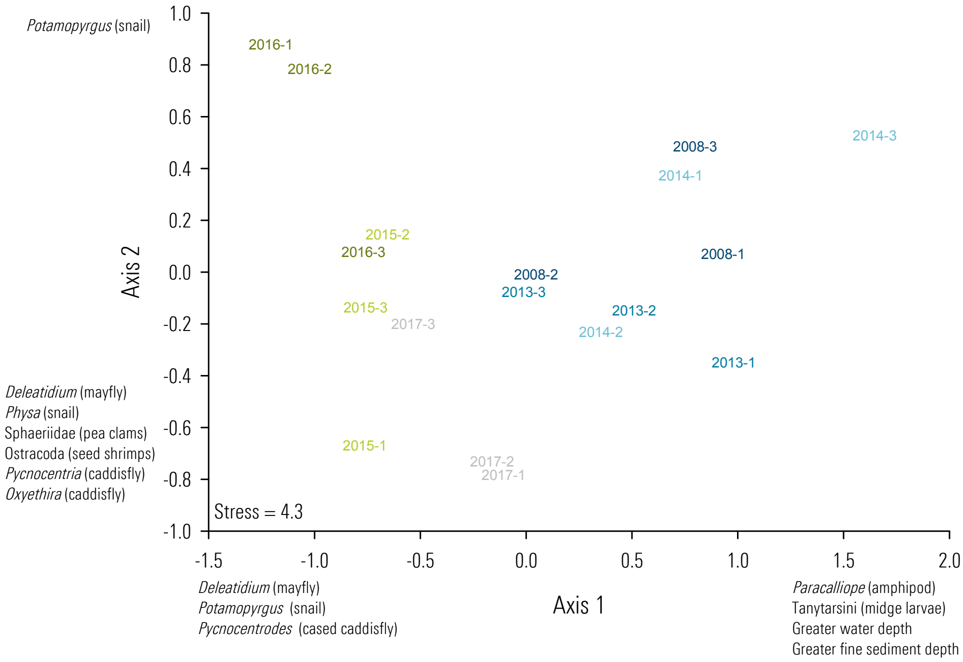

Figure 5 Non-metric multidimensional scaling (NMS) ordination plot of macroinvertebrate data from the Styx River at the Styx Mill Conservation Reserve survey site. Each point represents one of the three kick net samples taken in that respective year. Macroinvertebrates and habitat variables that are significantly associated with each axis are shown. The low stress value of 4.3 indicates the ordination is an excellent representation with little prospect of misinterpretation.

4 STYX RIVER SMP WATER QUALITY OBJECTIVES COMPARISON

Two of the surface water quality objectives from the Styx SMP consent CRC131249 were not met according to the assessment carried out on 23 February 2017. The mean value for QMCI was 4.0, which falls below the minimum score of 4.5 (Table 10). The total macrophyte cover was 69.5% of the total streambed, which exceeds the maximum of 50% set in the consent (Table 10).

A comparison was also made with the “Freshwater outcomes for Canterbury Rivers” as stated in the Canterbury Land and Water Regional Plan. At 69.5%, total macrophyte cover exceeded the maximum for both “spring-fed –plains” and “spring-fed –plains Urban” (Table 11). QMCI as measured on 23 February 2017 at the survey site was below the minimum score for “spring-fed –plains”, but above the minimum for “spring-fed –plains Urban” (Table 11). Fine sediment cover was at the maximum allowable value for “spring-fed –plains”, and below the threshold set for “spring-fed –plains Urban” (Table 11). All other relevant indicator measurements taken fell within the outcomes of the CLWRP.

Table 10 Comparison of the surface water quality objectives from Consent CRC131249 with measurements taken during the most recent survey of the Styx River at the Styx Mill Conservation Reserve survey site (23 February 2017). Parameters that breach the objectives are shaded.

Parameter	Surface water quality objectives from Consent CRC131249	Results from 2017 survey
Quantitative macroinvertebrate community index (QMCI)	Minimum score of 4.5	4.0
Fine sediment cover (<2 mm diameter)	Maximum of 40%	20%
Total macrophyte cover	Maximum of 50%	69.5%
Filamentous algae cover (>20 mm long)	Maximum of 30%	0%

Table 11 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 of the Styx River at the Styx Mill Conservation Reserve survey site (23 February 2017).

Parameter	Canterbury Land & Water Regional Plan		Results from February 2017 survey
	Spring-fed –plains	Spring-fed –plains Urban	
Quantitative macroinvertebrate community index (QMCI)	Minimum of 5	Minimum of 3.5	4.0
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%	5%
Total macrophyte cover	Maximum cover of 50%	Maximum cover of 60%	69.5%
Filamentous algae cover (>20 mm long)	Maximum cover of 30%	Maximum cover of 30%	0%

5 ASSESSMENT OF STORMWATER EFFECTS

Biomonitoring and habitat data from a single survey site provides no means of controlling for natural stochasticity, and therefore it is difficult to assess whether any trends in aquatic ecology of the Styx River at the Styx Mill Conservation Reserve survey site are the result of stormwater inputs or any other factor. Spot water quality, habitat, and substrate measures have remained broadly similar over the six years of monitoring, with fine sediment cover remaining within the consent objectives. Macrophyte cover has fluctuated from year-to-year and the aquatic vegetation has been dominated by exotic macrophytes (with the exception of 2014). The macroinvertebrate community has undergone shifts from dominant taxa of *Paracalliope*, *Potamopyrgus* and Ostracoda (2008, 2013, 2014) to *Potamopyrgus*, *Pycnocentrodes,* and *Deleatidium* (2015, 2016), and most recently Ostracoda, *Potamopyrgus*, and *Pycnocentrodes* (2017). The relative abundance of EPT taxa has been greater since 2015 than in 2008-2014. The presence of the mayfly *Deleatidium* is of particular note as this taxon is absent from more urbanised catchments in Christchurch (e.g., Ōtākaro/Avon and Ōpāwaho/Heathcote).

The MCI and QMCI scores declined slightly from 2016 to 2017, but remain within the "fair" classification. Analysis of trends indicates a 12.04% annual decline in the abundance of macroinvertebrates, although kick net sampling is only semi-quantitative and therefore is not a reliable indicator of overall macroinvertebrate abundance (quantitative Surber or Hess sampling would be required if more accurate abundance data was desired). Trend analysis also indicates a 3.70% annual decline in EPT richness, although no trend was found in the relative abundance of these taxa. The drop in MCI and QMCI from previous years, and the trends of declining abundance and EPT richness suggest a slight decline in the aquatic health of this site in the Styx River, although the changes in community structure largely result from shifts in the relative abundances of the most abundant taxa rather than any dramatic losses of pollution-sensitive taxa. The continued presence of three EPT taxa among the five most abundant macroinvertebrate taxa at this site suggest that it remains in relatively good condition compared to more urbanised catchments within Christchurch. Any interpretations of the trends at this site with regards to the impacts of stormwater discharge should be treated with caution due to the methodological limitations of the current monitoring program.

6 CONCLUSIONS AND RECOMMENDATIONS

Two water quality objectives were not met (QMCI and total macrophyte cover) and significant negative trends were identified for total abundance and EPT richness.

» The relatively low QMCI score in 2017 was primarily driven by the high relative abundances of Ostracoda and *Potamopyrgus* (which have low MCI scores) rather than the loss of any pollution-sensitive taxa so cannot be attributed to stormwater discharges. Also no temporal trend in QMCI was identified. It must also be remembered that MCI/QMCI was developed for assessing the effects of organic pollution, not the heavy metals and hydrocarbons that are typical stormwater-derived contaminants. Hence QMCI may not be the most reliable metric to use for investigating stormwater impacts. For example, Hickey & Clements (1998) reported QMCI was poor at distinguishing between reference and metal-polluted streams. They found the abundance and species richness of mayflies, number of EPT taxa, and total taxonomic richness to be the best indicators of heavy metals.

» In terms of total macrophyte cover, the site undergoes routine macrophyte removal, and thus macrophyte cover is likely to be most closely linked to the schedule of macrophyte removal rather than to stormwater discharge. As a consequence, the consent objectives relating to macrophyte cover are less relevant to the purpose of the consent than the other objectives.

» The significant 12.04% annual decline in total abundance should not be taken as any kind of negative effect of stormwater as kick net sampling is only semi-quantitative and therefore not a reliable indicator of overall macroinvertebrate abundance (quantitative Surber or Hess sampling would be required if more accurate abundance or density data was desired).

» The significant 3.70% annual decline in EPT richness is a small change over time and likely not overly relevant given EPT taxa remain among the top five most abundant taxa, although this metric should be examined in future years.

The full list of recommendations provided in James (2014) is still relevant with regard to achieving the desired outcome of detecting stormwater discharge impacts on the ecology of the receiving system. Considerations for a more effective monitoring programme include:

» Use of quantitative macroinvertebrate sampling (i.e. Surber sampling) rather than kicknet sampling in order to determine trends in total abundance and densities of the taxa present, particularly with regard to sensitive EPT taxa.

» Water quality sampling during rain events to assess contaminant levels such as heavy metals, total suspended sediment, and hydrocarbons. Sampling during rain events would provide a better indication of stormwater inputs to the Styx River than sampling during dry weather when stormwater is less likely to be discharging.

» Sampling at more than one biological monitoring site, and inclusion of an upstream reference site that receives little or no stormwater input in order to separate natural stochasticity from the impacts of stormwater on the aquatic ecology of the Styx River.

Despite these limitations, the annual monitoring programme is useful in providing a means of detecting rapid (i.e. yearly) site changes should any occur.

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8 APPENDIX

8.1 Site Photographs

Looking downstream from upstream survey boundary


2015
Photo by Boffa Miskell


2016


2017

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