Styx Mill Conservation Reserve Aquatic Ecology Survey

Monitoring of the Styx River for Consent CRC131249
Prepared for the Christchurch City Council

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Boffa Miskell

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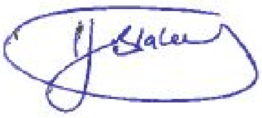
Prepared by:	Dr Tanya Blakely Senior Ecologist Boffa Miskell Limited	
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Cover photograph: Styx River within the Styx Mill Conservation Reserve © Boffa Miskell, 2015

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EXECUTIVE SUMMARY

The Christchurch City Council commissioned Boffa Miskell Ltd to undertake the 2015 Styx Mill Reserve Aquatic Ecology Survey. This work forms part of the annual aquatic ecology monitoring of the Styx River at the Styx Mill Conservation Reserve. The purpose of this monitoring is to assess compliance against the surface water quality objectives of the Environment Canterbury Resource Consent CRC131249 as part of the Styx Stormwater Management Plan.

The sampling location was within the Styx Mill Conservation Reserve. This site was previously surveyed in February 2014. Comparisons of habitat conditions and the macroinvertebrate community found in the 2014 and 2015 annual surveys have been made.

The water quality, as determined by spot measures of pH, conductivity, water temperature and dissolved oxygen, was within the guidelines of Canterbury's proposed Land and Water Regional Plan (pLWRP). There were slight differences in water velocity, water depth, and general riparian and in-stream habitat conditions measured in 2014 and 2015. However, generally the aquatic habitat was found to be similar in this compared to 2014.

The total cover of macrophytes (aquatic plants) at the site was found to be slightly greater than that recommended by the pLWRP and the Styx SMP consent surface water quality objectives for this site. This was similar to the finding of 2014, however, in this survey all macrophytes recorded at the site were introduced species. The endemic *Myriophyllum triphyllum* was not recorded in 2015.

There were no noticeable differences in the total abundance or richness of macroinvertebrates found in 2014 and 2015. Although there was no significant difference in the number of EPT taxa found between years, three of the five most abundant macroinvertebrate taxa were represented by the pollution-sensitive EPT taxa (compared to two of the five in 2014). EPT taxa accounted for approximately 40% of the macroinvertebrate community at the Styx River SMP site in 2015, compared to around 15% of the community in 2014.

Although there were subtle differences in the macroinvertebrate community composition between 2014 and 2015, the Macroinvertebrate Community Index (MCI) and its quantitative variant (the QMCI) were similar across years. The MCI and QMCI indicated the Styx River SMP site had fair stream health, with 'probable mild enrichment'. This had not changed from the findings in 2014.

Most importantly, the habitat and water quality conditions found in 2015 were of a similar standard to those found in 2014. The site continues to support pollution-sensitive EPT taxa, including the mayfly, *Deleatidium*, which is no longer present in the much more urbanised Avon or Heathcote River catchments.

Thus, the main findings of this survey indicated that there has been little significant change in habitat or macroinvertebrate community composition at the Styx River SMP site since monitoring under the Consent CRC131249 began in 2014. Based on this information, there does not appear to have been any detectable effects of stormwater discharges on this receiving environment.

SCOPE

The Christchurch City Council (CCC) commissioned Boffa Miskell Ltd (BML) to undertake the 2015 Styx Mill Reserve Aquatic Ecology Survey. This work forms part of the annual aquatic ecology monitoring of the Styx River at the Styx Mill Conservation Reserve, which commenced in 2014. The purpose of this monitoring is to assess compliance against the surface water quality objectives of the Environment Canterbury Resource Consent CRC131249 as part of the Styx Stormwater Management Plan.

The surface water quality objectives of Consent CRC131249 are:

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%

This 2015 survey included an ecological survey at one site on the Styx River, within the Styx Mill Conservation Reserve. The aims of this report are to:

- Detail the field methodologies employed;
- Describe the ecological condition of the Styx River at this site as assessed in February 2015;
- Compare the results to the surface water quality objectives of the consent (CRC131247) and other relevant guidelines, including the proposed Canterbury Land and Water Regional Plan;
- Compare the results of this survey with results from previous monitoring (February 2014) and discuss any observed trends;
- Discuss potential reasons for any observed trends; and
- Make recommendations, where relevant, on how to improve habitat quality at the site, particularly in relation to (a) any deviations from water quality objectives of the consent and other relevant guidelines.

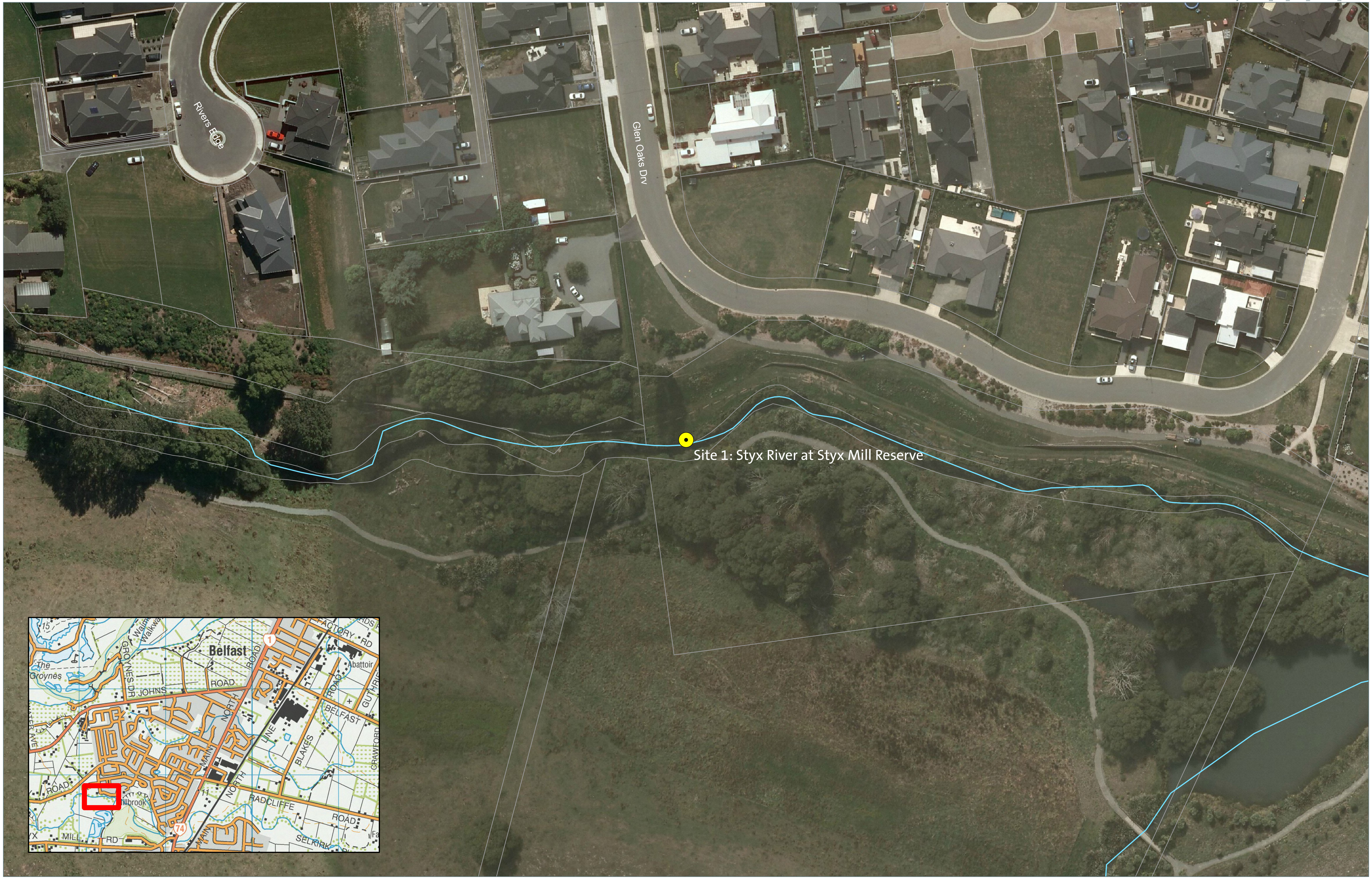
FIELD METHODS

The sampling location was within the Styx Mill Conservation Reserve (E2478252 N5749371) (Figure 1). This site was previously surveyed in February 2014 (EOS Ecology 2014) as part of the monitoring required for the Styx SMP. Comparisons of habitat conditions and the macroinvertebrate community found in the 2014 and 2015 annual surveys have been made.

Although this Styx River SMP site has also been surveyed, as part of larger surveying programmes, only comparisons between 2014 and 2015 have been made in this study. The data collection and calculation methods differ in other surveys of the site (EOS Ecology 2008, 2013), which can complicate statistical comparisons.

This aquatic ecology survey was conducted on 10 February 2015, in baseflow conditions and following fine weather. The CCC provided BML with co-ordinates (northing and easting) of this site, which was then located in the field using ArcGIS and Avenza pdf maps on an iPad.

Upon locating the Styx SMP monitoring site, three equally-spaced transects, at 10 m intervals, were established across the waterway. The downstream most transect (Transect 1) was situated in approximately the same location as that of previous surveys, based on site location notes provided by the CCC to BML. Transects 2 and 3 were located 10 m and 20 m upstream of Transect 1.



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Data Sources:
Waterways data and aerial photograpgy sourced from CCC.
Parcel and road data sourced from LINZ.

Legend

- Site 1: Styx River at Styx Mill Reserve
- CCC Waterway
- Parcel

Styx Mill Conservation Reserve Survey

Figure 1: Site Location

| **Date: 3 February 2015** | **Revision: 0** |

Plan prepared for Christchurch City Council by Boffa Miskell Limited

Project Manager: Tanya Blakely **Tanya.Blakely@boffamiskell.co.nz** | *Drawn:* CMu | *Checked:* TBl

Riparian and in-stream habitat conditions

A number of parameters were measured, to assess the riparian and in-stream habitat conditions at the site.photographs were taken showing an upstream and downstream view of the river at the Styx SMP site.

Water quality

Basic water quality measurements, including spot measures of water temperature (°C), dissolved oxygen (DO, %), pH and specific conductivity (µS / cm_{25}) were measured once at the site using handheld TPS WP-81 and TPS WP-82Y meters. Flow habitat composition was also assessed for the entire site, where the percentage of riffle, run, and pool habitat at the site was estimated.

Water velocity

Water velocity was measured at each transect, where one reading was taken from the middle of the channel, at an approximate distance of 0.4 x the water depth from the stream bed using a Seba Mini count meter. The Seba Mini count meter is a propeller-based flow meter, where the number of revolutions of the propeller, over a given time (in this case 40 seconds), is converted to velocity using the following formula:

Velocity = (S x RPS) + C, where S and C are constants specific to the propeller and RPS is revolutions per second.

General riparian and in-stream habitat conditions

At each transect, the surrounding land use was recorded (e.g. residential, rural / farming, reserve / park), along with the type of material that formed the lower bank (e.g. earth, wood, brick, rock, concrete, tyres), and measures of bank height (lower and upper, cm), bank slope (lower and upper, slope°). Visible bank erosion (%), the extent of undercut banks (cm) and amount of overhanging vegetation (cm) were also recorded within these 5 m bands at each transect.

Riparian cover, or condition, was assessed by recording the types and percent cover of ground vegetation present on both banks, separately, within a 5 m band (i.e. within the area 5 m from the water's edge) at each of the transects.

Canopy cover (%), as an estimate of how much of the waterway channel was shaded by tree cover, was assessed as one of five percent cover categories (<5%, 5-25%, 25-50%, 50-75%, >75%) for both banks, separately, at each transect.

Total wetted width (m) was recorded at each of the three transects, to give an average wetted width for the site. Water depth (cm), depth (cm) of fine sediment (<2 mm diameter) covering the stream bed, and substrate embeddedness (% of fine sediments surrounding surface substrates) were measured at each of five equally-spaced locations across each transect. Water depth was measured with a metal ruler, fine sediment depth was determined by gently pushing a metal rod (10 mm diameter) into the soft surface substrate until it hit the harder substrates underneath.

Substrate composition

Substrate composition (%) was measured within an approximately 20 x 20 cm quadrat placed at each of the five locations along the three transects. Within each quadrat, the percent composition of the following sized substrates was estimated: silt / sand (< 2 mm); gravels (2 – 16 mm); pebbles (16 – 64 mm); small cobbles (64 – 128 mm); large cobbles (128 – 256 mm); and boulders (> 256 mm).

Macrophytes and periphyton

Percent cover (total and emergent cover), type (dominant species) and depth (cm) of macrophytes (aquatic plants) were visually estimated within a 1 m band at each of the five locations across each transect. Total cover (%) and composition of periphyton (aquatic algae) was also measured at each of the five locations across the three transects, where percent composition was determined as % cover of thin (<0.5 mm), medium (0.5-3.0 mm), thick (>3.0 mm), short filamentous (<2 mm), and long filamentous (>2 mm) algae. Similarly, the percent cover of other organic matter (e.g. leaves, sticks, log jams, coarse woody debris) was estimated at each of the five locations across the three transects.

Total macrophyte, filamentous algal, and fine sediment cover (%) of the stream bed was also estimated for the entire site (i.e. across the 30 m survey reach), so as to provide comparable results to that of the Styx SMP surface water quality objectives of the consent.

Macrophytes are periodically removed from the Styx River as part of the CCC's channel maintenance programme. However, it was assumed that this survey took place prior to any macrophyte removal activities were undertaken in 2015 (as stated in the RFQ documentation issued by the CCC, December 2014).

Macroinvertebrate community

The macroinvertebrate community was sampled on the same day as the habitat assessments were made (i.e. prior to habitat assessments, but after basic water chemistry and temperature parameters were measured).

Macroinvertebrates (e.g., insects, snails and worms that live on the stream bed) can be extremely abundant in streams and are an important part of aquatic food webs and stream functioning. Macroinvertebrates vary widely in their tolerances to both physical and chemical conditions, and are therefore used regularly in biomonitoring, providing a long-term picture of the health of a waterway.

A single and extensive composite kick-net (500 µm mesh) sample was collected from each of the three transects in accordance with protocol C1 of Stark et al (2001). That is, approximately 1.0 m^2 of stream bed was sampled along each transect (i.e. each kick net sampled approximately 0.3 m x 3.0 m of stream bed), including sampling the variety of microhabitats present (e.g. stream margin, mid channel, undercut banks, macrophytes) so as to maximise the likelihood of collecting all macroinvertebrate taxa present at a site, including rare and habitat-specific taxa.

Macroinvertebrate samples were preserved, separately, in 70% ethanol prior to sending to Ryder Consulting, Dunedin, for identification and counting in accordance with protocol P3 of Stark et al (2001).

Data analyses

Riparian and in-stream habitat

Where parameters were measured at five locations across each of the transects (i.e. water depth, sediment depth, embeddedness, and macrophyte and periphyton cover), these were averaged to give a mean value for each transect.

A substrate index (SI) was calculated from the five replicate substrate composition measures taken along each transect. These values were then averaged, to give a mean SI for each transect.

The SI was calculated using the formula:

> *SI = (0.03 x %silt / sand) + (0.04 x %gravel) + (0.05 x %pebble) + (0.06 x (%small cobble + %large cobble)) + (0.07 x %boulder)*

The calculated SI can range between 3 and 7, where an SI of 3 indicates 100% silt / sand and 7 indicated 100% boulders. That is, the larger the SI, the coarser the substrate and the better the habitat for macroinvertebrate and fish communities. Finer substrates generally provide poor, and often unstable, in-stream habitat.

Wetted width was measured once at each of the three transects. These values were averaged to give a mean wetted width (m) for the Styx River SMP site.

Analyses of variance (ANOVAs) were used to test for differences in mean habitat conditions between 2014 (EOS 2014) and 2015 (this study). Response variables were *ln (x+1)* transformed, where necessary, to meet assumptions of normality and homogeneity of variances. ANOVAs were performed in R version 3.0.2 (The R Foundation for Statistical Computing 2013).

Macroinvertebrate community metrics

The following macroinvertebrate metrics were calculated from each of the three kick-net samples, separately, to provide an indication of stream health:

- **Total abundance** – the total number of individuals collected in the composite kick-net sample collected at each transect. Macroinvertebrate abundance can be a good indicator of stream health, or ecological condition, because abundance tends to increase in the presence of organic enrichment, particularly for pollution-tolerant taxa (e.g. chironomid midge larvae and oligochaete worms).

- **Taxonomic richness** – the total number of macroinvertebrate taxa recorded from the composite kick-net sample collected at each transect. Streams supporting high numbers of taxa generally indicate healthy communities, however, the pollution sensitivity / tolerance of each taxon needs to also be considered.

- **EPT taxonomic richness** – the total number of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) from the composite kick-net sample collected at each transect. These three insect orders (EPT) are generally sensitive to pollution and habitat degradation and therefore diversity of these insects provides a useful indicator of degradation. High EPT richness suggests high water quality, while low richness indicates low water or habitat quality.

- **EPT taxonomic richness (excl. hydroptilids)** – the total number of EPT taxa excluding the family Hydroptilidae. The algal piercing caddisflies belonging to the family Hydroptilidae are generally considered more tolerant of degraded conditions than other EPT taxa.
- **%EPT richness** – the total abundance of macroinvertebrates that belong to the pollution-sensitive EPT orders, relative to the total abundance of all macroinvertebrates found in the composite kick-net collected at each transect. High %EPT richness suggests high water quality.
- **%EPT (excl. hydroptilids)** – the percentage abundance of EPT taxa at each transect, excluding the more pollution-tolerant hydroptilid caddisflies.
- **Macroinvertebrate Community Index (MCI-hb)** – this index is based on tolerance scores for individual macroinvertebrate taxa found in hard-bottomed streams (Stark 1985, Stark and Maxted 2007). These tolerance scores, which indicate a taxon's sensitivity to in-stream environmental conditions, are summed for the taxa present in a sample, and multiplied by 20 to give MCI-hb values ranging from 0 – 200. Table 1 provides a summary of how MCI-hb and QMCI-hb scores were used to evaluate stream health.
- **Quantitative Macroinvertebrate Community Index (QMCI-hb)** – this is a variant of the MCI-hb, which instead uses abundance data. The QMCI-hb provides information about the dominance of pollution-sensitive species in a sample.
- **Urban Community Index (UCI) and Quantitative UCI (QUCI)** – these indices were developed by Suren et al. (1998) to indicate the health of urban waterways and are based on tolerance scores for individual macroinvertebrate taxa and their likely sensitivities to environmental conditions common to urban systems. UCI and QUCI are calculated in the same manner as the MCI and QMCI, but using the UCI tolerance scores. The calculated UCI and QUCIs can give positive or negative numbers, where negative scores are indicative of macroinvertebrate communities tolerant of slow-flowing waterways with high levels of soft sediments; positive scores indicate communities from fast-flowing waterways with coarser substrates.

Table 1. Interpretation of MCI-hb and QMCI-hb scores for soft- bottomed streams (Stark & Maxted 2007).

Stream health	Water quality descriptions	MCI	QMCI
Excellent	Clean water	>119	>5.99
Good	Doubtful quality or possible mild enrichment	100-119	5.00-5.90
Fair	Probable moderate enrichment	80-99	4.00-4.99
Poor	Probable severe enrichment	<80	<4.00

Note, the MCI and QMCI were developed primarily to assess the health of streams impacted by agricultural activities and should be interpreted with caution in relation to urban systems.

Macroinvertebrate community - statistical analyses

ANOVAs were used to test for differences in macroinvertebrate community metrics between 2014 (EOS 2014) and 2015 (this study). Response variables were *ln* (x+1) transformed to meet assumptions of normality and homogeneity of variances. Where data could not be transformed to meet these assumptions, response variables were ranked and parametric analyses were performed on these ranked variables. ANOVAs were performed in R version 3.0.2 (The R Foundation for Statistical Computing 2013).

A non-metric multidimensional scaling (or NMDS) ordination[1], with 1000 random permutations, of abundance data was used to determine if the macroinvertebrate community found was similar between 2014 and 2015.

NMDS ordinations rank sites (i.e. Styx River SMP site in 2014 and in 2015) such that distance in ordination space represents community dissimilarity (in this case using the Bray-Curtis metric). Therefore, an ordination score (an x and a y value) for the entire macroinvertebrate community found at a 'site' can be presented on an x-y scatterplot to graphically show how similar (or dissimilar) the community was between 2014 and 2015. Ordination scores that are closest together are more similar in macroinvertebrate community composition, than those further apart (Quinn and Keough 2002).

An analysis of similarities (ANOSIM), with 100 permutations, was then used to test for significant differences in macroinvertebrate community composition between 2014 and 2015. It is helpful to view ANOSIM results when interpreting an NMDS ordination. An NMDS ordination may show that communities appear to be quite distinct (i.e. when shown graphically, sites could be quite distinct from one another in ordination space), but ANOSIM results show whether these differences are in fact statistically significantly different[2].

If ANOSIM revealed significant differences in macroinvertebrate community composition (i.e. $R \neq 0$ and $P \leq 0.05$) between years, similarity percentages (SIMPER) were calculated[3] to show which macroinvertebrate taxa were driving these differences.

NMDS, ANOSIM and SIMPER analyses were performed in PRIMER version 6.1.13 (Clarke and Warwick 2001).

[1] Goodness-of-fit of the NMDS ordination was assessed by the magnitude of the associated 'stress' value. A stress value of 0 indicates perfect fit (i.e. the configuration of points on the ordination diagram is a good representation of actual community dissimilarities). It is acceptable to have a stress value of up to 0.2, indicating an ordination with a stress value of <0.2 corresponds to a good ordination with no real prospect of misleading interpretation (Quinn & Keough 2002).

[2] ANOSIM is a non-parametric permutation procedure applied to the rank similarity matrix underlying the NMDS ordination and compares the degree of separation among and within groups (i.e. sites or years) using the test statistic, R. When R equals 0 there is no distinguishable difference in community composition, whereas an R-value of 1 indicates completely distinct communities (Quinn & Keough 2002).

[3] The SIMPER routine computes the percentage contribution of each macroinvertebrate taxon to the dissimilarities between all pairs of sites among groups.

SUMMARY OF THE FINDINGS

Photos of the Styx River SMP site in 2015, looking upstream (right) and downstream (left).

Riparian and in-stream habitat

Water quality

The measures of pH, specific conductivity, water temperature and DO indicated water quality of the Styx River at the SMP monitoring site was generally within the ranges often encountered in spring-fed systems. However, it is important to note that these parameters were measured only once, and caution should be used when interpreting results based on a single water quality measure.

Specific conductivity, which is often used to indicate the level of pollutants in the water column, was 137 µS / cm_{25}, which was lower than the average conductivity recorded in the more urbanised Avon River catchment (mean conductivity across the catchment: 191 µS / cm_{25}; Boffa Miskell 2013). Water temperature was 13.6°C, which was below Canterbury's proposed Land and Water Regional Plan (pLWRP, Decisions Version 18 January 2014) guideline of a maximum water temperature of 20°C in spring-fed waterways. Similarly, a single measure of DO indicated the water was relatively well oxygenated at 86% saturation, however this was slightly below the pLWRP guideline of minimum DO of 90% for spring-fed waterways. pH was circum-neutral with a measure of 6.9.

These measures of basic water chemistry and temperature were not reported in the 2014 survey (EOS Ecology 2014), so no temporal comparisons were made.

Water velocity

Water velocity was relatively similar across the site in 2015, ranging from 0.58 to 0.68 m / s. The velocity readings were faster than those recorded at the site in 2014 (range: 0.32 – 0.39) (ANOVA: $F_{1, 4}$ = 64.5; P = 0.001) (Figure 2). However, this could be due to slight differences in transect location, or due to the change in methodology between years. In 2014, velocity was measured at 10 locations across each of three transects, taking into account the variety of flow regimes found across a relatively unmodified waterway (e.g. slower marginal areas, versus faster areas in the mid channel). The velocity range for 2014 given above was based on an average for each of the three transects (n = 10).

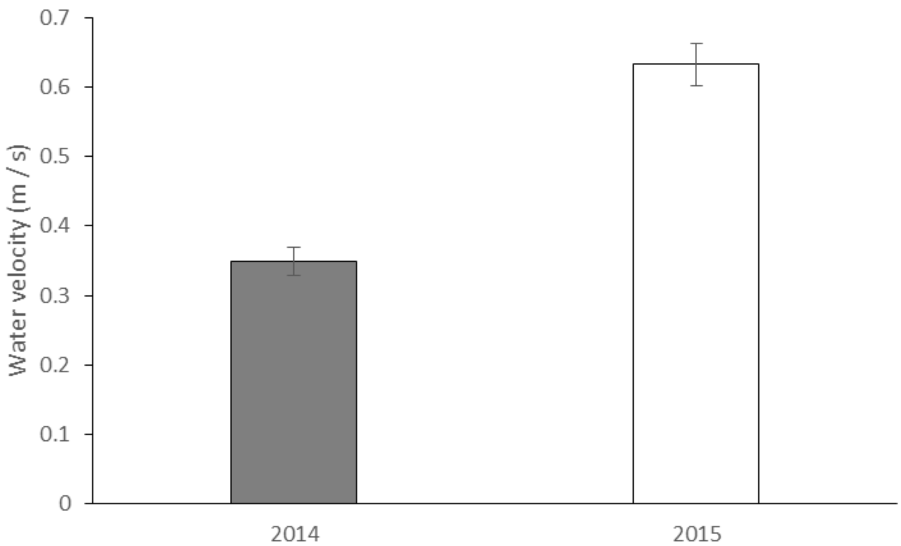

Figure 2. Average (±1SE) water velocity (m / s) measured at three locations at the Styx SMP site in 2015, compared to the 30 velocity measures taken in 2014.

General riparian and in-stream habitat conditions

The site was found to be 100% run habitat, which was also the case in 2014. However, earlier estimates indicated there may have been more variety in flow habitat types prior to this 2015 survey (Table 2).

Other habitat conditions measured in this survey are comparable to those measured in the previous 2014 survey (EOS Ecology 2014). Table 2 summarises these comparisons, indicating that although there are some differences in the estimates of habitat riparian and in-stream habitat conditions, for the most part, the condition of the habitat at this Styx SMP site appears to have remained relatively constant over time. This is not surprising, given that the site is located within the Styx Mill Conservation Reserve. However, it is anticipated that the riparian vegetation will mature over time particularly that of the planted native shrubs and trees (e.g. *Carex*, cabbage trees, and lancewoods), and as a result of the added benefits of the predator-proof fence along the true left bank of the river / reserve.

Table 2. Riparian and in-stream habitat variables as indicators of habitat condition at the Styx River SMP site, estimated in March 2008, February 2013 and 2014 (EOS Ecology 2008, 2013, 2014) and in this survey (February 2015).

	13-Mar-08	**27-Feb-13**	**21-Feb-14**	**10-Feb-15**
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
Bank material	Earth (minor wood)	Earth	Earth	Earth
Canopy cover	5-25%	<5%	5-25%	<5%
Substrate embeddedness	50-75%	25-50%	25-50%	25-50%
Flow habitat type (% riffle:run:pool)	50:0:50	60:40:0	0:100:0	0:100:0
Substrate composition: Silt/sand	33%	45%	21%	31%
Gravel	60%	15%	5%	15%
Pebbles	0%	4%	70%	37%
Small cobbles	5%	0%	5%	16%
Large cobbles	2%	0%	1%	1%

The average SI for the site was 4 (±0.14) indicating the substrate was comprised mainly of small substrates such as pebbles, gravels and silt / sand (Table 2). This is qualitatively similar to the findings of 2014 (Table 2), however, as SI was calculated in a different manner in 2014 the results are not directly comparable. In 2014, SI was calculated from a single substrate (the dominant substrate) measure at each of 12 locations along three transects at the site. These were then used to calculate a SI for each of the 12 locations, but only based on the dominant substrate at the location. The 12 SIs were summed to give a total SI for the transect. Whereas, in 2015, substrate composition (i.e. % cover of silt / sand, gravel, pebbles, small and large cobbles, and boulders) was estimated in a quadrat at each of five locations along three transects.

Average water depth at the site was significantly lower than those measured in 2014 ($F_{1,4}$ = 119.3; $P < 0.001$) (Figure 3). Again, this is likely to be due to slight differences in transect locations at the site, rather than significant and substantial changes in water depth over time (2014 vs 2015).

The average depth of fine sediment covering the stream bed did not significantly differ between 2014 and 2015 (ANOVA: $F_{1,4}$ = 3.36; P = 0.141) (Figure 3).

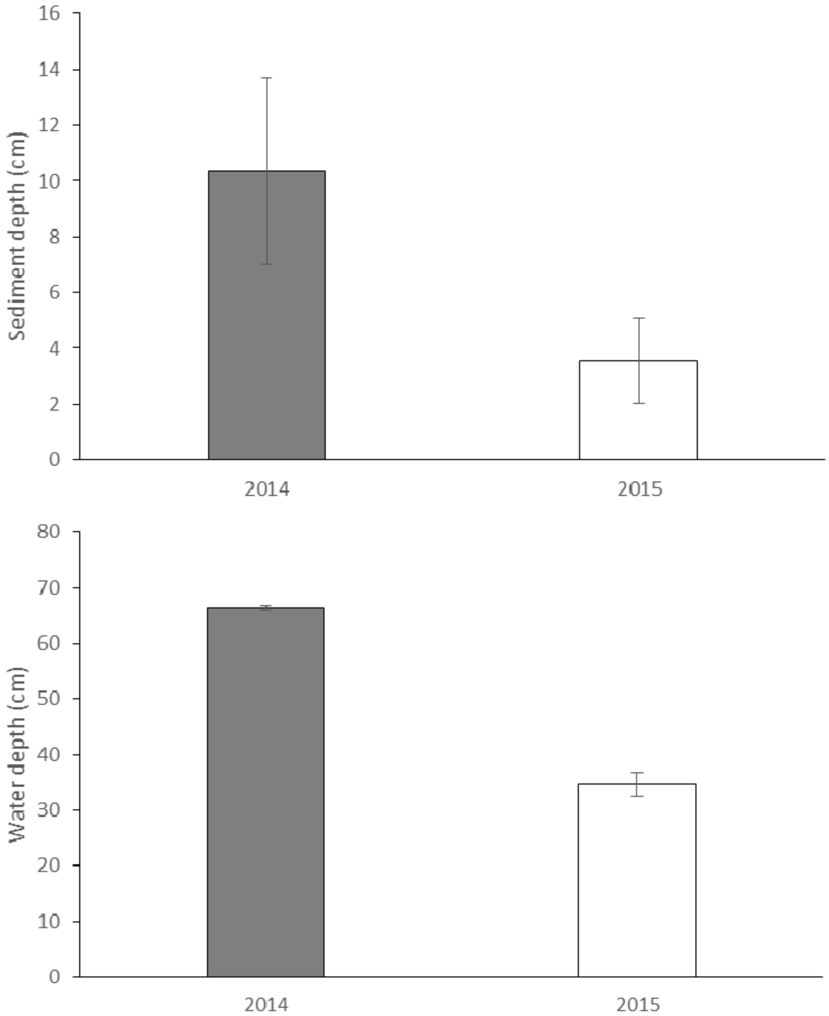

Figure 3. Average (±1SE) water (top) and sediment (bottom) depths recorded at the Styx River SMP site in 2014 (EOS Ecology) and 2015 (this study).

Macrophytes and periphyton

Macrophyte cover (%) was generally low across each transect, with average cover estimated between 20% and 22% for the three transects at the site. However, as macrophytes can be patchily distributed, macrophyte cover across the entire site was also estimated, with an approximate macrophyte cover of 70% at the Styx River SMP site. All macrophytes recorded at the site in 2015 were introduced species. The endemic species, *Myriophyllum triphyllum*, recorded in 2014 was not found[4] in this survey. This exceeded both the pLWRP guidelines for spring-fed streams and the Styx SMP consent surface water quality objectives for the site (maximum total macrophyte cover of streambed, 50%). However, this 2015 estimate was lower than the estimate of total macrophyte cover of the site in 2014, where EOS Ecology (2014) recorded 92% of the stream bed was covered by macrophytes.

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[4]The native (NZ endemic) macrophyte *Myriophyllum triphyllum* is thought to be rare in the Styx River catchment (van den Ende 2007). Although this species was not recorded in this 2015 survey, it may be present but was not detected during surveying. *Myriophyllum triphyllum* was recorded at the Styx SMP site in February 2014, but not in March 2008, or February 2013 (EOS Ecology 2014).

The macrophyte cover estimates at each of the three transects were also different between the surveys, with a greater cover estimated in 2014 than 2015 (ANOVA: $F_{1, 4}$ = 31.3; P = 0.005) (Figure 4).

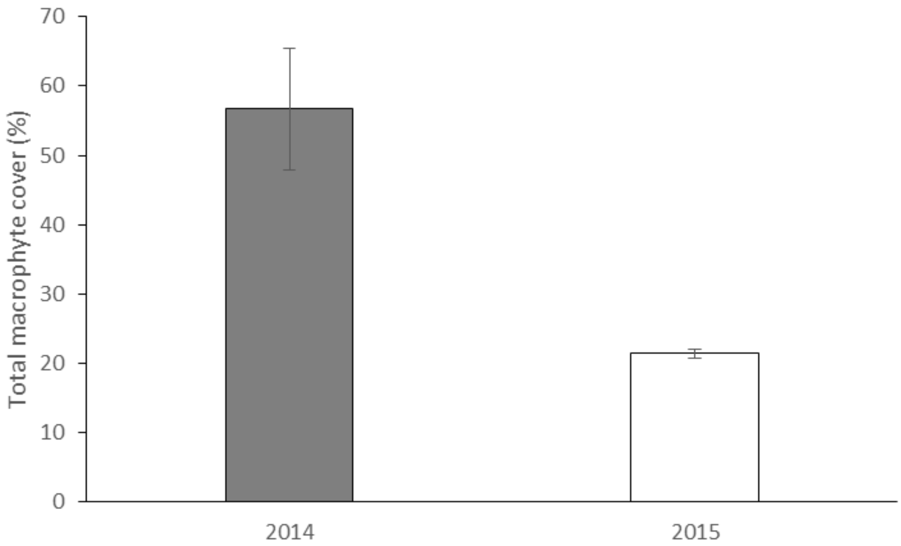

Figure 4. Average (±1SE) macrophyte cover (%) at three transects in the Styx River SMP site in 2014 and 2015.

The dominant macrophytes at the site in 2015 were the marginal species *Mimulus guttatus* (monkey musk), and *Nasturtium nasturtium-aquatica* (watercress). *Glyceria fluitans* (reed sweetgrass) and *Ranunculus trichophyllus* (aquatic buttercup), with its distinctive yellow flowers, dominated the submerged macrophytes.

Thin algae was present at the majority of locations along the three transects, with average percentage cover ranging from 50-67% at the site. Only occasional filamentous algal patches were found, with a maximum of 1% and 9% cover of short and long filamentous algae, respectively, found along the three transects. These measures were well within the pLWRP guidelines for spring-fed streams and below the Styx SMP consent surface water quality objectives for the site (maximum filamentous algal cover of streambed, 30%). Interestingly, neither short nor long filamentous algae has been observed at the Styx River SMP site in previous surveys (EOS Ecology 2008, 2013, 2014).

Macroinvertebrate Community

Overview

A total of 4,128 macroinvertebrates (average abundance: 1376 ± 54.11), belonging to 26 taxonomic groups (average taxonomic richness: 22 ± 1.67), were collected from the Styx River SMP site. The most diverse groups were the caddisflies (Trichoptera) and the true flies (or two-winged flies; Diptera), with ten different caddisfly and eight dipteran taxa being recorded from the site in this 2015 study. The freshwater snails and bivalves (Mollusca: 3 taxa) and crustaceans (Crustacea: 2 taxa) were the next most diverse groups, followed by a single mayfly taxon (Ephemeroptera), aquatic beetles (Coleoptera, 1 taxon), aquatic worms (Oligochaeta: 1 taxon), and flatworms (Platyhelminthes: 1 taxon). Freshwater snails and bivalves numerically dominated the macroinvertebrate community (39.7% of all macroinvertebrates were snails or bivalves), followed closely by caddisflies (28.3%).

Total abundance

By far the most abundant taxon found at the Styx River SMP site in 2015 was the ubiquitous native mud snail *Potamopyrgus antipodarium* (accounting for 33.9% of all macroinvertebrates collected). The caddisfly *Pycnocentrodes* and the mayfly *Deleatidium* were also quite abundant at the site, consisting of 19% and 11.7% of all the macroinvertebrates captured. Table 3 provides a comparison of the five most abundant macroinvertebrate taxa found in 2015, to those of previous surveys in 2014, 2013 and 2008 (EOS Ecology 2008, 2013, 2014).

Table 3. Relative abundances (%) of the five most abundant macroinvertebrate taxa found in surveys of the Styx River SMP site in 2008, 2013, and 2014 (EOS Ecology 2008, 2013, 2014) and in 2015 (this study). Shaded cells indicate the pollution-sensitive EPT taxa.

	13-Mar-08	**27-Feb-13**	**21-Feb-14**	**10-Feb-15**
Relative abundance (%) of the five most abundant macroinvertebrate taxa	*Paracalliope fluviatilis* (freshwater amphipod): 37%	*Paracalliope fluviatilis* (freshwater amphipod): 33%	*Paracalliope fluviatilis* (freshwater amphipod): 63%	*Potamopyrgus antipodarum* (NZ mud snail): 34%
	Potamopyrgus antipodarum (NZ mud snail): 27%	*Potamopyrgus antipodarum* (NZ mud snail): 15%	*Potamopyrgus antipodarum* (NZ mud snail): 13%	*Pycnocentrodes* (cased caddisfly): 19%
	Ostracoda (seed shrimp): 12%	Ostracoda (seed shrimp): 12%	Ostracoda (seed shrimp): 10%	*Deleatidium* (mayfly): 12%
	Orthocladiinae (non-biting midge larvae): 7%	*Pycnocentria* (cased caddisfly): 9%	*Deleatidium* (mayfly): 2%	Oligochaeta (oligochaete worm): 10%
	Pycnocentrodes (cased caddisfly): 4%	*Deleatidium* (mayfly): 6%	*Hudsonema amabile* (cased caddisfly): 2%	*Pycnocentria* (cased caddisfly): 5%

Taxonomic richness

There was no significant difference in the number or diversity of macroinvertebrate taxa found in the Styx River SMP site in 2014 and 2015 (ANOVA abundance: $F_{1, 4}$ = 0.38; P = 0.57; ANOVA richness: $F_{1, 4}$ = 0.16; P = 0.71) (Figure 5).

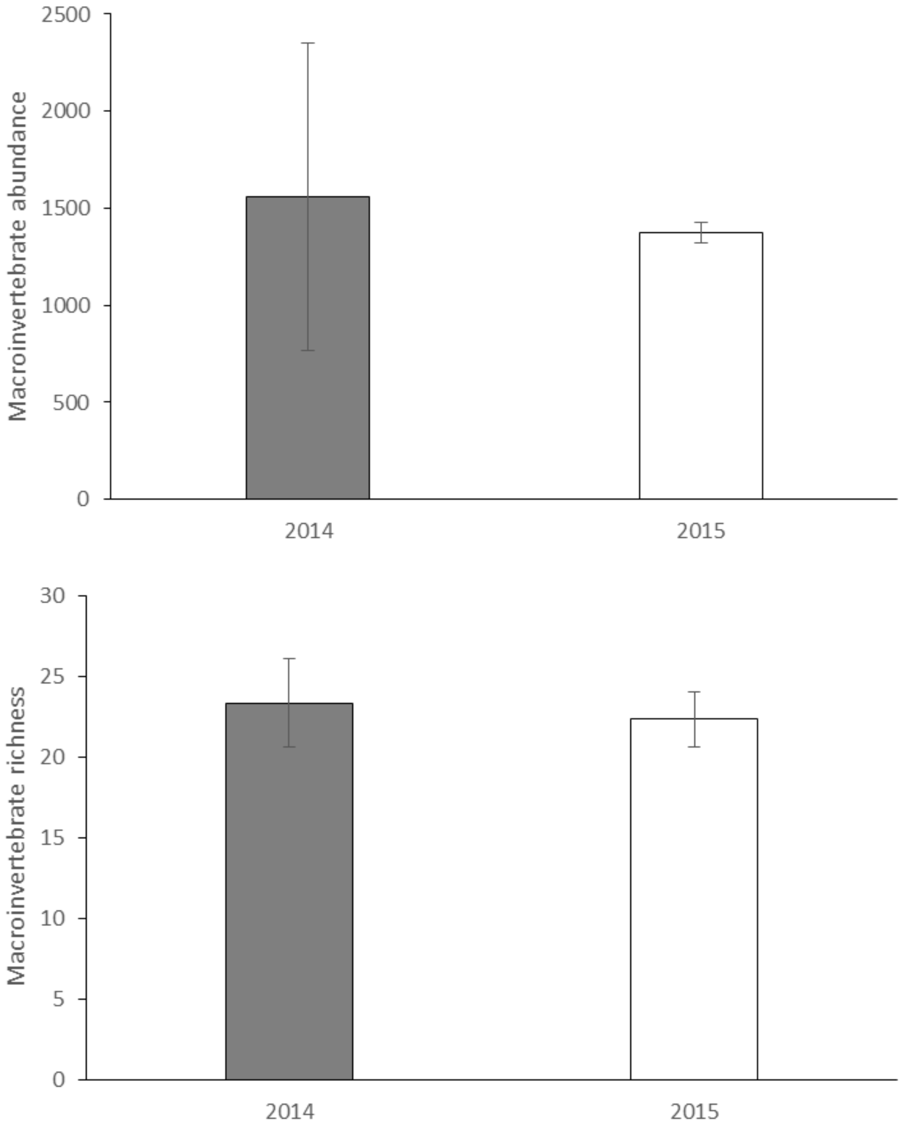

Figure 5. Average (±1SE) total abundance (top) and taxonomic richness (bottom) of macroinvertebrates found in the Styx River SMP site in 2014 (EOS Ecology) and 2015 (this study).

EPT richness and composition

Although, three of the top five most abundant macroinvertebrate taxa were represented by EPT taxa (compared to two of the five in 2014), there was no significant difference in the number of EPT taxa found between years ($F_{1, 4}$ = 0.02; P = 0.884) (Figure 6). The EPT orders (Ephemeroptera, mayflies; Plecoptera, stoneflies; and Trichoptera, caddisfies), which are generally sensitive to pollution and habitat degradation, are useful indicators of stream health. High EPT richness suggests high water and habitat quality, while low EPT richness suggests low water and habitat quality, and degraded stream health.

EPT taxa accounted for approximately 40% of the macroinvertebrate community at the Styx River SMP site in 2015, compared to around 15% of the community in 2014. However, there was a great deal of variation between the relative abundances of EPT taxa in the three kick-net samples collected in both years, so this difference was not statistically significantly different (ANOVA: $F_{1, 4}$ = 1.25; P = 0.326, based on ranked data) (Figure 7).

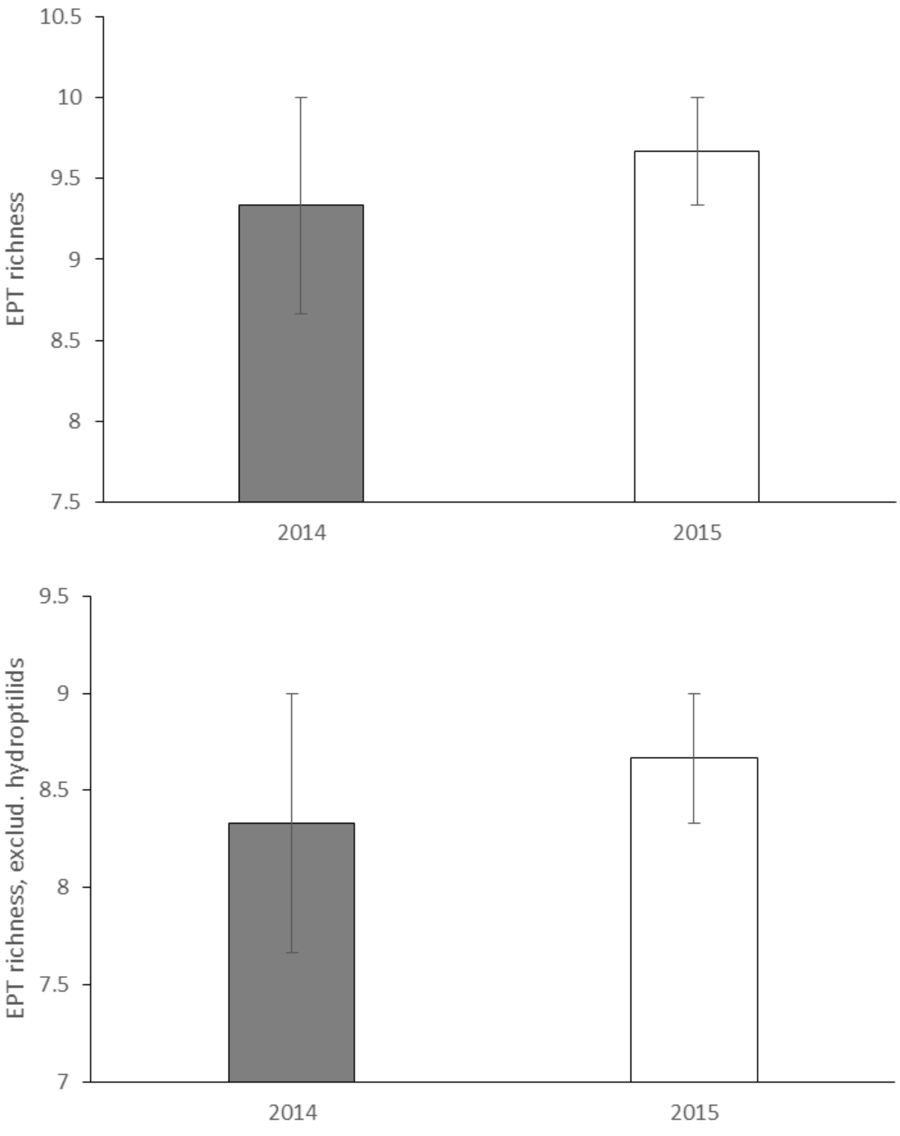

Figure 6. Average (±1SE) EPT richness (top) and EPT richness, excluding hydroptilid caddisflies (bottom) found in the Styx River SMP site in 2014 (EOS Ecology) and 2015 (this study).

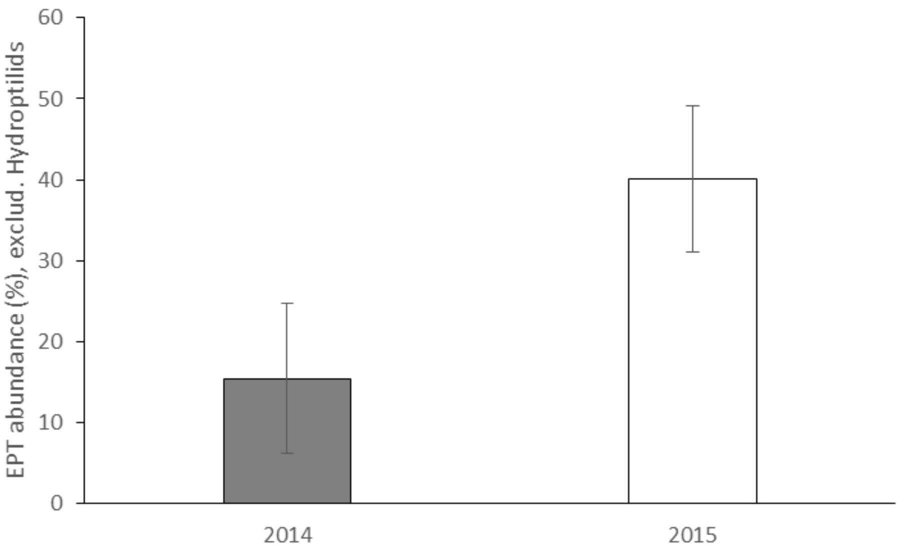

Figure 7. Average (±1SE) relative abundance (%) of EPT taxa, excluding hydroptilid caddisflies found in the Styx River SMP site in 2014 (EOS Ecology) and 2015 (this study). Note, the ANOVA was carried out using ranked data (see methods section), but this figure shows the raw, untransformed data.

Macroinvertebrate Community Index

The Macroinvertebrate Community Index (MCI) and its quantitative variant (QMCI) indicated the Styx River SMP site had fair stream health (based on the water quality categories of Stark and Maxted 2007), with 'probable mild enrichment'. This was similar to the findings of the 2014 survey (EOS Ecology 2014), where no significant differences were found between the MCI (ANOVA: $F_{1, 4}$ = 0.48; P = 0.525) and QMCI (ANOVA: $F_{1, 4}$ = 0.81; P = 0.420) scores for the site in 2014 and 2015 (Figure 8).

The QMCI value for 2015 was slightly below the guidelines of the pLWRP of a minimum QMCI score of 5.0, but within the guidelines of QMCI 4.5-5.0 for the Styx River Surface water quality objectives (CRC131249).

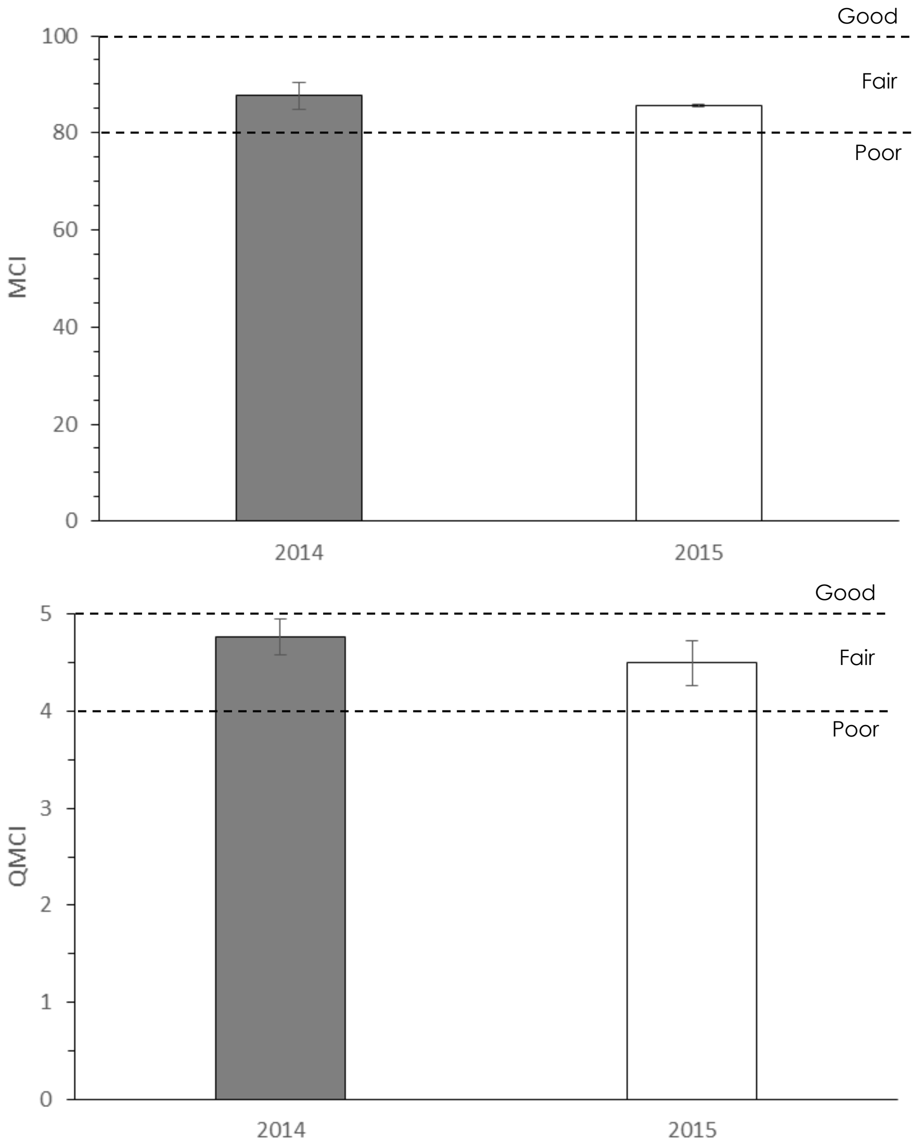

Figure 8. Average (±1SE) MCI (top) and QMCI (bottom) scores for the Styx River SMP site in 2014 (EOS Ecology) and 2015 (this study).

Urban Community Index

The UCI score, and its quantitative variant QUCI, developed by Suren et al. (1998), were both positive, indicating macroinvertebrate communities from fast-flowing waterways with coarser substrates as compared to negative UCI / QUCI scores indicating communities tolerant of the environmental conditions found in urban freshwater systems (e.g. slow-flowing waterways with high levels of soft sediments). The UCI was significantly greater in 2015, compared to 2014 (ANOVA: $F_{1, 4}$ = 11.01; P = 0.029), but QUCI scores were similar between years (ANOVA: $F_{1, 4}$ = 0.34; P = 0.590) (Figure 9). Differences in the UCI between years could, in part, be due to differences in velocity and sediment levels between years. Velocity was greater in 2015, compared to 2014, while less fine sediments were found covering the stream bed. However, these differences in UCI values between years could also be a reflection of subtle differences in the macroinvertebrate sampling locations and the naturally patchy distribution of macroinvertebrates in rivers. It is anticipated that this magnitude of difference in UCI values (i.e. 2 units) is likely to have little biological relevance. Most importantly, there were no major differences in the macroinvertebrate community (see section below), and therefore no indication that the macroinvertebrate community has changed markedly overtime.

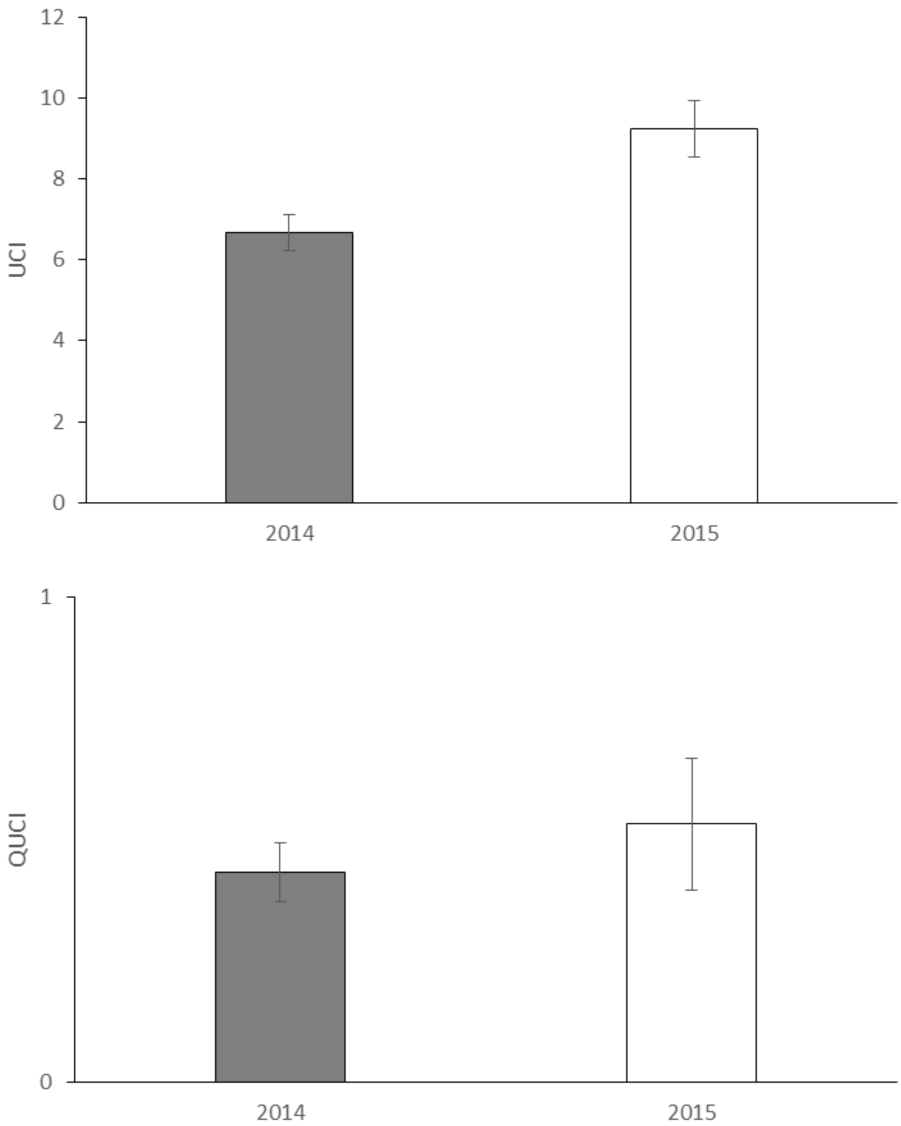

Figure 9. Average (±1SE) UCI (top) and QUCI (bottom) scores for the Styx River SMP site in 2014 (EOS Ecology) and 2015 (this study).

Macroinvertebrate community composition

The NMDS ordination indicated that the macroinvertebrate community composition was variable between survey years (Figure x). However, the differences in community composition were weak (ANOSIM: R = 0.417; P = 0.04).

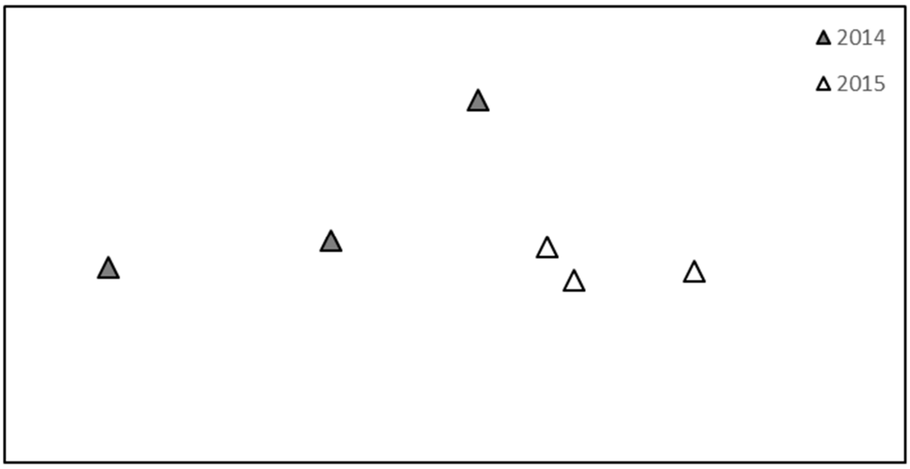

Figure 10. Non-metric multivariate scaling (NMDS) ordination based on a Bray-Curtis matrix of dissimilarities calculated from macroinvertebrate abundance data collected in a kick net at the Styx River SMP site in 2014 (EOS Ecology 2014) and 2015 (this study). The NMDS gave a good representation of the actual community dissimilarities between years (two-dimensional stress < 0.01). Axes are identically scaled so that the samples closest together are more similar in macroinvertebrate community composition than those further apart.

SIMPER indicated that these significant (albeit statistically weak) differences were largely due to variations in the abundances of macroinvertebrate taxa among sites (rather than differences in the presence or absence of certain taxa). For example, 35% of the variation in community composition was due to the high numbers of the freshwater amphipod *Paracalliope fluviatilis* in 2014, compared to 2015 (Table 4). The NZ mud snail *Potamopyrgus antipodarum* was more abundant in the 2015 samples than 2014, as were the cased caddis *Pycnocentrodes* and *Pycnocentria*, the mayfly *Deleatidium*, oligochaete worms, and the freshwater limpet *Ferrissia*.

Table 4 shows the macroinvertebrate taxa that explain the majority (>90%) of the variation in community composition between years.

Table 4. The macroinvertebrate taxa that explain > 90% of the variation in community composition found in the Styx River SMP site in 2014 (EOS Ecology 2014) and 2015 (this study). Bold values indicate the year each taxon was most abundant.

Taxon	**Average abundance**		**Average dissimilarity**	**Cumulative % variation**
	2014	2015		
Paracalliope fluviatilis	**982.67**	47.67	24.48	35.78
Potamopyrgus antipodarum	207.33	**467.00**	11.49	52.57
Pycnocentrodes	14.67	**261.33**	9.84	66.95
Deleatidium	30.33	**161.67**	5.04	74.32
Oligochaeta	13.00	**135.00**	4.70	81.19
Ostracoda	**160.67**	51.00	3.56	86.39
Ferrissia	6.33	**65.67**	2.29	89.74
Pycnocentria	25.33	**71.33**	1.89	92.51

COMPARISONS WITH STYX RIVER SMP SURFACE WATER QUALITY OBJECTIVES AND OTHER GUIDELINES

Comparisons of the results with previous monitoring, to the surface water quality objectives of the Consent CRC131249, and to the relevant indicator thresholds outlined in the proposed Canterbury Land and Water Regional Plan (pLWRP, decisions version January 2014) have been made throughout the 'Summary of findings' section above.

To recap, only total macrophyte cover measured at the Styx River SMP site in February 2015 breached surface water quality objectives for the Consent CRC131249 (Table 5). The QMCI score was just within the minimum range of 4.5-5.0, while sediment cover was below the recommended 40%. Filamentous algae, which had not been previously recorded at the site (EOS Ecology 2014) was well below the maximum guideline of 30%.

The QMCI, fine sediment cover, and total macrophyte cover were above the pLWRP (decisions version, 18 January 2014) guidelines recommended for spring-fed (plains) waterways.

Table 5. Comparison of the surface water quality objectives from Consent CRC131249 and the guidelines from the proposed Canterbury Land and Water Regional Plan with the measurements recorded from the Styx River SMP site in February 2015. Parameters that breach the Styx River SMP objectives are shaded grey; breaches of the pLWRP are in bold.

	Surface water quality objectives from Consent CRC131249	**Guidelines from the proposed Canterbury Land and Water Regional Plan**	**Results from February 2015**
QMCI	Minimum of 4.5-5.0	Minimum of 5.0	**4.5**
Fine sediment cover	Maximum of 40%	Maximum of 20%	**33%**
Total macrophyte cover	Maximum of 50%	Maximum of 50%	**70%**
Filamentous algae cover (> 20 mm long)	Maximum of 30%	Maximum of 30%	9%

CHANGES OVER TIME

There has been little significant change in habitat or macroinvertebrate community composition at the Styx River SMP site since monitoring under the Consent CRC131249 began in 2014. Based on this information, there does not appear to have been any detectable effects of stormwater discharges on this receiving environment.

The habitat and water quality conditions are of a similar standard to those found in 2014, and continue to support EPT taxa that are relatively sensitive to pollution and urbanisation. For example, the mayfly, *Deleatidium*, is still present at this site, but is no longer present in the much more urbanised Avon or Heathcote River catchments.

Total macrophyte cover was the only parameter recorded in 2015 that was found to exceed the surface water quality objectives of the Consent CRC131249. However, this was consistent with the findings of the 2014 survey at this site.

RECOMMENDATIONS

While macrophyte coverage can respond to a variety of parameters, including (but not limited to) nutrient levels and light availability in the waterway, as well as the natural tendency for spring-fed systems to have higher abundance and diversity of macrophytes, the total coverage in the Styx River SMP site exceeded that of the Consent's recommended objectives. Macrophytes are regularly maintained in Christchurch's waterways, with annual channel maintenance activities scheduled to occur after this survey was conducted. As a result, it is anticipated that macrophyte cover fluctuates at this site.

However, increased shading of the channel may assist with reducing the macrophyte cover, in places, at this site. Despite the high cover of riparian vegetation throughout the site, there is limited in-stream shading (<5% of the channel was shaded in February 2015). This is consistent with the findings of the 2014 survey, and previous surveys of the Styx River catchment (Table 2).

Continued monitoring of the site is crucial to detect any changes in habitat conditions or macroinvertebrate community composition that may be as a result of stormwater effects. The presence of the mayfly *Deleatidium*, and the relatively high percentage of all EPT taxa found in 2015, are parameters of greatest interest.

EPT taxa are considered generally sensitive to pollution, and are often used as indicators of change. EPT taxa richness and percent abundance are often very low in urbanised waterways, and usually limited to only the more tolerant taxa, such as hydroptilid caddisflies. Similarly, oligochaete worms, snails, and chironomid larvae often become more abundant in waterways affected by stormwater inputs.

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