Annual Monitoring of Cashmere Stream: South-West Christchurch Monitoring Programme 2019

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Prepared for:
Christchurch City Council

Instream Consulting Limited
PO Box 28 173
Christchurch 8242

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EXECUTIVE SUMMARY

This report describes results from the 2019 round of annual macroinvertebrate monitoring of Cashmere Stream in relation to Canterbury Regional Council stormwater discharge consent CRC120223. Macroinvertebrate communities were similar to previous years, being dominated by pollution-tolerant taxa at all sites. No statistically significant increasing or decreasing trends were detected for any macroinvertebrate metrics examined over the seven years of annual monitoring from 2013 to 2019 ($P>0.05$). As in previous years, compliance with consent surface water quality objectives was variable in 2019, reflecting local differences in substrate composition and riparian shading, rather than impacts of consent-related stormwater discharges. We reiterate our recommendation from last year: that trees and tall shrubs are planted along open sections of Cashmere Stream such as Site 3, where there is currently poor shade and consequently excessive macrophyte cover.

1. INTRODUCTION

Christchurch City Council (CCC) holds resource consent CRC120223, which authorises the discharge of stormwater from the South-West Christchurch area. The discharge consent has various monitoring requirements attached, including annual monitoring of aquatic macroinvertebrates at three sites in Cashmere Stream. The purpose of the annual monitoring is to assess trends in ecological values over time. Monitoring commenced in 2013. This report describes the results of the 2019 round of annual monitoring and assesses any trends in macroinvertebrate communities over time.

2. METHODS

2.1. Monitoring Sites

Cashmere Stream was chosen for annual ecological monitoring because of its high ecological values relative to other waterways in the South-West area (EOS Ecology et al. 2005). The exact location of the three annual monitoring sites are stipulated in consent CRC120223. The monitoring sites are located within Cashmere Stream at sites immediately downstream of waterways where substantial residential development is proposed. The three tributaries are Dunbar Waterway, Henderson Drain, and Ballintines Drain (see Table 1 and Figure 1). Landuse within the catchment of each monitoring site is a mixture of urban (mainly residential) and rural, with increasing residential development in recent years. Site 1 is located within a reserve area, so has the greatest riparian vegetation cover. Half of Site 2 is located underneath concrete bridge abutments, which provides shade but no other natural bank features. Site 3 has houses and partial shading from trees on the true right bank (looking downstream) and farmland on the true left, with no trees or shrubs on that bank. Note that at Site 1 the monitoring reach was moved approximately 5 m upstream compared to last year, to avoid a new deep pool (>1 m deep) beside an area of recent bank works.

Table 1: Monitoring site locations. Eastings and northings are from the downstream end of each reach.

Site	Location	NZTM Easting	NZTM Northing
1	Downstream of Ballintines Drain	1567915	5175088
2	Downstream of Henderson Drain	1567664	5175040
3	Downstream of Dunbar Waterway	1567370	5174795

2.2. Sampling

Fieldwork was undertaken on the 7th and 8th of February 2019 during baseflow conditions. Field methods were identical to those used in previous years (see Instream 2018). Methods are therefore summarised in text here and the reader is referred to previous reports for more detailed methods.

Monitoring includes measurements of water quality, habitat, macrophyte and periphyton cover, and sampling of benthic macroinvertebrates. Each sampling site comprises a 20 m long sampling reach.

Water quality sampling entailed measurement of dissolved oxygen (DO), temperature, pH, and conductivity in the field, using a recently-calibrated Hannah Instruments water quality meter (model HI9829).

Habitat sampling was undertaken either at the reach scale (e.g., neighbouring landuse) or at each of three transects, located at 10 m spaces along the reach. Some habitat parameters were measured at multiple points across each reach (e.g., water depth), while other parameters were taken at the transect scale (e.g., macrophyte cover). Water velocity was measured at 10 points across each reach using a Seba Mini velocity meter.

Macroinvertebrate sampling entailed collection of a single kicknet (500 µm mesh) per transect, giving a total of three replicate kicknet samples per site. Each kicknet sample covered an approximately 0.3 m band over a channel width of 1.5 m, giving an average sampling area of approximately 0.45 m^2 per sample. Macroinvertebrates were preserved in denatured ethanol and sent to Biolive Consultants for sorting and identification.

Figure 1: Cashmere Stream annual monitoring sites.

2.3. Data Analyses

2.3.1. Data Management and Habitat Data

Data from 2019 were added to data from all previous years of monitoring in a single Microsoft Excel spreadsheet. The combined spreadsheet was provided to CCC in electronic form at the time this report was submitted, and the data is available from CCC on request.

Relevant habitat data chosen for statistical analyses included the following parameters that were analysed in previous years (James 2017, Instream 2018): channel width, water depth, water velocity, substrate index, fine sediment (<2 mm diameter) depth, fine sediment cover, total macrophyte cover, macrophyte depth, and bed cover with long filamentous algae (>2 cm long). Resource consent CRC120223 has fine sediment cover and macrophyte cover water quality objectives of <30% cover, while the objective is <20% for long filamentous algae cover. Macrophyte cover is estimated visually both as a reach average and as an average across each transect. Transect data was used for reporting macrophyte cover, as it is consistent with recommended national protocols for macrophyte monitoring and reporting (Matheson et al. 2012; Instream 2018).

Data were averaged for each transect (where relevant), plotted, compared with water quality objectives, and inspected for evidence of any patterns over time or amongst sites. Trends over time were examined statistically using the Mann-Kendall trend test on annual median data for each site in Time Trends statistical software (version 6.30). Trend analysis was used in favour of two-way analysis of variance because, with seven years of monitoring data, it is appropriate to focus on trend analysis. In addition, interpretation of site by year interactions with two-way ANOVA have previously yielded statistically-significant interaction effects, but no ecologically meaningful patterns (James 2017).

2.3.2. Macroinvertebrate Analyses

The following biological indices were calculated from the raw invertebrate data:

Total Abundance: The total number of invertebrates per sample. Total abundance may be reduced by sedimentation, but is not a reliable metric for kicknet samples, due to variable sampling area.

Taxa Richness: The number of different invertebrate taxa (families, genera, species) at a site. Richness may be reduced at impacted sites, but is not a strong indicator of pollution.

%EPT: The percentage of all individuals collected made up of pollution-sensitive Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) taxa. %EPT is typically reduced at polluted sites, and is particularly sensitive to sedimentation. This metric is calculated with and without pollution-tolerant hydroptilid caddisflies, which can skew %EPT results at sites where they are abundant.

EPT Taxa Richness: The number of different EPT taxa at a site. It is reduced at polluted sites. Calculated with and without hydroptilid caddisflies included.

MCI and QMCI: The Macroinvertebrate Community Index and the Quantitative MCI (Stark 1985). Invertebrate taxa are assigned scores from 1 to 10 based on their tolerance to organic pollution. Highest scoring taxa (e.g., many EPT taxa) are the least tolerant to organic pollution. The MCI is based on presence-absence data: scores are summed for each taxon in a sample, divided by the total number of taxa collected, then multiplied by a scaling factor of 20. The QMCI requires abundance data: MCI scores are multiplied by abundance for each taxon, summed for each sample, then divided by total invertebrate abundance for each sample. We calculated site MCI and QMCI scores using the tolerance scores for hard-bottomed streams for Sites 1 and 2 and soft-bottomed streams for Site 3, to reflect the dominant substrate present (Stark & Maxted 2007). MCI and QMCI scores can be interpreted as per the quality classes of Stark & Maxted (2007), as summarised in Table 2.

Table 2: Interpretation of MCI and QMCI scores (from Stark & Maxted 2007).

Quality Class	MCI	QMCI
Excellent	>119	>5.99
Good	100-119	5.00-5.90
Fair	80-99	4.00-4.99
Poor	<80	<4.00

Macroinvertebrate data were analysed statistically using the Mann-Kendall trend test. In addition, macroinvertebrate community composition was compared amongst sites and over time using non-metric multi-dimensional scaling (NMDS), a form of ordination. The ordination was based on a Bray-Curtis dissimilarity matrix, using square-root transformed data and the Ecodist package in R (version 3.6.0). Spearman rank correlation was used to reveal which taxa and habitat attributes were most closely correlated with NMDS axis scores. QMCI scores were compared with the surface water quality objective of a minimum QMCI of 4 for consent CRC120223.

3. RESULTS

3.1. Habitat

Sites 1 and 2 have moderate shading from trees (and a bridge in the case of Site 2), whereas Site 3 is poorly shaded (see photographs in Appendix 1). All sites are of moderate width, with annual mean widths ranging from approximately 3 to 4 m (Figure 2). Sites 1 and 2 are relatively shallow (annual mean depths of 20 to 30 cm), have stony beds, and have moderate to swift water velocities, with annual mean velocities in the range of 0.3 to 0.6 m/s (Figure 2). In contrast, Site 3 is relatively deep (annual mean depth of 30 to 60 cm), it has a silt/sand bed, and slower velocities (annual mean velocity typically 0.1 to 0.2 m/s; Figure 2). No significant trends were detected over time at any of the sites for channel width or water velocity ($P>0.05$; Appendix 2). A positive increasing trend in water depth was detected at Site 3 ($P=0.005$, 6.5% annual change), reflecting greater water depths in 2018 and 2019 (Figure 2). Substrate index showed a weak increasing trend at Site 3 ($P=0.02$; Appendix 2), but this was not a scientifically meaningful trend, with 0% annual change (Appendix 2).

Fine sediment cover has consistently been less than 20% at Sites 1 and 2, and approximately 100% at Site 3, for all monitoring years (Figure 3). That means that Sites 1 and 2 have consistently met the surface water quality objective of <30% fine sediment cover, while Site 3 has consistently not met the objective. Fine sediment depth has also been consistently greater at Site 3 than Sites 1 and 2 (Figure 3). No significant trends were detected over time for fine sediment cover or fine sediment depth (P>0.05, Appendix 2).

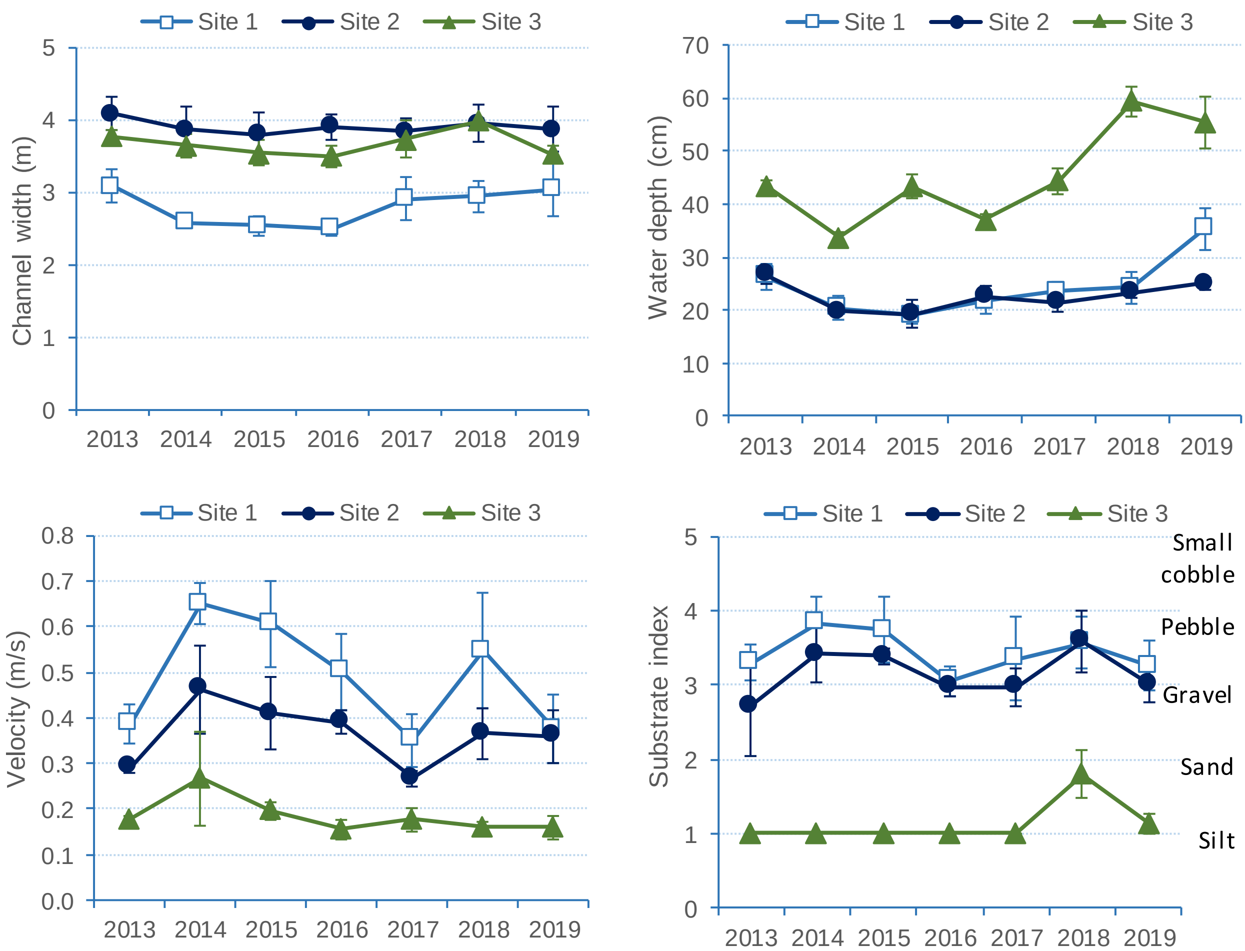

Figure 2: Mean (±1 SE) channel width, depth, velocity and substrate composition.

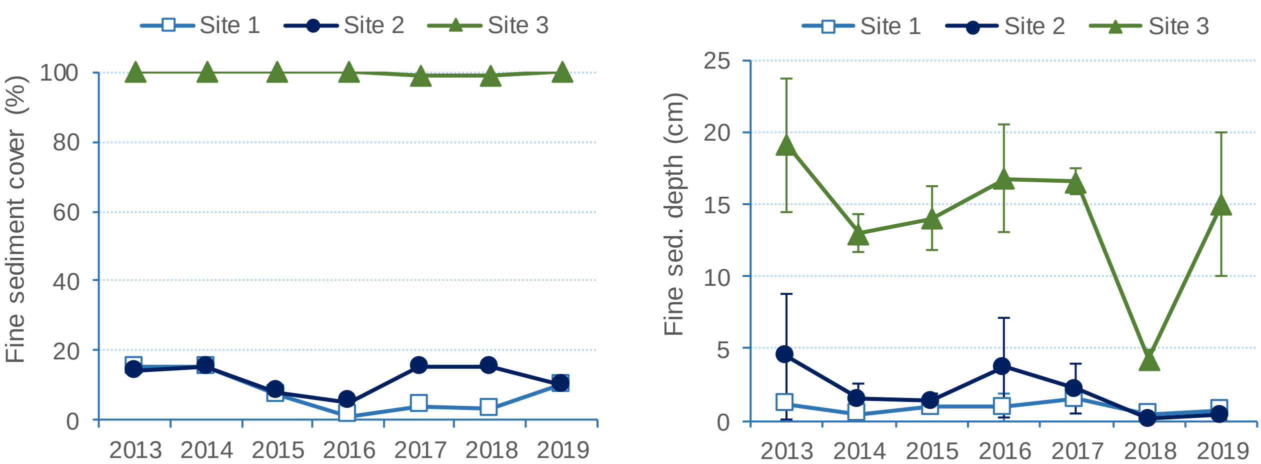

Figure 3: Fine sediment (<2 mm) cover and depth (mean ±1 SE).

Site 3 has consistently had greater macrophyte cover and macrophyte depth than Sites 1 and 2 for all years of monitoring (Figure 4). Total macrophyte cover has exceeded the surface water quality objective of <30% cover for all years of record at Site 3 and for the last three years at Site 2 (Figure 4). Macrophyte cover had statistically significant positive trend for Site 1 (P=0.029) and Site 3 (P=0.004), associated with a step increase in macrophyte cover between 2016 and 2017 (Figure 4). Macrophyte depth was high in 2018 at Site 3 compared to previous years, and there was a weak positive trend in macrophyte depth at Site 3 (P=0.04, Appendix 2).

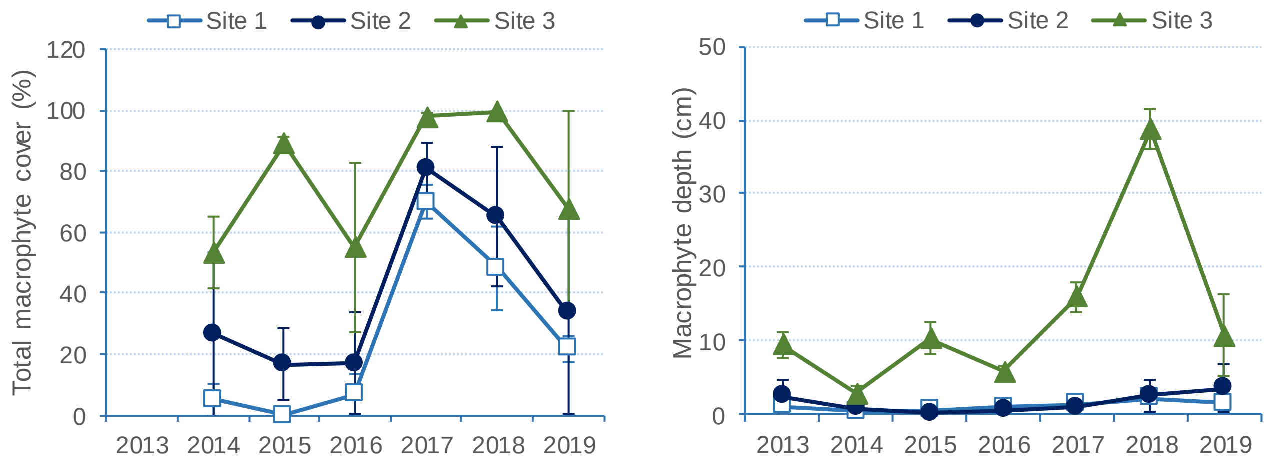

Figure 4: Mean (±1 SE) macrophyte cover and depth. Macrophyte cover estimates commenced in 2014.

As with previous years, Canadian pondweed (*Elodea canadensis*) dominated macrophyte cover at Site 3 in 2019 (70% cover), with curly pondweed (*Potamogeton crispus*) also common (20% cover). *P. crispus* was the most abundant macrophyte at Sites 1 and 2, comprising 15% cover at Site 1 and 10% cover at Site 2. Periphyton community composition was also similar in 2018 to previous years, with thin films present at Sites 1 and 2, minimal periphyton cover at Site 3, and long filamentous algae cover <2% at all sites. Thus, all sites have complied with the surface water quality objective of <20% cover with long filamentous algae for all monitoring years.

3.2. Macroinvertebrates

Macroinvertebrate community composition was similar in 2019 to previous years, being dominated by snails (Mollusca) and crustaceans at all monitoring sites (Figure 5). Across all years of monitoring, Mollusca have comprised 53% of total abundance and crustaceans 30%. The common mud snail *Potamopyrgus antipodarum* and the crustacean *Paracalliope* were the two most abundant taxa overall in 2019, as in previous years. Caddisflies (Trichoptera) were the next most abundant group in 2019 and in previous years, comprising an average of 8% of total abundance across all years. Other common, but less abundant taxa include two-winged flies (Diptera) and oligochaete worms (Figure 5).

A total of 51 distinct taxa have been identified from the three sites over the seven years of monitoring. However, only seven of the recorded taxa have an MCI score of 6 or higher, indicating relative sensitivity to pollution. Five of these taxa with MCI scores of 6 or higher are caddisflies (*Oecetis*, *Hudsonema amabile*, *H. alienum*, *Psilochorema*, *Polyplectropus*, and *Oeconesus*), and the other taxon is an elmid beetle. Inspection of the raw data shows no indication that any of these taxa are disappearing over time. *Oeconesus, Polyplectropus, H. alienum,* and elmid beetles occur in very low densities, such that sometimes they are not detected.

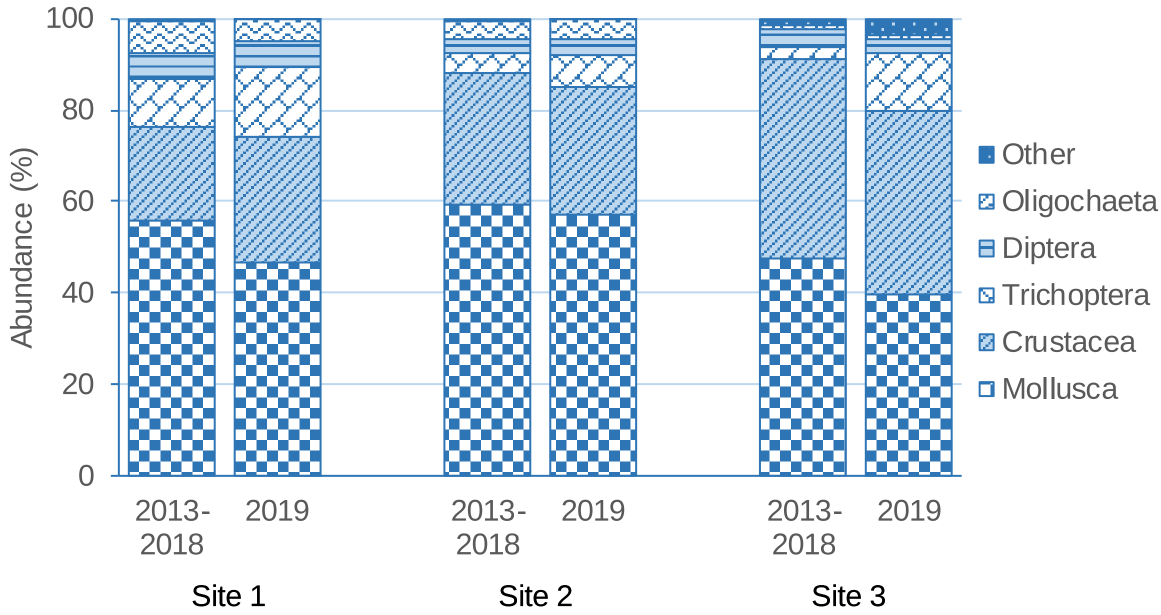

Figure 5: Macroinvertebrate community composition in 2019 compared to the mean of previous years.

Total abundance and taxa richness have varied over time, with mean taxa richness in 2019 ranging from 19 at Sites 1 and 2 to 20 at Site 3 (Figure 6). There were no significant trends over time in abundance or taxa richness for any of the sites (P>0.05; Appendix 2).

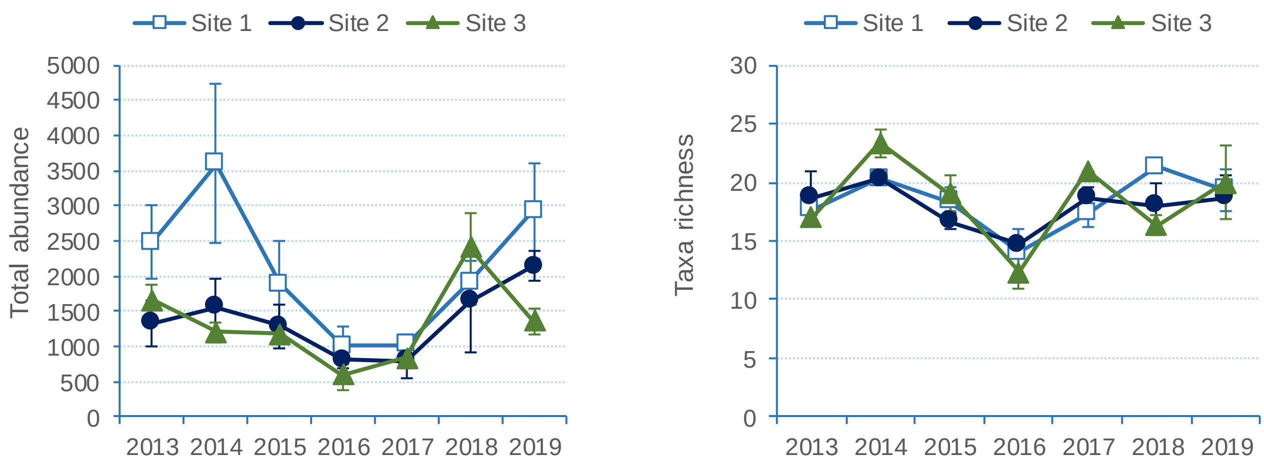

Figure 6: Mean (±1 SE) macroinvertebrate abundance (left) and taxa richness (right).

Mean QMCI scores at Sites 1 and 2 are typically in the range of 3.5 to 4.3 (Figure 7), and are indicative of poor to fair quality (Table 2). Mean QMCI scores are typically lower at Site 3, ranging from 2.5 to 3.4, (Figure 7), and are indicative of poor quality (Table 2). Mean QMCI scores in 2019 ranged from 3.4 at Site 3 to 3.8 at Site 1, so fell below the water quality objective of 4. Mean MCI scores in 2019 ranged from 75 at Site 3 to 79 at Site 2 (Figure 7), and all were indicative of poor quality (Table 2). There were no significant trends over time in QMCI or MCI scores for any of the sites (P>0.05; Appendix 2).

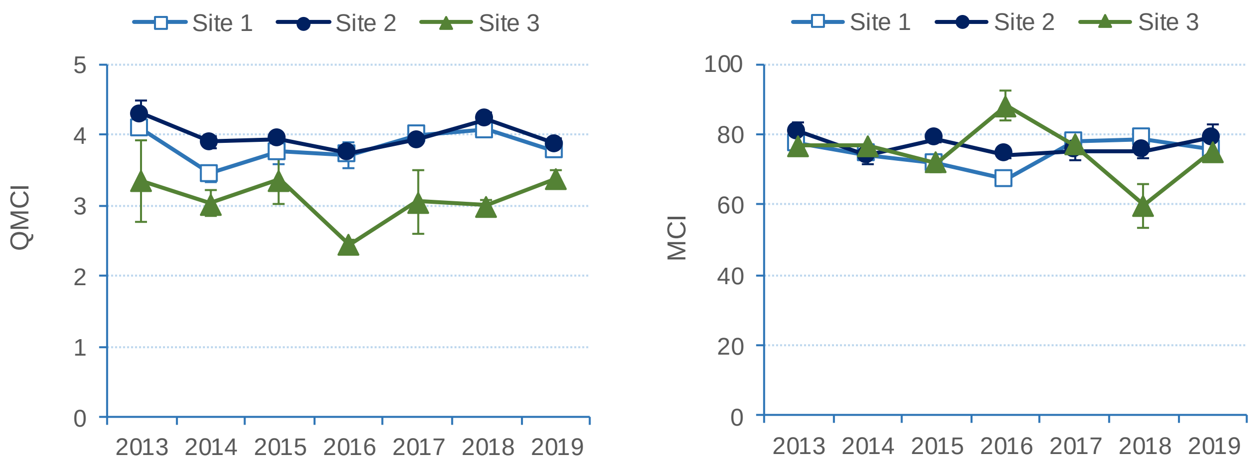

Figure 7: Mean (±1 SE) QMCI and MCI scores.

Mean EPT abundance (excluding pollution-tolerant Hydroptilidae) is typically less than 10% and EPT taxa richness less than 6 at all sites (Figure 8), reflecting the dominance of pollution-tolerant taxa at these sites. While EPT abundance and taxa richness has fluctuated over time, no significant trends have been detected for any of the sites (P>0.05, Appendix 2).

The NMDS ordination yielded a two-dimension solution with a stress value of 0.20, indicating fair relationship with the underlying dissimilarity matrix (Clarke 1993). There is a general pattern in ordination space, with samples from Site 3 grouped towards the left of the plot along Axis 1, compared to Sites 1 and 2, which are grouped together towards the right of the plot (Figure 9). There is no obvious separation in samples amongst sampling years (Figure 9). More macroinvertebrate taxa and habitat variables were correlated with Axis 1 scores than Axis 2 (Figure 9; Appendix 2). Axis 1 was negative correlated (P<0.001) with water depth, fine sediment depth, macrophyte depth, and total macrophyte cover, and positively correlated with substrate size and water velocity. Thus, the separation of samples from Site 3 from the other two sites along Axis 1 likely reflected the influence of finer substrate, lower velocities, greater depth, and greater macrophyte cover on macroinvertebrates at Site 3. This is a similar pattern to that observed in previous years (Instream 2018)

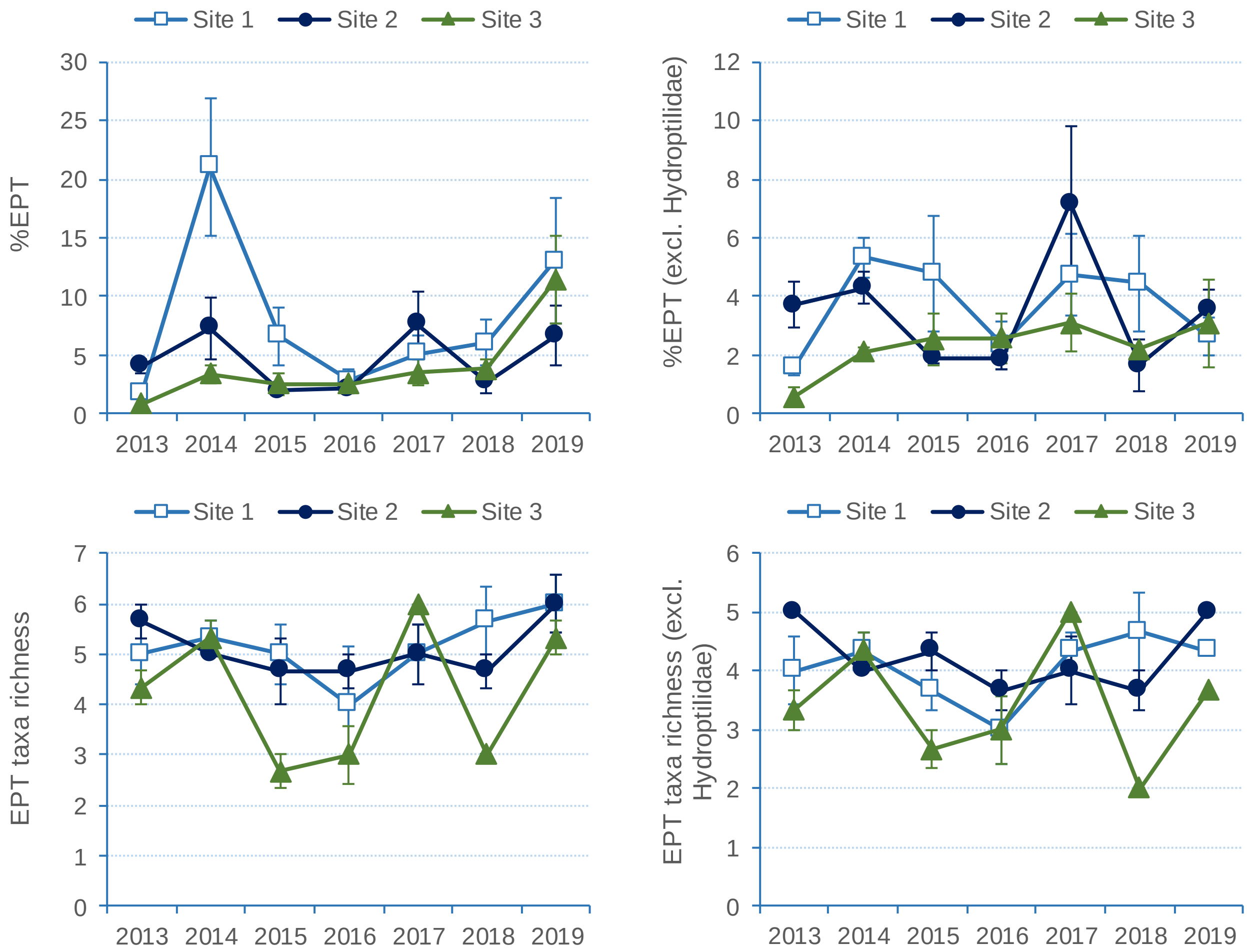

Figure 8: Mean (±1 SE) percent EPT abundance and taxa richness, with (left) and without (right) pollution-tolerant Hydroptilidae.

4. DISCUSSION AND CONCLUSIONS

No declining or increasing trends in invertebrate community health were detected at the three Cashmere Stream sites monitored annually from 2013 to 2019. This finding is consistent with previous years (Instream 2018) and it indicates that changes from rural to urban landuse in the catchment over this period have not impacted negatively on aquatic ecosystem health.

As noted previously (Instream 2018), variation in macroinvertebrate community composition is more clearly impacted by differences in aquatic habitat amongst sites than changes over time. In particular, the dominance of fine sediment, lack of shade and high macrophyte cover at Site 3 are associated with greater abundance of pollution-tolerant taxa. Pollution-tolerant taxa typically prefer silt-free stony sediments, which is likely why they are more common at Sites 1 and 2 than at Site 3.

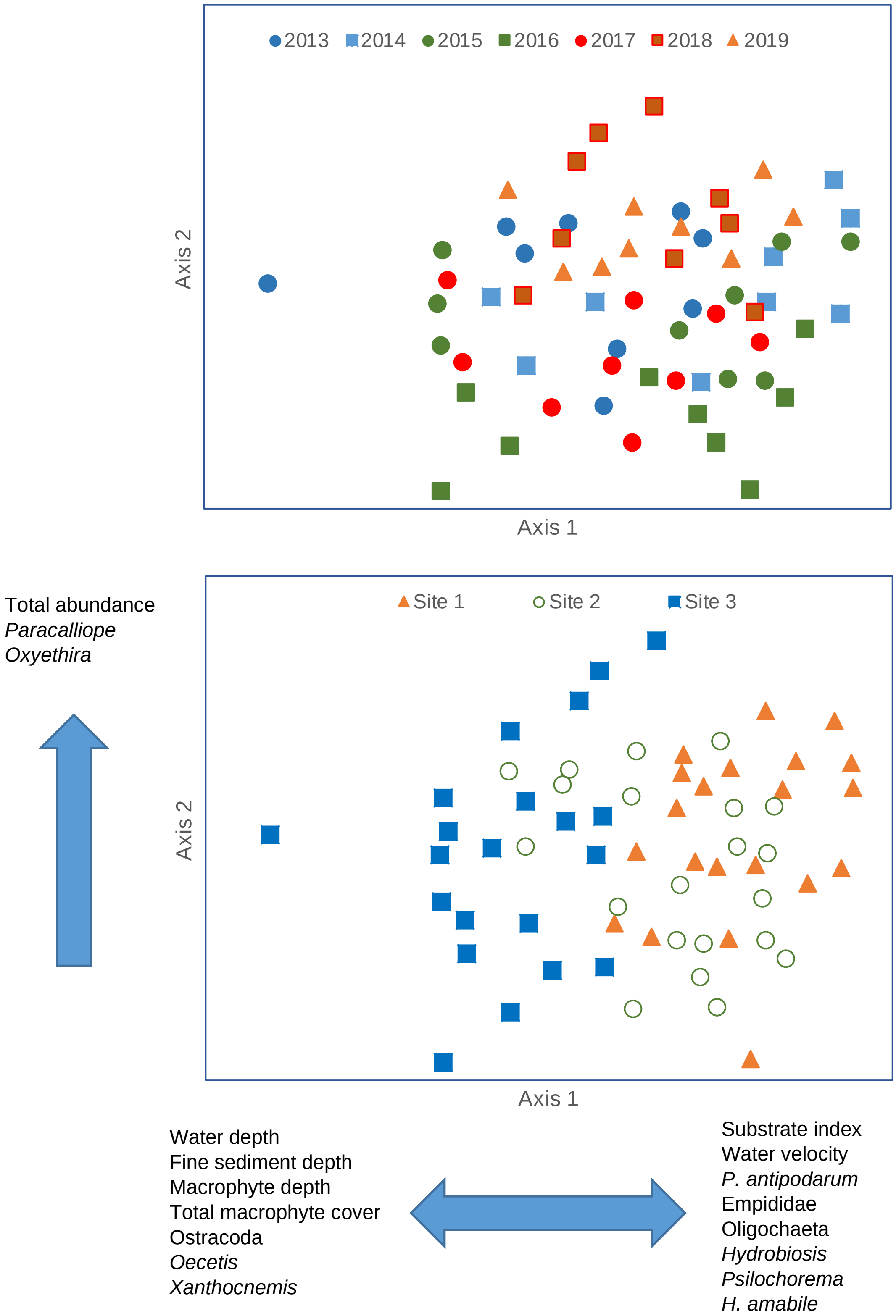

Figure 9: NMDS plot of macroinvertebrate communities, grouped by year and site. Habitat parameters and species most strongly correlated with axis scores are shown. Plot stress = 0.20.

In 2019, fine sediment cover complied with surface water quality objectives for consent CRC120223 at Sites 1 and 2, but not at Site 3 (Table 3). In addition, QMCI scores fell just below the consent objective of 4 at Sites 1 and 2, but were well below the objective at Site 3 (Table 3). This is generally consistent with previous years (Instream 2018) and largely reflects the lack of coarse substrates and hence dominance of pollution-tolerant taxa at Site 3. As noted previously (Instream 2018), some sections of Cashmere Stream appear to be naturally dominated by fine sediments, reflecting a combination of underlying geology and flow characteristics. This means that compliance with the fine sediment cover and QMCI objective will likely always be difficult at Site 3, unless major fine sediment removal was undertaken and stony sediments added.

Total macrophyte cover exceeded the water quality objective of 30% cover at Sites 2 and 3 in 2019 (Table 3). In contrast, bed cover with long filamentous algae was minimal and complied with the water quality objective of 20% at all sites in 2019 (Table 3). The dominance of macrophytes at all sites reflects a combination of the stable, spring-fed flow source, available nutrients, adequate lighting and relatively fine bed sediments. The particularly high macrophyte cover at Site 3 is most likely due to the combination of a lack of shade and fine bed sediments for macrophytes to establish roots in. Lack of shading is independent of the stormwater discharge consent, but could be improved over time with planting of trees and tall shrubs along the banks.

Greater macrophyte cover in 2017 and 2018 at Sites 1 and 2 was attributed to either natural variation, or factors other than the regular macrophyte clearance by CCC contractors (Instream 2018). Reduced macrophyte cover in 2019 is also unlikely due to recent macrophyte clearance, as sampling in 2019 occurred two months after macrophyte removal at Sites 1 and 2, and six months after macrophyte removal at Site 3 (pers. comm. Wayne Myall, Waterways Supervisor, CitycareWater, 17 May 2019). The observation of rapid regrowth of macrophytes by James (2016) highlights the value in improving stream shade as a more sustainable option to manual macrophyte removal.

Table 3: Comparison of 2019 data with surface water quality objectives from consent CRC120223. Bold indicates sites that do not comply with an objective.

	Fine Sediment Cover (%)	Total Macrophyte Cover (%)	Filamentous Algae Cover (>2 cm)	QMCI
Objective:	30 (maximum)	30 (maximum)	20 (maximum)	4 (minimum)
Site 1	10	22	0	**3.8**
Site 2	10	**34**	0	**3.9**
Site 3	**100**	**68**	0	**3.4**

In summary, monitoring of macroinvertebrate communities to date indicate no adverse impacts of landuse changes associated with resource consent CRC120223. Lack of compliance with some surface water quality objectives largely reflects the impacts of local variations in habitat quality, rather than the catchment-scale impacts of stormwater discharges. Significant improvements in aquatic habitat could be made at Site 3, particularly in relation to increased riparian shading, which may benefit macroinvertebrate communities and overall ecosystem health.

5. REFERENCES

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APPENDIX 1: 2019 SITE PHOTOGRAPHS

Downstream end of reach, looking upstream | **Upstream end of reach, looking downstream**

APPENDIX 2: SUMMARY RESULTS OF STATISTICAL TESTS

Mann-Kendall trend test results for habitat variables. These results statistically test trends over time and use data for all seven monitoring years (2013-2019) at each individual monitoring site. Significant (P<0.05) trends are shown in bold.

Variable	Site	Median value	Kendall statistic	Variance	Z	P-Value	Percent annual change
Channel width (m)							
	1	2.7	12	1052.005	0.339	0.735	0.5
	2	3.8	-13	1059.111	-0.369	0.712	-0.4
	3	3.7	0	1063.137	0	1	0.0
Depth (cm)							
	1	24	58	1070.1	1.742	0.081	5.2
	2	23	24	1070.1	0.703	0.482	1.6
	3	44	93	1071	2.811	**0.005**	6.5
Velocity (m/s)							
	1	0.44	-31	1071	-0.917	0.359	-4.0
	2	0.34	-1	1071	0	1	-0.1
	3	0.17	-35	1071	-1.039	0.299	-2.4
Substrate index							
	1	0.4	-16	1064.937	-0.46	0.646	-0.9
	2	0.3	-22	1056.884	-0.646	0.518	-1.0
	3	0.1	53	497.653	2.331	**0.020**	0.0
Fine sediment cover (%)							
	1	7.0	-8	43.333	-1.063	0.155	-18.6
	2	14.0	0	40.667	0	0.500	0.0
	3	100.0	-6	26.667	-0.968	0.236	0.0
Fine sediment depth (cm)							
	1	0.8	-23	1065.837	-0.674	0.5	-5.5
	2	0.4	-38	1067.4	-1.132	0.257	-19.4
	3	14.2	-29	1071	-0.856	0.392	-6.5
Total macrophyte cover (%)							
	1	18	56	630.662	2.19	**0.029**	28.6
	2	30	43	658.676	1.636	0.102	19.9
	3	91	74	657.794	2.846	**0.004**	5.4
Macrophyte depth (cm)							
	1	1	68	1065.837	2.052	**0.040**	16.6
	2	0	28	865.705	0.918	0.359	0.0
	3	11	71	1071	2.139	0.032	21.0

Mann-Kendall trend test results for macroinvertebrate variables. These results statistically test trends over time and use data for all seven monitoring years (2013-2019) at each individual monitoring site. No significant trends were detected (P>0.05).

Variable	**Site**	**Median value**	**Kendall statistic**	**Variance**	**Z**	**P-Value**	**Percent annual change**
Total abundance							
	1	1940	-11	1071	-0.306	0.760	-3.1
	2	1045	15	1071	0.428	0.669	3.1
	3	1291	-2	1070.1	-0.031	0.976	-0.2
Taxa richness							
	1	19	29	1048	0.865	0.387	1.3
	2	18	-11	1050	-0.309	0.758	0.0
	3	18	-13	1050	-0.370	0.711	0.0
QMCI							
	1	4.0	15	1071	0.428	0.669	0.2
	2	4.0	-17	1071	-0.489	0.625	-0.4
	3	3.0	5	1071	0.122	0.903	0.7
MCI							
	1	74	20	1067	0.582	0.561	0.5
	2	76	-22	1069	-0.642	0.521	-0.4
	3	76	-23	1071	-0.672	0.501	-0.6
%EPT							
	1	4.2	41	1071	1.222	0.222	12.4
	2	3.6	-1	1071	0	1.000	-0.6
	3	2.8	105	1071	3.178	0.001	25.0
%EPT (excluding Hydroptilidae)							
	1	3.1	15	1071	0.428	0.669	4.3
	2	3.0	-19	1071	-0.55	0.582	-5.2
	3	2.2	53	1071	1.589	0.112	11.1
EPT taxa richness							
	1	5	33	973	1.026	0.305	0.0
	2	5	-1	920	0	1.000	0.0
	3	4	12	1009	0.346	0.729	0.0
EPT taxa richness (excluding Hydroptilidae)							
	1	4	23	854	0.753	0.452	0.0
	2	4	-25	882	-0.808	0.419	0.0
	3	3	-11	994	-0.317	0.751	0.0

Spearman rank correlation coefficients for correlations between macroinvertebrate taxa, habitat variables, and NMDS ordination axis scores, using data from all three sites and all six years of monitoring (2013-2018). Only correlations with p<0.01 (r=0.323, n=63) are shown. Bold indicates correlations with p<0.001 (r=0.408, n=63). ns = not significant (P>0.05).

Taxon	Axis 1		Taxon	Axis 2
Ostracoda	**-0.696**		*Paradixa*	0.332
Oecetis	**-0.584**		Orthocladiinae	0.355
Xanthocnemis	**-0.486**		Oligochaeta	**0.414**
Tanypodinae	-0.363		*Physa*	**0.427**
Polyplectropus	-0.354		Cladocera	**0.435**
Tanytarsini	0.344		Copepoda	**0.441**
Oxyethira	0.367		*Hudsonema amabile*	**0.477**
Triplectides	0.403		*Oxyethira*	**0.729**
Orthocladiinae	0.406		*Paracalliope*	**0.906**
Hudsonema amabile	**0.427**			
Psilochorema	**0.560**			
Hydrobiosis	**0.658**			
Oligochaeta	**0.691**			
Empididae	**0.752**			
Potamopyrgus antipodarum	**0.767**			

Parameter	Axis 1	Axis 2
Water depth	**-0.72**	ns
Fine sediment depth	**-0.69**	ns
Macrophyte depth	**-0.59**	ns
Total macrophyte cover	**-0.58**	ns
Total abundance	0.39	**0.82**
Water velocity	**0.74**	ns
Substrate index	**0.78**	ns