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Long-term Monitoring of Aquatic Invertebrates in Christchurch's Waterways: Heathcote River Catchment 2010

EOS Ecology Report No. 06064-CCC02-03 | December 2010

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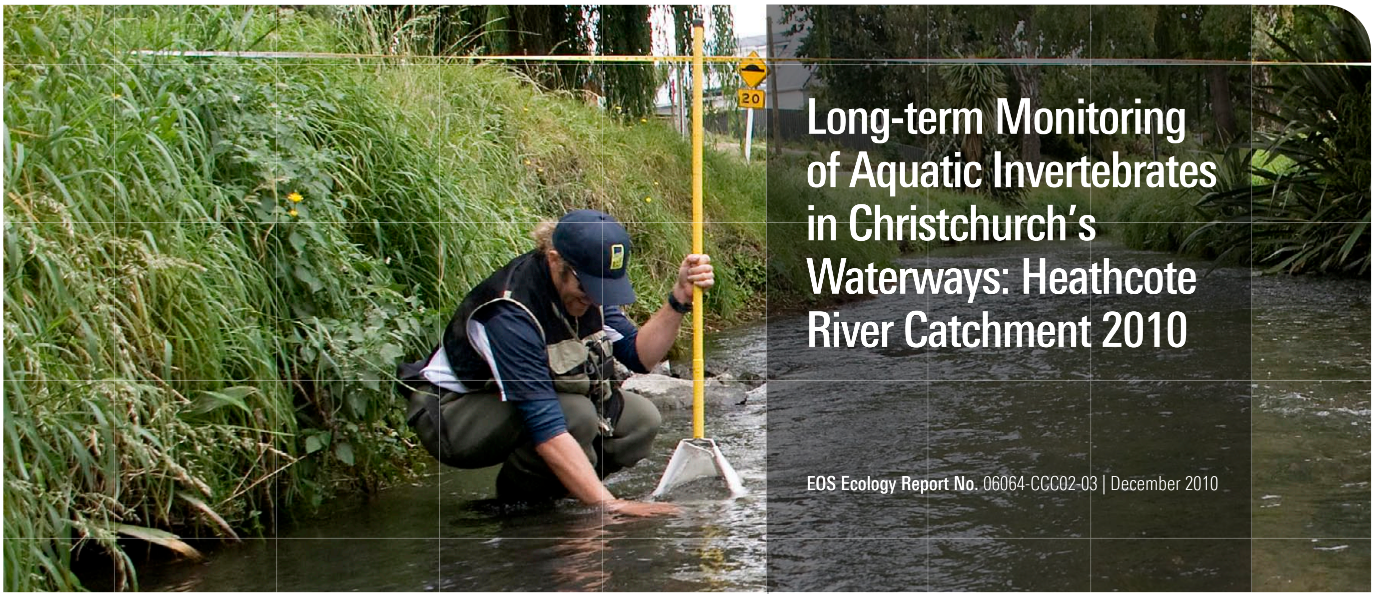

Long-term Monitoring of Aquatic Invertebrates in Christchurch's Waterways: Heathcote River Catchment 2010

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REPORT

Prepared for
Christchurch City Council

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EXECUTIVE SUMMARY

The Christchurch City Council (CCC), in conjunction with Environment Canterbury (ECan) and the Avon-Heathcote Estuary Ihutai Trust, has instigated a long-term monitoring programme for aquatic invertebrates and habitat of the City's waterways. Invertebrates are useful animals to monitor as they are a good indication of stream health and respond to catchment land use changes. EOS Ecology was commissioned by the CCC to develop and undertake an aquatic invertebrate monitoring program that incorporated the Styx, Otukaikino, Avon, Heathcote, and Halswell catchments. It was requested by the CCC that each catchment was surveyed once every five years, with two catchments to be surveyed in the first year of the programme.

This report summarises the results of the third year of monitoring, where ten sites in the Heathcote River catchment were surveyed during March 2010. Sites along the mainstem rivers as well as tributary waterways were included in the monitoring programme. The sites surveyed had slow-moderate water velocity and a substrate that although coarse (gravel-pebble size) was partially embedded with fine particles and algae. The invertebrate community was moderately diverse, with a total of 49 different taxa identified from the study area and 16–27 taxa found on a site basis. The most diverse groups were two-winged flies with 16 taxa and caddisflies with 12 taxa identified.

At all sites the aquatic invertebrate community was rated as being in 'poor' health by the MCI/QMCI biotic indices. Cleanwater taxa (made up of mayflies, stoneflies, and caddisflies) were limited to caddisflies, which were in low abundance (e.g., < 10%) at all but two sites. Mayflies and several other caddisfly taxa which were found in surveys conducted in the late 1970s and 1980s were not found at any of the sites during the current study. Ranking of the ten sites based on seven biotic metrics found the highest ranking site to be that with the least urbanised catchment. In contrast, the lowest ranking site had one of the most urbanised catchments. Today the aquatic fauna of the Heathcote River catchment is dominated by pollution-tolerant taxa that are common throughout New Zealand's urban waterways, and is symptomatic of the 'urban stream syndrome'.

1 INTRODUCTION

In the Christchurch City Council's (CCC) Long-Term Council Community Plan (LTCCP; Christchurch City Council (2006)) Christchurch residents identified the retention and restoration of biodiversity and protection of the environment as key factors important to their well-being. The LTCCP states that the CCC will know it is succeeding in meeting these community desires when 'our lifestyles reflect our commitment to guardianship of the natural environment in and around Christchurch', when 'biodiversity is restored, protected and enhanced', and when 'we manage our city to minimise damage to the environment' (Christchurch City Council, 2006). Furthermore, in the recently adopted Surface Water Strategy 2009–2039 (Christchurch City Council, 2010) the CCC's vision aims that "the surface water resources of Christchurch support the social, cultural, economic, and environmental well-being of residents, and are managed wisely for future generations."

Inevitably urbanisation of a catchment is detrimental to biodiversity values and the general health of waterways. As a catchment is developed it becomes more impervious to stormwater run-off, causing lower but flashier flows (Suren & Elliott, 2004). Pollutants and fine sediment from road run-off accumulate in the river sediment and the addition of buildings, bridges, culverts, and light pollution impede the dispersal and influence the behaviour of adult aquatic insects (Suren, 2000; Longcore & Rich, 2004; Blakely *et al.*, 2006). These factors detrimentally affect the health of our waterways by making the river suitable for only a small subset of the aquatic invertebrates and fish usually found in our streams and rivers. With increasing residential development of the outlying areas of Christchurch City and infill housing occurring in the suburbs, much of the land surrounding our city's waterways has, or is, changing from rural to urban use. This change in land use impacts the health of the catchment's rivers.

To be successful in achieving the community's desire for biodiversity and healthy ecosystems in the face of urban expansion and its negative impacts on waterways, first requires a better understanding of the current state of our waterways. In an attempt to achieve this the CCC, in conjunction with Environment Canterbury (ECan) and the Avon-Heathcote Estuary Ihutai Trust, has decided to instigate a freshwater monitoring programme that will help to determine the existing state of our waterways and monitor any change in health over time (Batcheler *et al.*, 2006). Such monitoring is required for the CCC to successfully identify if they are making headway in achieving a number of the goals outlined in the Surface Water Strategy: 2009–2039 (Christchurch City Council, 2010), including "improving the water quality of our surface water resources", "improving the ecosystem health of surface water resources", and "protecting and restoring Ngai Tahu values associated with surface water resources".

EOS Ecology was commissioned by the CCC to develop and undertake a suitable freshwater invertebrate monitoring program for the City's main waterways. This incorporated the City's five main river catchments: the Styx, Otukaikino, Avon, Heathcote, and Halswell Rivers. The Styx and Otukaikino River catchments were surveyed in March 2008 (McMurtrie & Greenwood, 2008), the Avon catchment in March 2009 (McMurtrie, 2009), and the Heathcote River catchment for this current study in March 2010. The remaining Halswell catchment will be sampled in March 2011. This cycle of five yearly sampling will be repeated to allow for comparisons of temporal change within each catchment as well as between-catchment comparisons. Sampling all five river systems will provide data over a range of catchment land use types including fully urbanised (Avon River catchment), urban-rural mixture (Heathcote River catchment), rural-urban mixture (Styx River catchment), and a predominantly rural catchment (Halswell and Otukaikino River catchments).

1.1 Aim of this report

This report is designed to provide a summary of the results for the Heathcote River catchment. It is not designed to provide any detailed statistical comparison between sites within the same catchment or between other previously surveyed catchments. On the completion of the first round of sampling for each catchment an additional report will be produced that provides more detailed analysis of the data including catchment-wide comparisons.

1.2 Why is monitoring important?

Long-term monitoring of invertebrate communities will tell us how the health of the rivers is changing over time (e.g., is it getting better, worse, or remaining the same). In more sensitive systems such as the Otukaikino and Styx catchments we would expect the fauna to change more rapidly in response to land use changes (e.g., rural to urban), which will give us an early warning that stream health is declining. In comparison, we would expect those rivers that are already heavily urbanised (e.g., the Avon and Heathcote) to change less over time as their invertebrate fauna may already be limited to pollution-tolerant taxa. Results from the monitoring will also be important in designing restoration and remediation efforts to minimise the impact of urban development on our rivers. Refer to McMurtrie & Greenwood (2008) for further information on why invertebrates are important to monitor.

2 METHODS

The aim of the monitoring programme was to use the 'River Habitat and its Biota' section of Batcheler *et al*. (2006) as the basis for this monitoring programme. Batcheler *et al*. (2006) recommends sampling 'within the shallower, gravel bottom reaches of the Avon/Otakaro and Heathcote/Opawaho rivers', which are the two main rivers that drain into the Avon-Heathcote Estuary/Ihutai. However, this programme has been broadened to include the Styx, Otukaikino, and Halswell river systems, which are partly or fully within the confines of the Christchurch City boundary.

Due to CCC budgetary limitations, it was not possible to sample all five catchments at one time, thus a yearly programme was developed to sample one catchment per year, with a five-year repeat cycle for each catchment. The catchments will be surveyed in the following order: Otukaikino, Styx, Avon, Heathcote, and Halswell. This report represents the third year of the monitoring programme, where the Heathcote River catchment has been sampled, while in previous years the Otukaikino, Styx, and Avon catchments were surveyed (McMurtrie & Greenwood, 2008; McMurtrie, 2009).

2.1 Site selection

Ten sites were selected in the mainstem and tributaries of the Heathcote River (Sites 29–38 in Figure 1 and Table 1). Site numbering continues on from the previous years' monitoring of the Styx, Otukaikino, and Avon catchments (McMurtrie & Greenwood, 2008; McMurtrie, 2009).

Tributary as well as mainstem river sites were included, as the small size of tributaries makes them more susceptible to changes in environmental conditions, such as water quality or sediment inputs. Sampling sites were chosen in areas of riffle habitat, or if this did not exist, in runs with coarse substrate. These types of habitats were chosen for monitoring to better enable between-site comparisons and because these areas typically support the most diverse invertebrate communities that are also the most sensitive to change. Sections of waterway that are deeply silted will support an invertebrate community already tolerant of

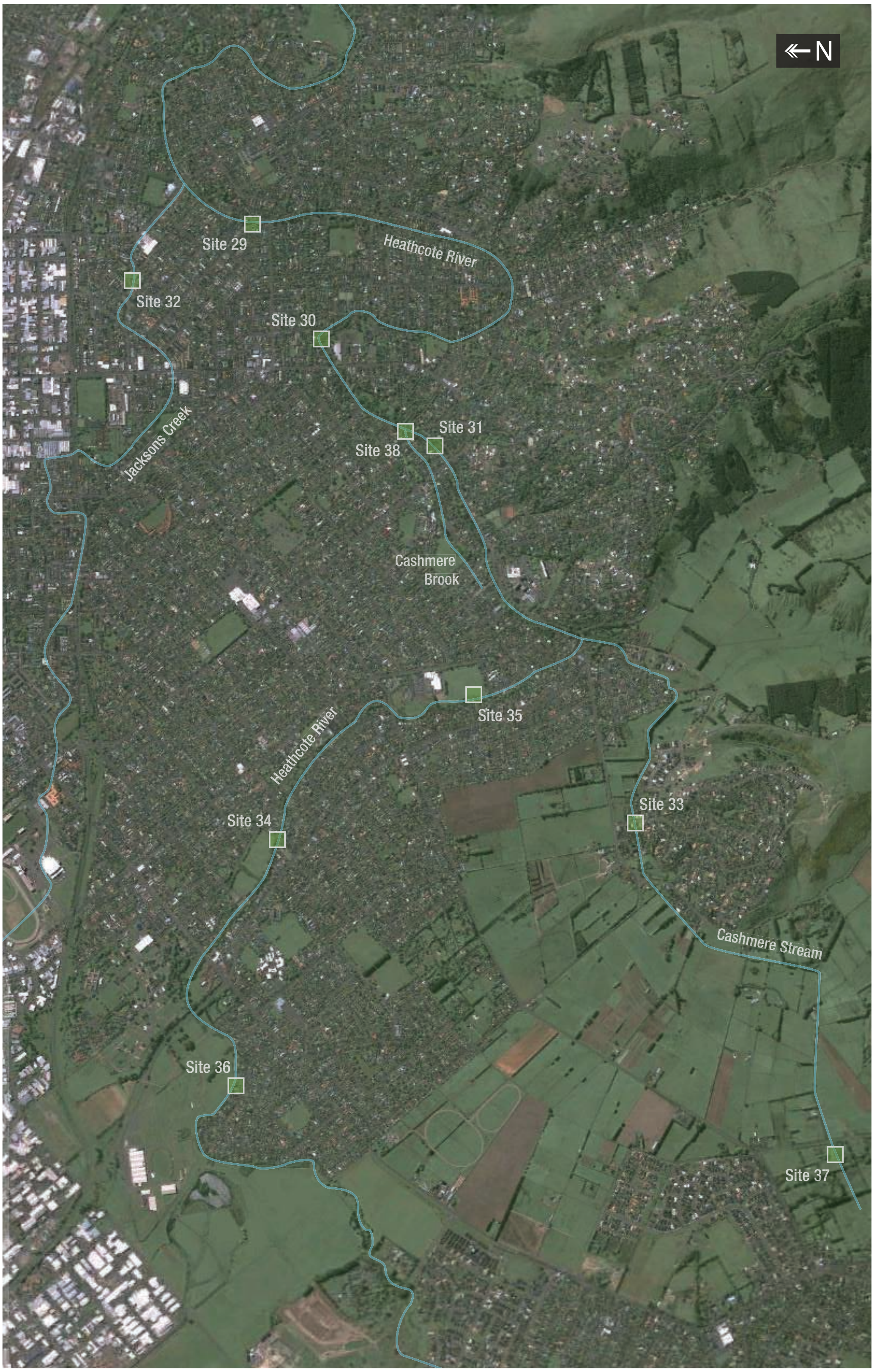

FIGURE 1 Location of the ten sites in the Heathcote River catchment surveyed from 24th to 26th March, 2010. Site photographs are provided in Appendix I (Section 7.1).

particularly degraded conditions and as such they will be unlikely to respond to small changes in water and habitat quality.

Initial site location was derived using local knowledge and the CCC's Christchurch River Assessment Survey (CREAS) data, with final locations modified to suit the on-site conditions. The most downstream site in each catchment represented the downstream extreme of wadeable water with suitable riffle habitat for sampling.

2.2 Sampling

Following fine weather conditions, habitat and aquatic invertebrate communities were surveyed between the 24th and 26th March, 2010. At each site three equally-spaced transects were placed across the stream at 10 m intervals (i.e., at 0, 10, and 20 m) and aspects of the instream habitat and aquatic invertebrate community quantified along them. A detailed and quantitative to semi-quantitative methodology was developed to act as a suitable monitoring protocol that would enable a comparable repeat survey of habitat and invertebrate communities.

TABLE 1 Locations of the Heathcote River mainstem and tributary monitoring sites within the Heathcote River catchment. Refer to Figure 1 for further information on location.

Site No.	Site location
29	Heathcote River downstream of Tennyson Street
30	Heathcote River downstream of Colombo Street
31	Heathcote River downstream of Barrington St bridge
32	Jacksons Creek at Cameron Reserve
33	Cashmere Stream at Penruddock Rise
34	Heathcote River downstream of Spreydon Domain
35	Heathcote River at Rose Street/Centennial Park
36	Heathcote River at Canterbury Park/Showgrounds
37	Cashmere Stream upstream of Sutherland's Road bridge
38	Cashmere Brook at Ashgrove Terrace

Instream habitat variables were quantified at equidistant points across each of the three transects, with the first and last measurements across the transect at the water's edge. Habitat variables measured included substrate composition, presence and type of organic material, depths (water, macrophyte, and sediment), and water velocity (Figure 2). General bank attributes, including lower and upper bank height and angles, lower bank undercut, and lower bank vegetative overhang were measured for each bank at each transect. Bank material and stability were also assessed.

FIGURE 2 Measuring water velocity at Site 29 (left) and collecting an invertebrate kicknet sample at Site 29 (right) in the Heathcote River on March 24, 2010.

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

Aquatic benthic invertebrates were collected at each transect by disturbing the substrate across an approximate 1.5 m width and within a 0.3 m band immediately upstream of a conventional kicknet (ca. 500 µm mesh size; Figure 2). 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 60% isopropyl alcohol, and taken to the laboratory for identification. The contents of each sample were passed through a series of nested sieves (2 mm, 1 mm, and 500 µm) and placed in a Bogorov sorting tray (Winterbourn *et al.*, 2006). All invertebrates were counted and identified to the lowest practical level using a binocular microscope and several identification keys. Sub-sampling was utilised for particularly large samples and the unsorted fraction scanned for taxa not already identified.

2.3 Data analysis

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

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

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

Invertebrate data were summarised by taxa richness, total abundance, abundance of common taxa, and Detrended Correspondence Analysis (DCA) axis scores. Biotic indices calculated were the number of Ephemeroptera-Plecoptera-Trichoptera taxa (EPT richness), % EPT, 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. For a more detailed description see McMurtrie & Greenwood (2008).

Taxa richness can be used as an indication of stream health or habitat type, where sites with greater taxa richness are usually healthier and/or have a more diverse habitat. DCA 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.

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. EPT richness and % EPT scores can provide a good indication as to the health of a particular site.

The MCI/QMCI score can be used to determine the level of organic enrichment for stony-bottomed waterways in New Zealand (Stark, 1985). It calculates 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/QMCI indices are best suited to waterways with shallow depths (0.1–0.4 m), moderate velocities (0.2–1.2 m/s), and a coarse substrate (Stark, 1993); conditions which the sites surveyed in this study met.

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.

3 RESULTS

3.1 Habitat

The mainstem sites tended to be wider ranging from 2–7.4 m in width compared to 0.7–3.4 m for the tributary sites (Figure 3) and tended to get wider with distance downstream. The deepest site was on Cashmere Stream (Site 33) and the most downstream mainstem sites (Sites 29, 30, and 31) were deeper than those

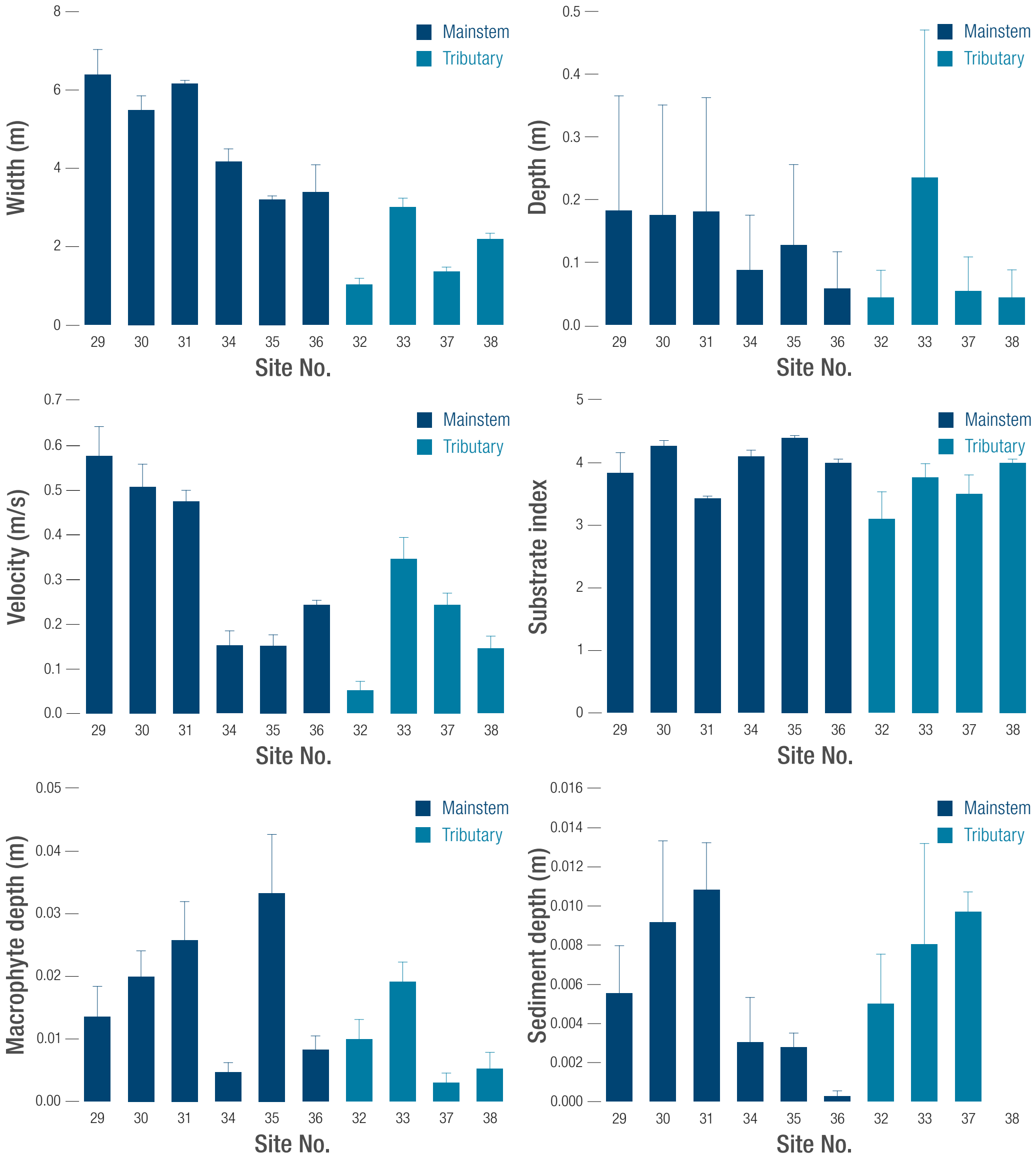

FIGURE 3 Average (+/- SE) aquatic habitat conditions at ten sites in the Heathcote River catchment sampled between 24th and 26th March, 2010. For site locations refer to Figure 1 and Table 1.

further upstream. However, all sites were relatively shallow at less than 0.25 m deep (Figure 3). The most downstream mainstem sites tended to have the fastest water velocity of around 0.5–0.6 m/s. All other sites had slower water velocities of less than or close to 0.25 m/s (Figure 3). Substratum size was relatively equitable over all the sites with moderate substrate index values and made up of mostly of pebble, gravel, and small cobble size substrate (Figure 3). Macrophytes were present at all sites in small amounts with mean macrophyte depths being no more than a few centimetres (Figure 3). Fine sediment depths at all sites were minimal with a mean of less than one centimetre at most sites (Figure 3). The broad water velocity preferences of many of New Zealand's aquatic invertebrates (Jowett *et al.*, 1991) means that most of these sites contain habitat suitable for a wide range of aquatic invertebrates, including cleanwater EPT taxa.

3.2 Invertebrates

3.2.1 Overview

A total of 49 invertebrate taxa were recorded from the Heathcote River catchment. The most diverse groups were the two-winged flies (Diptera: 16 taxa), followed by caddisflies (Trichoptera: 12 taxa), molluscs (Mollusca: 5 taxa), and crustaceans (Crustacea: 5 taxa). Groups represented by one taxon included damselflies (Odonata), worms (Nematoda, Nemertea, Oligochaeta, Platyhelminthes), leaches (Hirudinea), springtails (Hexapoda: Collembola), hydra (Cnidaria: Hydrozoa: Hydridae), and mites (Arachnida: Acari).

On average, the community was dominated by the freshwater snail *Potamopyrgus antipodarum* (47.5% ± 14.4%, Figure 4) and micro-crustacean ostracods (18.4% ± 12.5%). Other relatively abundant taxa included the amphipod *Paracalliope fluviatilis* (7.4% ± 5.6%) and oligochaete worms (6.7% ± 3.2%), the introduced snail *Physa acuta* (5.6% ± 2.8%), the cased-caddis *Hudsonema amabile* (4% ± 2.9%), orthoclad non-biting midge

Pollution-tolerant taxa


Potamopyrgus antipodarum (47.5%, widespread)


Ostracod (18.4%, widespread)


Paracalliope fluviatilis (7.4%)

Oligochaete worm (6.7%, widespread)


Physa acuta (5.6%, widespread)


Orthoclad midges (3.1%, widespread)


Sphaeriidae pea clams (2.3%, widespread)

Cleanwater (EPT) taxa


Hudsonema amabile (4%)

FIGURE 4 **Photographs of the most abundant (% indicated) and widespread (found in at least 29 of the 30 samples) aquatic invertebrates in the Heathcote River catchment sampled between the 24th and 26th March, 2010. Unless indicated, photos are by EOS Ecology.**

larvae (3.1% ± 2.1%), and pea-clams (2.3 ± 1.1; Figure 4). The above mentioned eight taxa account for 95% of all taxa in samples from the Heathcote River catchment.

The most widespread taxa (e.g., found in 100% of samples) were pollution-tolerant taxa such as oligochaete worms, the snails *P. antipodarum* and *P. acuta*, and pea-clams (Sphaeriidae). Other widespread taxa included orthoclad midges and microcrustacean ostracods (both found in 29 of 30 samples; Figure 4).

The cleanwater EPT group was represented by caddisflies (order Trichoptera) only, with both the mayfly (Ephemeroptera) and stonefly (Plecoptera) orders absent. Caddisflies accounted for only 4.6% of total invertebrate abundance, but had a good diversity with 12 different taxa recorded. Of these 12 taxa, only *Hudsonema amabile* (4% % ± 2.9%) had an overall abundance greater than 1%. *H. amabile* was also the most widespread caddisfly, being found in 26 of the 30 samples (87% of samples). The more pollution-tolerant hydroptillid caddisfly *Oxyethira albiceps* was also widespread, being found in 25 of 30 samples (83% of samples).

3.2.2 Biotic indices

The DCA indicated there was little difference in the invertebrate communities from the mainstem river or tributary waterway sites (Figure 5). Along Axis 1, three sites (Sites 34 and 35 from the Heathcote River; Site 38 from Cashmere Brook) were distinctly separated from all the other sites and associated with mites (Acarina), muscid fly larvae, orthoclad midge larvae, ostracods, the caddisflies *Oxyethira* and *Triplectides,* and a coarser substrate. Along Axis 1 all the other sites were associated with snails (*Potamopyrgus* and *Gyraulus*) and increased velocities (Figure 5).

Along Axis 2 samples from some sites (Sites 29, 30, and 31 from the Heathcote River; Site 33 from Cashmere Stream) were somewhat separated from the other samples. These samples were associated with a suite of invertebrates including *Hudsonema* caddisflies, oligochaete worms, the amphipod *Paracalliope*, and pea-clams. These sites also tended to have greater width, velocity, and depth (Figure 3). The other sites were associated with *Potamopyrgus* and muscid fly larvae.

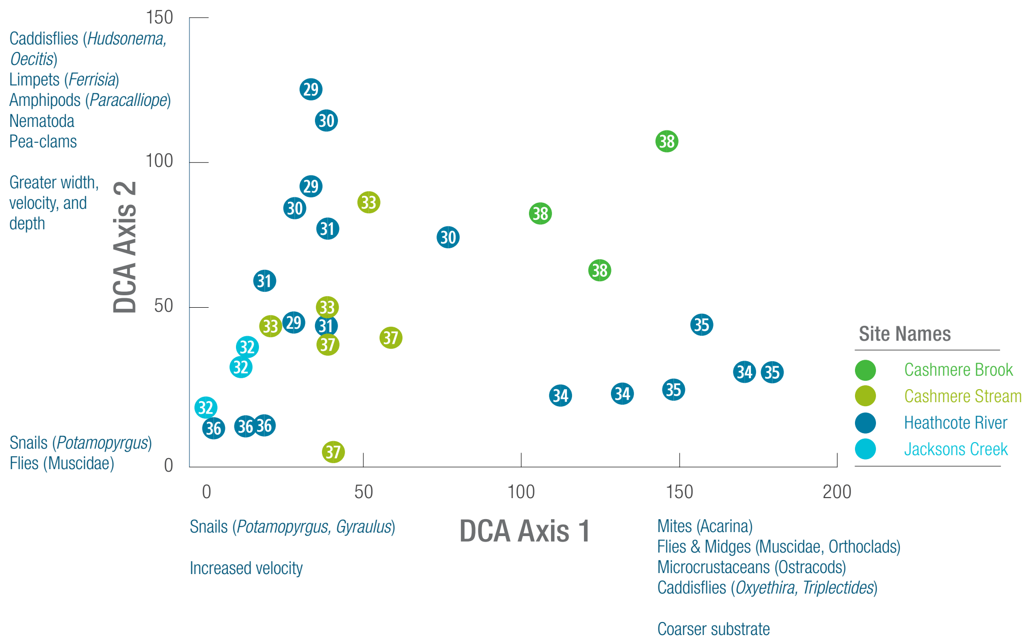

FIGURE 5 **Detrended Correspondence Analysis (DCA) at the ten sites surveyed in the Heathcote River catchment between the 24th and 26th March, 2010. Invertebrate taxa and habitat variables correlated with the axes are shown. For site locations see Figure 1.**

The overall best site in terms of ranking by seven biotic indices was the most upstream site on Cashmere Stream (Site 37). This site ranked 1st, 2nd, or 3rd for the seven metrics calculated (Table 2). Interestingly, the second highest ranking site was the other Cashmere Stream site (Site 33). Those sites regarded as the worst were the three upstream most Heathcote River sites (Sites 34, 35, and 36) and the tributary Jacksons Creek (Site 32; Table 2). These sites supported the lowest number of taxa, the lowest % EPT, had the lowest MCI scores, and some of the lowest QMCI and QUCI scores (Figure 6). Jacksons Creek was clearly the worst site overall scoring last of all the sites for five of the seven metrics.

The abundance of EPT taxa were the same (nine different taxa) in the mainstem and tributaries (Table 3). The most sensitive (in terms of MCI score) EPT taxa—the free-living caddisfly *Psilochorema*—was present in tributary sites (Cashmere Stream only) but not in mainstem Heathcote River sites (Table 3). In contrast, the cased-caddisflies *Triplectides cephalotes* and *Paroxyethira* were only found at mainstem sites.

FIGURE 6 Average (+/- SE) biotic indices of invertebrate community health at the ten sites surveyed within the Heathcote River catchment between the 24th and 26th March, 2010. The dotted lines on the QMCI and MCI graphs indicate the probable level of organic pollution (Stark, 1985; Stark, 1998). Poor conditions (probable severe organic pollution) are indicated less than 80 for the MCI and less than 4 for the QMCI.

TABLE 2 An overall site ranking (1 (best) – 10 (worst)) of each of the ten sites surveyed in the Heathcote River catchment; with site rank based on the summation of ranks for each biotic index. The possible final ranking score is from 7 (ranking 1 on all variables) to 70 (ranking 10 on all variables). The sites have also been divided into comparative groupings (best, medium, and worst) according to their final score.

Waterway	Site	Biotic Indices							Sum	Final Rank	Grouping
		TAXA	EPT	% EPT	MCI	QMCI	UCI	QUCI			
Cashmere Stream	37	3	3	2	1	1	2	1	13	1	best
Cashmere Stream	33	2	1	5	3	7	1	3	22	2	best
Heathcote River	31	6	2	6	2	2	3	2	23	3	best
Heathcote River	29	4	4	3	4	3	6	5	29	4	med
Heathcote River	30	5	5=	4	5	5	4	4	32	5	med
Cashmere Brook	38	1	5=	1	6	8	8	7	36	6	med
Heathcote River	34	9	9	8	7	9	5	9	56	7	worst
Heathcote River	36	7	7=	9	8	4	9	6	50	8	worst
Heathcote River	35	8	7=	7	9	10	7	10	58	9	worst
Jacksons Creek	32	10	10	10	10	6	10	8	64	10	worst

TABLE 3 The presence of EPT taxa in the mainstem river and tributary waterways of the Heathcote River catchment, as indicated by an X. The MCI values indicate the tolerance of the taxa to organic pollution (10 = highly pollution sensitive, 1 = pollution tolerant; (Stark, 1985)). A stream with good water quality has more pollution sensitive taxa, i.e., those with high MCI scores. MCI values are from Boothroyd & Stark (2000).

EPT taxa (caddisflies only)		MCI Value	Mainstem	Tributaries
Hudsonema amabile (pictured)		6	X	X
Hudsonema alienum		6		X
Hydrobiosis sp.		5	X	X
H. parumbripennis (pictured)		5	X	X
H. umbripennis		5	X	X
Oecetis		6	X	X
Oxyethira		2	X	X
Paraoxyethira		2	X	
Psilochorema		8		X
Triplectides cephalotes		5	X	
Triplectides obsoletus (pictured)		5	X	X
Total EPT taxa			9	9

Unless indicated photos are © Shelley McMurtrie

All sites were in the "poor" category in terms of MCI and QMCI scores which are based on tolerance to organic pollution (Figure 6). Tributary sites (excepting Site 32) had higher taxa richness than mainstem sites and a tributary site (Site 33) had the highest number of EPT taxa (Figure 6). A tributary site (Site 38) also had the greatest percentage of EPT abundance resulting from relatively high numbers of the cased caddis fly *Hudsonema amabile* (Figure 6). QUCI was quite variable although two mainstem sites (Sites 34 and 35) scored much lower than all other sites (Figure 6).

4 DISCUSSION

Overall health as categorised by the MCI and QMCI score indicated that all sites in the Heathcote River catchment were in 'poor' condition while the Avon River catchment had sites rated as either 'poor' or 'fair' (McMurtrie, 2009). In contrast, in the rural Otukaikino River catchment sites were mostly rated as being in 'fair' or 'good' condition (McMurtrie & Greenwood, 2008). The invertebrate community of the Heathcote River catchment was dominated by taxa typical of those usually found in urban rivers of moderate degradation (i.e., snails, ostracods, amphipods, worms, chironomids; Suren, 2000). These taxa are generally indifferent to degraded water and habitat quality and indicative of a worldwide phenomena referred to as the 'urban stream syndrome' which describes the consistently observed ecological degradation of streams with catchment urbanisation (Walsh *et al,* 2005; Figure 7). This 'syndrome' is characterised by symptoms including a flashier hydrograph (because of increased imperviousness), elevated nutrient and contaminant concentrations (especially heavy metals and polycyclic aromatic hydrocarbons), altered channel morphology, and shifts in biotic communities to dominance by more tolerant species (Walsh *et al.*, 2005). Upstream-downstream and between-catchment connectivity, which is especially important to many flying adult aquatic insects (i.e., mayflies, stoneflies, caddisflies), is reduced by buildings, bridges, and culverts (Blakely *et al.,* 2006). Furthermore, the abundance of artificial light sources creates polarised light pollution that can confuse species that use such light to navigate and select oviposition sites (Horvath *et al.*, 2009).

Cleanwater taxa in the Heathcote River catchment were limited to caddisfly taxa. No mayflies or stoneflies were found although mayflies, a stonefly, and some other caddis species were present in the Heathcote River catchment in the past. The earliest invertebrate surveys of the Heathcote River catchment were undertaken in the 1978–79 summer by Dr. J. Robb of the Christchurch Drainage Board (Christchurch Drainage Board, 1980), who found the mayfly *Deleatidium* at one site in the Cashmere Stream, and the free-living caddisflies *Polyplectropus puerilis* (five sites) and *Aoteapsyche colonica* (one site), and the cased-caddisflies *Olinga feredayi* (one site) and *Pycnocentrodes aureola* (20 sites) in the Heathcote mainstem (Figure 8). A repeat survey in 1989–91 (Robb, 1994) found that *Deleatidium*, *Olinga feredayi*, *Aoteapsyche colonica,* and *Pycnocentrodes aureoloa* had disappeared. Interestingly this repeat survey also found two EPT taxa in Cashmere Stream that had not previously been found in the Heathcote River catchment (the mayfly *Coloburicus humeralis* and stonefly *Zelandobius confusus*). These two taxa, along with five other EPT taxa (*Polyplectropus puerilis*, *Aoteapsyche*, *Olinga*, *Pycnocentrodes*, *Deleatidium*) found in earlier Robb surveys were not found in the current survey. The only caddisfly genus we encountered that was not found in the Robb surveys was the free-living caddis *Psilochorema*, which we only found at the two Cashmere Stream sites (Sites 33 and 37).

It thus appears the remaining EPT taxa found in the Heathcote River are an assemblage of caddisflies that are relatively tolerant of degraded conditions. Of the EPT taxa that have disappeared, *Deleatidium, Olinga,* and *Pycnocentrodes* are algal grazers and there is some evidence that their algal food source accumu-

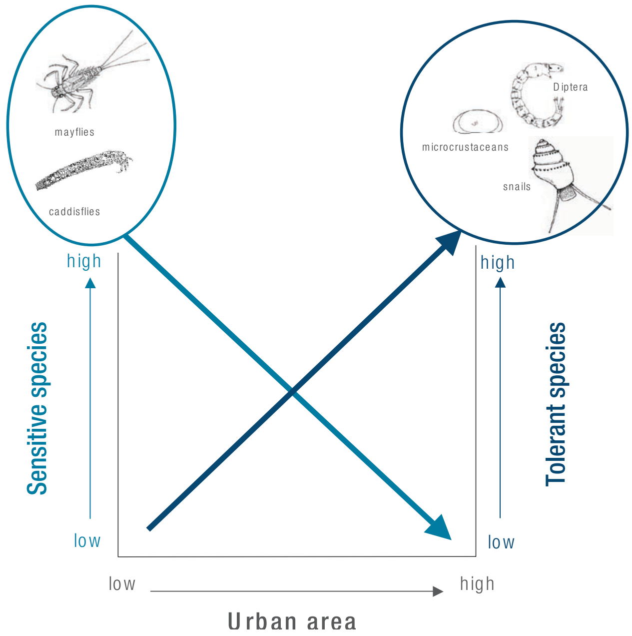

FIGURE 7 The Urban Stream Syndrome describes the decline in cleanwater EPT taxa (mayflies, stoneflies, and caddisflies) and increase in pollution-tolerant taxa (flies, snails, and worms) with an increase in urban area and catchment imperviousness.

FIGURE 8 EPT taxa that were found in the Heathcote River catchment in the 1980s and/or 1990s but have since disappeared (absent in the in the current survey, March, 2010).

lates heavy metals and polycyclic aromatic hydrocarbons (PAHs). Unpublished work by EOS Ecology and NIWA indicates *Deleatidium* survival is reduced by feeding on such contaminated algae. *Aoteapsyche*, *Polyplectropus*, and *Coloburiscus* are all filter feeders that prefer a hard, clean substrate with interstitial spaces in which to hide. The beds of the Heathcote River and its tributaries have undergone significant sedimentation over the last 100 years or so, which has acted to clog such interstitial habitat. The disappearance of these EPT taxa, which all have winged adults, may also be related to riparian habitat effects such as a lack of continuously vegetated banks, culverts, and light pollution, all which act to fragment habitat and confuse the adults of some species (Blakely *et al.*, 2006; Horvath *et al.*, 2009).

Community composition was not related to waterway type (tributary and mainstem). Tributary sites were ranked as the best and worst sites based on the ranking of the seven biotic indices. The best site was the most upstream site on Cashmere Stream (Site 37; Figure 9). This site was in the headwaters of the Cashmere Stream and of all the ten sites had the least urbanised catchment and the highest MCI, QMCI, and QUCI scores and the second highest UCI and % EPT scores. The other Cashmere Stream site (Site 33) was ranked second highest. Thus Cashmere Stream is the best quality subcatchment of the Heathcote River and the most pollution-sensitive invertebrate encountered—the free-living caddisfly *Psilochorema*—was found only there. In contrast, the worst site—Jacksons Creek (Site 32; Figure 9)—had a nearly 100% urban catchment and a significant portion that is piped, and scored the lowest for the number of taxa, EPT taxa, % EPT, MCI, and UCI metrics.

Of the six Heathcote mainstem sites sampled the three most upstream sites (Sites 34–36; Appendix I-Section 7.1) ranked lower than the three most downstream sites (Sites 29–31; Appendix I-Section 7.1). The three most upstream sites tended to have lower taxa richness, number of EPT taxa, and % EPT than the most downstream sites. The three most downstream sites had greater velocities (> 0.45 m/s) than the upstream sites (< 0.25 m/s) which possibly reduces sedimentation making these more desirable to EPT taxa that prefer a clean substratum. Additionally, the most downstream sites are downstream of the Cashmere Stream–Heathcote River confluence and the higher-quality Cashmere Stream may be acting as a source of EPT colonists for these lower mainstem sites.

Overall, of the major Christchurch catchments sampled over the past three years (Otukaikino, Styx, Avon, and Heathcote) the Heathcote River catchment is the most degraded in terms of the aquatic macroinvertebrate community present, closely followed by the Avon catchment (McMurtrie, 2009). Given these are the most heavily urbanised catchments, the "urban stream syndrome" is clearly manifested in Christchurch. The upper Heathcote River also has a number of large industrial subcatchments which have had a number of accidental spills of various contaminants over the years. It is highly likely that industrial land use runoff contributes to the degraded state of the Heathcote River. It is thus no coincidence that the "best" site in the current survey (Cashmere Stream, Site 37) was the least urbanised/industrialised in the Heathcote River catchment and the second "best" site was also located on this stream (Site 33). Previous work in the Cashmere Stream has indicated this Heathcote tributary also has populations of two regionally uncommon species, freshwater mussels and bluegill bullies (Burdon, in press; James & Taylor, 2010; Figure 10).

FIGURE 9 The best site based on the ranking of seven biotic indices was on the upper Cashmere Stream (Site 37; left) which drains predominantly rural land while the worst was on Jacksons Creek which has a heavily urbanised catchment (Site 32; right). These sites are otherwise similar in water depth and both have a coarse substratum. Sites were sampled 24–26 March, 2010.

Freshwater mussel

Bluegill bully

FIGURE 10 The regionally uncommon freshwater mussel and bluegill bully are found in sections of the Cashmere Stream.

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7 APPENDICES

7.1 Appendix I: Site photographs

SITE 29 Heathcote River downstream of Tennyson Street (looking downstream from top of site)

SITE 30 Heathcote River downstream of Colombo Street (looking downstream from top of site)

SITE 31 Heathcote River downstream of Barrington St bridge (looking downstream from top of site)

SITE 32 Jacksons Creek at Cameron Reserve (looking downstream from top of site)

SITE 33 Cashmere Stream at Penruddock Rise (looking downstream from top of site)

SITE 34 Heathcote River downstream of Spreydon Domain (looking upstream from bottom of site)

SITE 35 Heathcote River at Rose Street/Centennial Park (looking downstream from top of site)

SITE 36 Heathcote River at Canterbury Park/Showgrounds (looking upstream from bottom of site)

SITE 37 Cashmere Stream upstream of Sutherland's Road bridge (looking upstream from bottom of site)

SITE 38 Cashmere Brook at Ashgrove Terrace (looking upstream from bottom of site)

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