Ecological Values of the Avon River Catchment

An ecological survey of the Avon SMP catchment
Prepared for the Christchurch City Council

5 May 2014

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Cover photograph: Avon River at Hagley Park, looking downstream, © Boffa Miskell, 2013

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EXECUTIVE SUMMARY

The Christchurch City Council (CCC) commissioned Boffa Miskell Ltd to conduct an ecological survey of the Avon River catchment, including a survey of habitat, periphyton and macrophytes, and macroinvertebrate and fish communities at 29 sites within the catchment, and a survey of the macrophyte community at a further 11 sites along the Avon River. The main objectives of this work were to describe the existing ecological values of the Avon River catchment, to identify parts of the catchment that have high ecological values, and to make recommendations to the CCC so as to assist its development of a Stormwater Management Plan for the Avon River catchment.

This ecological assessment indicated that waterways within the Avon River catchment were generally of poor ecological health, and that in-stream conditions and macroinvertebrate and fish communities were typical of waterways in moderately urbanised catchments. However, there were clear patterns indicating some areas within the catchment were likely to be of greater ecological value than others. For example, the north-western headwaters and tributaries of the Avon catchment were found to be of better ecological health than other areas of the Avon River catchment. Furthermore, some of the areas of greater ecological value also supported populations of bluegill bullies, a threatened native freshwater fish species.

Other areas of the catchment had poorer ecological health, however, some of these were also identified as areas of interest and that may be considered priority areas for increased stormwater management or retrofitting of stormwater systems. This might lead to a relative improvement in ecological health, particularly in areas that already have good in-stream and riparian habitat conditions.

There were only subtle differences in some of the macroinvertebrate biotic indices and ecological health indicators in the CCC's long-term monitoring sites. There were both improvements and declines in ecological condition, or stream health, as determined by the MCI and QMCI scores. However, multivariate ordination analyses of the entire macroinvertebrate community composition indicated that there were only very subtle differences in community composition between 2008 and 2013. It may, therefore, be concluded that the macroinvertebrate community in the 10 long-term monitoring sites has not markedly changed since it was last surveyed in 2008.

The findings of this work reiterate the need for a multi-faceted approach to catchment management, whereby areas of greatest ecological health need to be maintained through appropriate management activities, but some of the more degraded areas may also be improved over time through more intensive management of stormwater and contaminated sediments, and in-stream and riparian habitat enhancement activities.

INTRODUCTION

The Avon River catchment is around 84 km^2 and drains much of the north, north-western and central areas of Christchurch before discharging into the north of Ihutai / the Avon-Heathcote Estuary. This lowland spring-fed system is comprised of the 26 km long Avon River, with its headwaters in Avonhead and numerous lowland spring-fed tributaries. Many of the Avon's natural tributaries, including Okeover, Waimairi and Wairarapa Streams flow into the Avon upstream of Hagley Park. Other major tributaries of the Avon are St Albans Creek, Papanui Stream and Dudley Creek and Shirley Stream, which flow from the more northern suburbs of St Albans, Papanui, Mairehau, and Shirley. These waterways all converge and, via Dudley Creek, enter the lower reaches of the Avon River upstream of Gayhurst Road, Dallington. A further two major tributaries of the Avon River drain the wetland areas of Travis Swamp and Marshlands: No. 2 Drain enters the Avon River via Horseshoe Lake, and Corsers Stream flows into the tidal reaches of the lower Avon just upstream of Anzac Drive, New Brighton. Two man-made 'drains', Riccarton Stream and Addington Brook, also feed into the Avon River, draining the suburbs of Riccarton and Addington and southern parts of Hagley Park.

The entire Avon catchment is urbanised, to some degree, and like all urban freshwater systems, its waterways have been variously modified as the catchment has been developed since human settlement. Although the effects of urbanisation on freshwaters are complex, urban waterways generally have altered hydrological regimes (e.g. reduced baseline water tables and exaggerated, 'flashy' flooding), elevated inputs of pollutants, chemicals and sediments (via connectedness to an open stormwater system), and reduced in-stream and riparian habitat complexity. These changes all result in the loss of clean-water taxa and the dominance of species 'tolerant' to poor ecological conditions (Walsh et al. 2005a). This ecological degradation has been termed the "urban stream syndrome", a phenomenon common to urban streams around the world (Walsh et al. 2005a).

The Christchurch City Council (CCC) is developing a Stormwater Management Plan (SMP) for the Avon River catchment. As part of the SMP, the current ecological values of the waterways within the Avon River catchment needed to be assessed. Boffa Miskell Ltd (Boffa Miskell) was commissioned by the CCC to undertake this ecological assessment, and to describe the existing ecological values of this urban catchment. This assessment will build on the existing knowledge that the CCC has on the catchment, assist the CCC in its application for a catchment stormwater discharge consent from Environment Canterbury, and help the CCC improve future stormwater treatment and management of the Avon River catchment.

SCOPE

The CCC commissioned Boffa Miskell to conduct two studies within the Avon River catchment in 2013: an ecological survey of waterways within the Avon River catchment; and a re-survey the aquatic macrophytes of the Avon River. These studies were designed to:

- Describe the existing ecological values of the main waterways of the Avon River catchment, with respect to in-stream and riparian physical habitat, including macrophyte (aquatic plants) and periphyton (algae) cover, and macroinvertebrate and fish communities;
- Describe the existing aquatic macrophyte communities in the upper and lower reaches of the Avon River;
- Build on previous relevant ecological information available across the catchment;
- Identify parts of the catchment that have high ecological values; and
- Make recommendations as to where stormwater design could be used to maintain or enhance the ecological values of these sites.

METHODS

This report presents the findings of two studies conducted with the Avon River catchment in 2013:

1. An ecological survey of waterways within the Avon River catchment; and
2. A re-survey the aquatic macrophytes of the Avon River

Ecological Survey of the Avon River catchment

Site Locations

The CCC provided Boffa Miskell with the locations of twenty-nine sites (shown in Appendix 1), located throughout the Avon River catchment, to be surveyed in this study (Figure 1). These sites covered a range of habitat types and locations within the wadeable reaches of the Avon catchment, including one or more sites on the following waterways:

- Avon River (9 sites);
- Ilam Stream (1 site);
- Okeover Stream (1 site);
- Waimairi Stream (3 sites);
- Wairarapa Stream (3 sites);

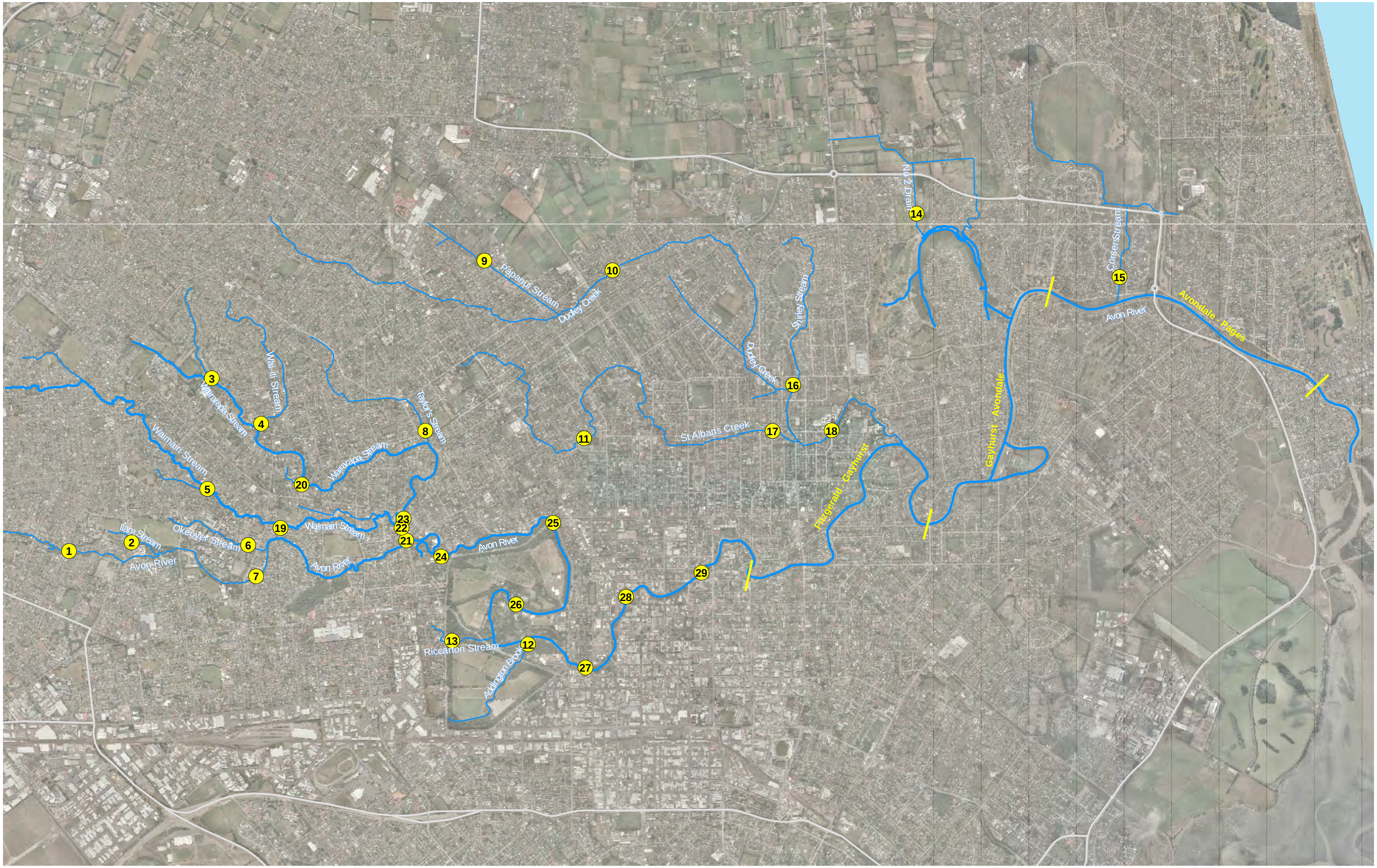
- Wai-iti Stream (1 site);
- Taylors Stream (1 site);
- Riccarton Stream (1 site);
- Addington Brook (1 site);
- St Albans Creek (2 sites);
- Dudley Creek (2 sites);
- Papanui Stream (1 site);
- Shirley Stream (1 site);
- No. 2 Drain (1 site); and
- Corsers Stream (1 site).

The co-ordinates (northing and easting) of each site (as provided by the CCC to Boffa Miskell) were loaded into Avenza pdf maps using ArcGIS, and using a geo-referenced pdf map on an iPad, sites were easily and accurately re-located and navigated to in the field.

At each of the twenty nine sites, assessments of the riparian and in-stream habitat (including periphyton and macrophytes) conditions and the macroinvertebrate and fish communities were conducted during base-flow conditions and following fine weather.

A separate study, conducted by EOS Ecology (2012a), was conducted to assess the ecological values of the non-wadeable reaches of the lower Avon River. Although the current study briefly summarises the EOS Ecology (2012a) results, the reader is referred to their report ("Post-Quake Ecology of the Lower Avon River: current state of the fish and invertebrate community") for full details. EOS Ecology's work included the assessment of three reaches (or sites) in the lower Avon River from Fitzgerald Avenue to Pages Road (EOS Ecology 2012a) (also shown on Figure 1).

Direct comparisons between this study and the EOS Ecology (2012a) work could not be made, nor the data from EOS Ecology's (2012a) study merged in our results, because different sampling methods and different sampling efforts were used. For example, due to the nature of non-wadeable sites, alternative methods using nets and traps to survey fish, and grab samplers to survey macroinvertebrates were used, which are different from the methods used in wadeable sites. Furthermore, EOS Ecology's (2012a) sites were multiple transects across the river within an approximately 3 km study reach. Nevertheless, the findings of the EOS Ecology (2012a) study of the non-wadeable reaches of the lower Avon River have been incorporated into this work, so that an assessment of the entire Avon River catchment can be made.



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Legend
- Sampling Sites
- REC Network Position
- Low-Order Waterways
- Mid-Order Waterways

AVON RIVER ECOLOGY

Figure 1 : Ecological Survey Site Locations

Date: 31 March 2014 | Revision: 0

Plan Prepared for CCC by Boffa Miskell Limited

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Figure 1. Locations of the 29 sites for the Ecological Survey of the Avon River catchment. EOS Ecology (2012a) study reach locations in the non-wadeable reaches of the Avon River are also shown. Site numbers are shown in the circles. Each of the 29 sites were categorised as either low- or mid-order waterways according to the River Environment Classification (REC) developed by the National Institute for Water and Atmospheric Research (NIWA). See Data Analyses section for further details.

Habitat Assessment

A variety of in-stream and riparian habitat parameters were recorded at each site between 22 October and 7 November 2013.

At each site, basic water chemistry, temperature and velocity parameters were measured. Spot measures of pH, dissolved oxygen (DO, ppm), specific conductivity (μS_{25} / cm) and water temperature (°C) were recorded at each site with a TPS 90FL-T Field Lab Analyser. Velocity was recorded using the ruler method as described by Drost (1963) and Harding et al. (2009) at three random locations within the 20 m study reach.

Three equally-spaced transects, at 10 m intervals, were established across the waterway at each site where the downstream most transect was situated at the location listed in Appendix 1 with transects two and three located 10 m and 20 m upstream of the first.

Total wetted width (m) was recorded at each of the three transects, to give an average wetted width (m) for each site. Canopy cover (%), undercut bank extent (cm) (if present), extent of any overhanging vegetation (cm), ground cover (%), and general riparian vegetation conditions were recorded on the true left (TL) and true right (TR) banks along each of these transects at each site.

Water depth (cm), soft sediment depth (cm), substrate composition (%), macrophyte depth (cm), percent cover, type (submerged or emergent) and dominant species of macrophytes, percent cover of organic material (leaves, moss, coarse woody debris), and percent cover and type of periphyton were measured at three locations (TL bank, mid channel and TR bank) along each of the three transects at each site.

Soft sediment depth was determined by gently pushing a metal rod (10 mm diameter) into the substrate until it hit the harder substrates underneath. Substrate composition was measured within an approximately 20 x 20 cm quadrat randomly placed at each of the three 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).

Photographs were also taken at each site.

Macroinvertebrate Community

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.

The macroinvertebrate community was assessed at each site within the same 20 m reach where in-stream habitat was surveyed. The macroinvertebrate community was sampled at each site on the same day that the habitat assessment was conducted (i.e. prior to habitat assessments, but after basic water chemistry and temperature parameters were measured).

A single and extensive composite kick-net (500 µm mesh) sample was collected from each site in accordance with protocols C1 and C2 of Stark et al (2001). That is, approximately 0.6 m^2 of stream bed was sampled at each site (i.e. each kick net sampled approximately 0.3 m x 2.0 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) (see Appendix 2 for further details on processing methods).

Fish Community

Each site was revisited between 18 and 27 November 2013 during which time the fish community was surveyed from within at least a 20 m reach (i.e. the same survey reach as habitat and macroinvertebrate community were assessed) at each site. Each survey reach included the variety of habitats typically present in the reach being surveyed (e.g. stream margin, mid channel, undercut banks, macrophytes, silt, riffles). Survey reaches were divided into many subsections of approximately 2-3 m in length and electro-fished using multiple passes with a Kainga EFM 300 backpack mounted electro-fishing machine (NIWA Instrument Systems, Christchurch). Fish were captured in a downstream push net or in a hand (dip) net and temporarily held in buckets. All fish were then identified, counted and measured (length, mm) before being returned alive to the stream.

Two fyke nets and 6 Gee minnow traps were also set at one site (Site 23, Wairarapa Stream downstream Fendalton Road) as the deep fine sediments on the stream bed at this site made using the electro-fishing machine difficult (i.e. largely due to reduced visibility). This was exacerbated by the fact that weed removal / maintenance by Council had taken place just prior to our survey. Therefore, nets and traps were set overnight at this site. The fyke nets were baited with beef offcuts, and the Gee minnow traps were baited with marmite.

Data Analyses

The 29 sites were categorised as either low- or mid- order waterways according to the River Environment Classification (REC) developed by the National Institute for Water and Atmospheric Research (NIWA). Waterway order provides an indication of stream, or waterway size. That is, low-order waterways are smaller, headwater waterways with less upstream habitat than mid-order waterways, which are larger, mid-catchment waterways (Figure 1). Site 6, Okeover Stream, was classified by the REC as a mid-order stream, however, in this study Okeover Stream has been more correctly grouped as a low-order waterway

Habitat

The multiple measures across transects, and at multiple transects within a site for water depth, soft sediment, substrate composition, macrophyte depth, percent cover of macrophytes, organic materials and periphyton were averaged to give one value for each parameter per site

A substrate index (SI), modified from Jowett and Richardson (1990), was calculated for each measure taken across the three transects at each site, using the formula:

SI = (0.06% boulder) + (0.05% large cobble) + (0.04% small cobble) + (0.03% pebble) + (0.02% gravel) + (0.01% silt / sand)

The calculated SI can range between 1 and 12, where an SI of 1 indicates 100% silt / sand and 12 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. The multiple SIs calculated for each site (i.e. multiple values across three transects at each site) were averaged, to give one value per site.

Analyses of variance (ANOVAs) were used to test for differences in mean in-stream and riparian habitat conditions among sites and between low- and mid-order waterways. Response variables (wetted width, water depth, sediment depth and Substrate Index) were *ln* (x+1) transformed where necessary 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).

Comparisons over Time

As part of the CCC's long-term monitoring of Christchurch's waterways, EOS Ecology conducted a survey in 2008 of the habitat conditions and macroinvertebrate communities at 10 of the sites also surveyed in this study (EOS Ecology 2009) (Table 1). As such, as comparison of the general habitat conditions in 2008 (EOS Ecology 2009) versus 2013 (this study) have also been made in this report.

Table 1. The 10 sites that were surveyed in both 2008 and 2013, and used in the comparisons over time, were:

	Site number	
Site name	This study, Boffa Miskell 2014	EOS Ecology 2009
Avon River downstream of Clyde Road	7	27
Okeover Stream at Canterbury University	6	26
Papanui Stream at Erica Reserve	9	28
Waimairi Stream at Fendalton Park	19	25
Wairarapa Stream upstream of Glandovey Road	20	24
Avon River downstream of Mona Vale weir	24	23
Avon River in Hagley Park	26	22
Avon River near Durham Street	27	21
Avon River at Victoria Square	28	20
Avon River near Kilmore Street	29	19

Macroinvertebrate Community

The following macroinvertebrate metrics and indices were calculated to provide an indication of stream health:

- **Total abundance** – the total number of individuals collected in the composite kick-net sample collected at each site. Comparisons of abundance of macroinvertebrates among sites can be useful as abundance tends to increase in the presence of organic enrichment, particularly for pollution-tolerant taxa.
- **Taxonomic richness** – the total number of macroinvertebrate taxa recorded from the composite kick-net sample collected at each site. 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 site. These three insect orders (EPT) are generally sensitive to pollution and habitat degradation and therefore the numbers of these insects present provide 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 caddisflies belonging to the family Hydroptilidae, which are generally more tolerant of degraded conditions than other EPT taxa.
- **%EPT richness** – the percentage of macroinvertebrates that belong to the pollution-sensitive EPT orders found in the composite kick-net collected at each site, i.e. relative to total richness of all macroinvertebrates at each site. High %EPT richness suggests high water quality.
- **%EPT (excl. hydroptilids)** – the percentage of EPT taxa at each site, 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 and Maxted 2007). These tolerance scores, which indicate a taxon's sensitivity to in-stream environmental conditions, are summed for the taxa present at a site, and multiplied by 20 to give MCI-hb values ranging from 0 – 200.
- **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 at a site.

Table 2 provides a summary of how MCI-hb and QMCI-hb scores were used to evaluate stream health.

Table 2. 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.

ANOVAs were used to test for differences in means between low- and mid-order sites in macroinvertebrate abundance, taxonomic richness, EPT richness, EPT-except Hydroptilidae richness, %EPT richness, and MCI and QMCI values. Response variables were either *ln* (x+1) transformed to meet assumptions of normality and homogeneity of variances, or ranked where data could not be transformed to meet these assumptions. ANOVAs were performed in R version 3.0.2 (The R Foundation for Statistical Computing 2013).

Sites were ranked from 1 (best) to 29 (worst) for the following biotic indices: taxonomic richness, EPT richness, %EPT richness, MCI, and QMCI. Other biotic indices listed above were not included as many are derivatives of these key biotic indices. These ranks (of the included biotic indices) were then summed to give an over rank for each site, where 1 was the best site overall (based on all of the biotic indices) and 29 was the worst site overall (based on the biotic indices). This gave an indication of differing ecological conditions and values among sites and how each sat within the wider Avon River catchment.

A non-metric multidimensional scaling (or NMDS) ordination[1], with 1000 random permutations, using abundance data was used to determine if the macroinvertebrate community found was similar among the 29 sites surveyed, and particularly:

1. Among the 16 waterways surveyed; and
2. Between low- and mid-order sites.

NMDS ordinations rank sites 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 any site can be presented on an x-y scatterplot to graphically show how similar (or dissimilar) the community at a site is from that found at another site. 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 (1) among the 16 waterways surveyed; and (2) between low- and mid-order sites. 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

[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).

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 ≠ 0 and P ≤ 0.05) either among waterways or between low- and mid-order sites, 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; Clarke and Gorley 2006).

Comparisons over Time

A separate NMDS ordination, with 1000 permutations, was conducted, using presence-absence data, to compare changes (or similarities) in macroinvertebrate communities at a 10 sites (i.e. a subset of the 29 sites surveyed in this study) that were surveyed in 2008 by EOS Ecology (2009). This was part of the CCC's long-term monitoring of Christchurch's waterways. The NMDS ordination methods were the same as above, however, presence-absence rather than abundance data were used. This was because EOS Ecology (2009) collected multiple kick-net samples from each site in 2008, while in this study one composite kick-net sample was collected from each site. Reducing the data to presence-absence meant that the data collected from these two sampling periods (i.e. 2008 and 2013) were generally comparable. Furthermore, there were some differences in the level to which macroinvertebrates were identified between years, which if not controlled for would bias the NMDS ordination results (i.e. indicating differences in macroinvertebrate community composition that may actually be due to taxonomic resolution or identification, rather than true differences in community composition). Therefore, the caddisfly taxa Hydroptilidae, *Oxyethira*, and *Paraoxyethira* were all grouped into the family Hydroptilidae (i.e. the highest taxonomic grouping common to both 2008 and 2013 sampling). Similarly, the non-biting chironomid midge larva *Corynoneura*, was grouped into the family Orthocladiinae (again, the highest taxonomic grouping common to both sampling occasions).

As above, an ANOSIM, with 100 permutations, was then used to test for significant differences in macroinvertebrate community composition between the survey periods 2008 (EOS Ecology 2009) and 2013 (this study). If ANOSIM revealed significant differences, SIMPER were calculated to show which macroinvertebrate taxa were driving these differences.

Fish Community

The total distance fished (in metres) at each site and the amount of time spent actively fishing (i.e. time displayed on the electro-fishing machine) were recorded. The fish capture data were then expressed as 'catch per unit effort' (CPUE), to standardise for the different sampling effort among sites (i.e. total distance). CPUE was calculated by dividing the number of fish captured by the area fished (total distance fished multiplied by average wetted width of a site), and extrapolated up to 100 m^2 for each site. CPUE was, therefore, expressed as number of fish captured per 100 m^2.

ANOVAs were used to test for differences in mean fish abundance (per 100 m^2) and species richness between low- and mid-order sites. Response variables were either *ln* (x+1) transformed to meet assumptions of normality and homogeneity of variances, or ranked where

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[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.

data could not be transformed to meet these assumptions. ANOVAs were performed in R version 3.0.2 (The R Foundation for Statistical Computing 2013).

Re-Survey of Macrophytes in the Avon River

Site Locations

The CCC provided Boffa Miskell with the locations of 16 sites (shown in Appendix 1), located in the upstream and lower reaches of the Avon River, to be surveyed in this study (Figure 2). There were five upstream sites, located in the Avon River where it flows through Mona Vale and the northern part of Hagley Park, upstream of the Carton Mill corner. A further eleven sites were located in the lower reaches of the Avon River, where it flows through the suburbs of Avondale and Bexley. These sites were different from those where the Ecological Survey also presented in this report were conducted.

These macrophyte survey sites were previously surveyed by van den Ende and Partridge (2008). The purpose of this study was to re-survey these sites in order to determine if the macrophyte communities have changed in areas that were identified by van den Ende and Partridge (2008) as areas of biodiversity value.

Macrophyte Community Assessments

The macrophyte assessments at the 16 sites were undertaken on 19, 20 and 21 November 2013 by Boffa Miskell Ecologists. The co-ordinates (northing and easting) of each site (as provided by the CCC to Boffa Miskell) were loaded into Avenza pdf maps using ArcGIS, and using a geo-referenced pdf map on an iPad, sites were easily and accurately re-located and navigated to in the field.

The methods of van den Ende and Partridge (2008) were repeated at each of the 16 sites. This entailed the following methodology.

At each site, a 20 m survey reach was established along the bank with a tape measure. The 20 m reach was located as 10 m upstream and 10 m downstream a site's centre point as determined by the co-ordinates supplied by the CCC. Each survey reach was divided into three sections running the length of the reach: true left bank zone (TLB); In-stream zone (IN); and true right bank zone (TRB). The rationale for and delineation of these zones are described further by van den Ende and Partridge (2008).

At each site, all aquatic macrophyte species present, and their growth forms (e.g. floating, submerged, emergent, raft-forming; see van den Ende and Partridge 2008 for a description) in each of the TLB, IN and TRB zones were recorded.

Records for the TLB, IN and TRB zones were kept separate. Species abundance was subjectively assessed for each species present, in each of the zones, using the standard 'DAFOR' scale, which represents the following cover classes:

5	75 – 100% cover	D = Dominant
4	50 – 75% cover	A = Abundant
3	25 – 50% cover	F = Frequent
2	5 – 25% cover	O = Occasional
1	less than 5% cover	R = Rare

However, due to poor visibility estimating abundance of macrophytes in the lower reaches was not always possible, and therefore, species were only recorded as present.

The three zones were surveyed from the riparian margins of both banks. In wadeable reaches, the IN zone was also surveyed by wading out into the river, however, this was not always possible, particularly in the lower reaches of the Avon River. In the non-wadeable reaches of the river, binoculars were also used to survey macrophytes of the IN zones.

As the sites in the non-wadeable, lower reaches of the Avon River were too deep to safely wade and water clarity too poor to allow direct observation, an alternative method was employed (also employed by van den Ende and Partridge 2008). At each site, the 20 m survey reach was divided into five equally spaced sampling points, and at each point a sample of the macrophytes present in the river were retrieved using a 30 m long, heavy nylon fishing line with attached sinkers and treble fishing hooks[4]. At each of the five sampling points, the line was thrown into the river so that it landed approximately 10%, 25%, and 40% of the distance across the river width. Staggering the distances of the throws like this gave a good coverage of the IN zone. This gave three throws of the line at each of the five locations within the 20 m survey reach. This was repeated from both banks at each site, giving a total of 30 'retrieves' of macrophytes from the river at each of the eleven lower Avon River sites.

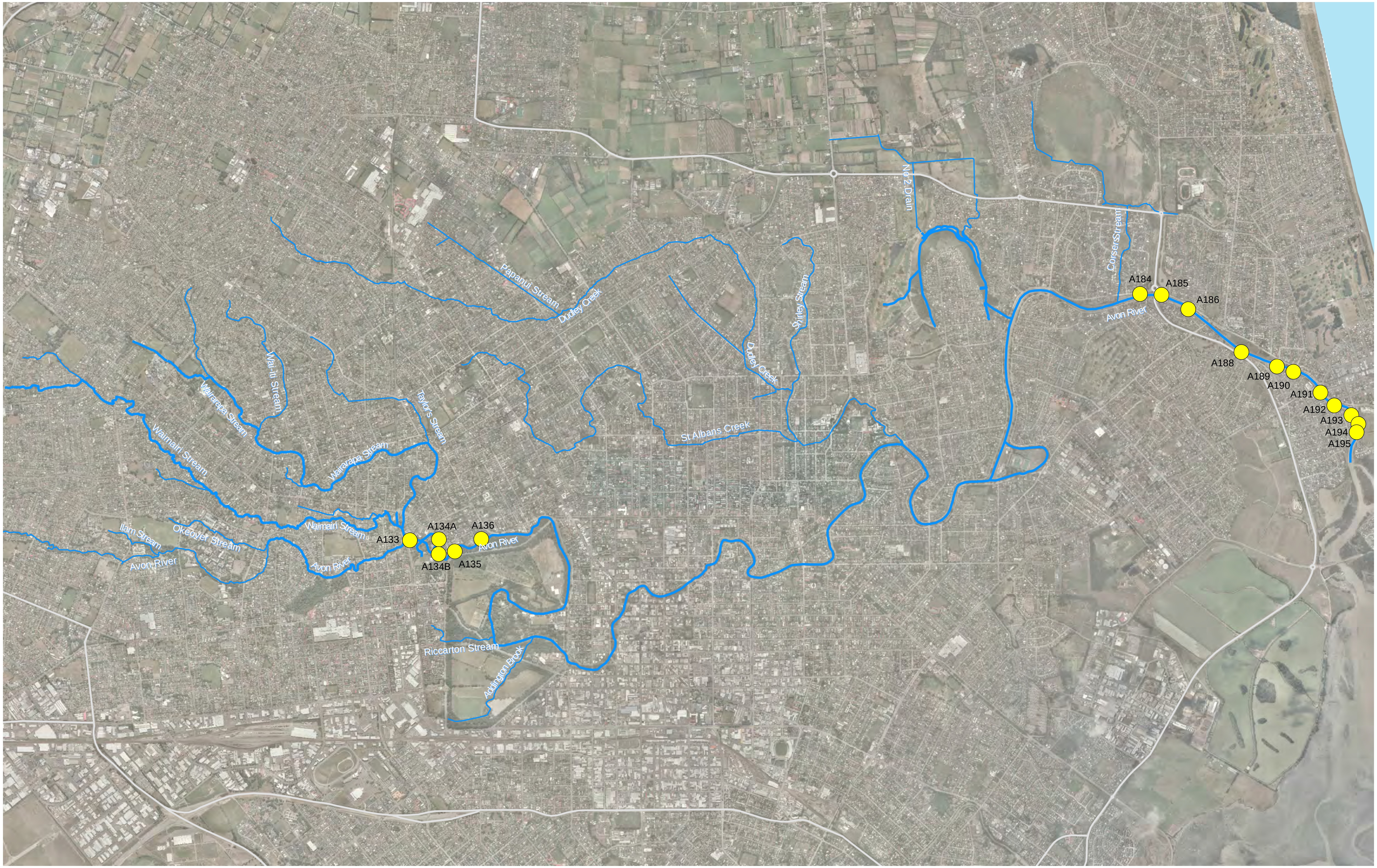
On each throw, the line was thrown out into the river and allowed to sink into the macrophytes. The line was then quickly retrieved so that the treble hooks were dragged along the bottom and caught macrophytes all the way back across the river bed, rather than just at the point of landing.

Note, this alternate method provides presence information only based on the macrophyte species retrieved during multiple throws at a site. This method does not provide abundance information, and due to the limited water clarity at the lower Avon River sites, only presence data was obtained for these eleven sites.

Surveying was undertaken in the best conditions possible, and the following additional techniques were employed throughout this survey, where possible, to maximise reliability of data collection in the field:

- In-stream macrophytes were visually surveyed by eye and / or using binoculars from select vantage points above the river (e.g. from bridges or large overhanging trees);
- Surveys were undertaken when there was no or little wind, when glare from the sun was minimal, and (in tidal areas) when the tide was low (where possible).
- Polarised glasses were worn by the observer when conducting the macrophyte surveys.

[4] The barbs of the treble hook were filed off and the points were blunted for safety reasons.



Boffa Miskell
www.boffamiskell.co.nz

0 1.2 km
1:35,000 @ A3

Aerials Flown 2011 NZAM - Sourced from CERA.

Projection: NZGD 2000 New Zealand Transverse Mercator

Legend

- Sampling Sites
- REC Network Position
  - Low-Order Waterways
  - Mid-Order Waterways

AVON RIVER ECOLOGY

Figure 2 : Macrophyte Re-Survey Site Locations

Date: 9 April 2014 | Revision: 0

Plan Prepared for CCC by Boffa Miskell Limited

Author: brian.mcauslan@boffamiskell.co.nz | *Checked:* TBI

Figure 2. Locations of the 16 sites for the Re-Survey of Macrophytes in the Avon River.

Data Analyses

The macrophyte data were transformed to presence only information, as abundance data could not be collected at the non-wadeable sites due to water clarity and sampling issues. All macrophyte species collected were categorised as native or introduced. A number of macrophyte metrics were then calculated based on these presence data for each site, including:

- **Total richness** – the total number of macrophyte species (or taxa) recorded at each site.
- **Percentage of native species** – the percentage (or proportion) of species that are native at each site.

ANOVAs were used to test for differences in means between upper (wadeable) and lower (non-wadeable) sites in macrophyte richness and percentage of native species. Macrophyte richness was ln (x+1) transformed to meet assumptions of normality and homogeneity of variances, while percentage of native species was ranked. ANOVAs were performed in R version 3.0.2 (The R Foundation for Statistical Computing 2013).

An NMDS, with 1000 random permutations, using presence data was used to determine if the macrophyte community found was:

- Similar among the 16 sites surveyed; and
- If the community at these sites had changed over time (i.e. 2007 vs 2013 data)

Detailed methods of NMDS ordinations are given in the Data Analyses, Macroinvertebrate Community section above. An ANOSIM, with 100 permutations, was then used to test for significant differences in macrophyte community composition (1) among the 16 sites surveyed; and (2) between 2007 and 2013. If ANOSIM revealed significant differences in macrophyte community composition (i.e. $R \neq 0$ and $P \leq 0.05$), either among sites or between sampling years, SIMPER were calculated to show which macrophyte species, or taxa, were driving these differences.

NMDS, ANOSIM and SIMPER analyses were performed in PRIMER version 6.1.13 (Clarke and Warwick 2001; Clarke and Gorley 2006).

RESULTS

Ecological Survey of the Avon River Catchment

Figure 1 shows the location of the 29 sites within the Avon River catchment surveyed in this study. The three sites in the non-wadeable reaches of the lower Avon River, as surveyed by EOS Ecology (2012a) are also shown.

Note, many of the figures shown in this section order the sites by site number, and by ‘stream order’. That is, all of the low-order waterways (i.e. all of the smaller waterways in the headwaters and the tributaries of the Avon River) are Sites 1 – 18. While Sites 19 – 29 are located within the larger waterways (mid-order waterways) of the main stem of the Avon River and the lower reaches of the Wairarapa Stream.

General Site Descriptions

A brief summary of the general habitat conditions encountered at each site is given in Appendix 3. Sites 1 – 18 were described as low-order waterways, while sites 19-29 were classified as mid-order waterways, based on the REC data.

Habitat

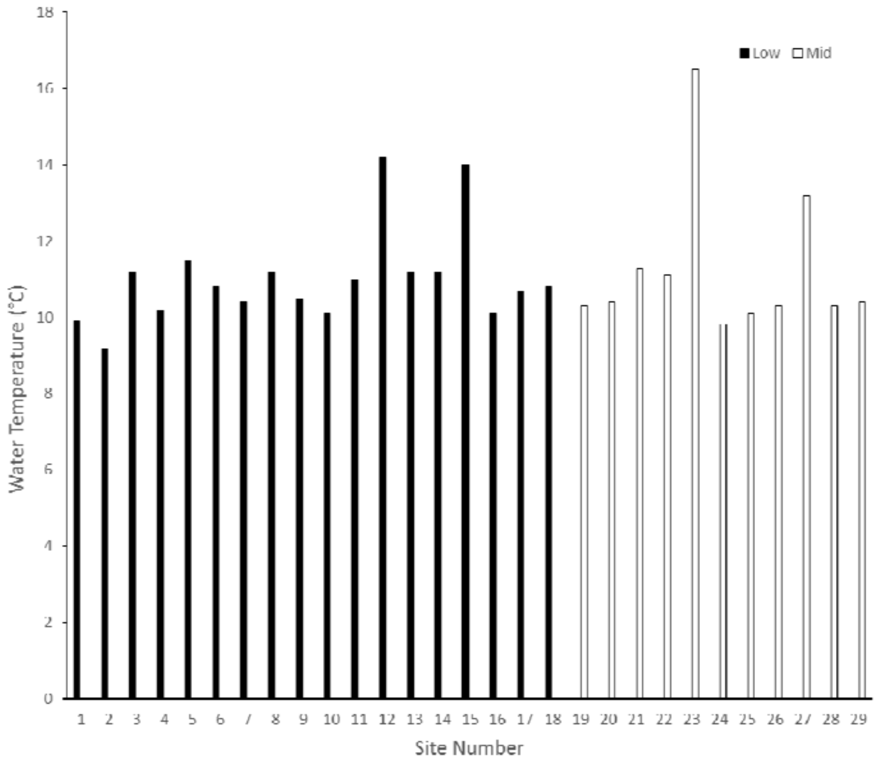
The measures of pH, specific conductivity, and water temperature indicated water quality of the 29 sites surveyed was generally within the ranges often encountered in urban spring-fed systems[5]. Specific conductivity, which is often used to indicate the level of pollutants in the water column, was fairly consistent across the catchment with a median value of 178 µS / cm and an average of 191 µS / cm for the 29 sites. Conductivity was, however, markedly higher at Sites 12 (Addington Brook upstream of Avon confluence), 13 (Riccarton Stream downstream of Deans Ave), and 15 (Corsers Stream at Brooker Reserve), compared to the remainder of the Avon River catchment (Figure 3).

Spot water temperature measures at each site ranged from 9.2 – 16.5 °C, with the highest water temperature being recorded in Site 23, Wairarapa Stream downstream of Fendalton Road, where there was very little cover with the majority of the channel being in full sun at the time of sampling. The majority of sites (25 of 29 sites) had relatively cool water temperatures (i.e. between 9.2 and 11.5 °C) (Figure 3). Water temperature at all sites was below Canterbury's proposed Land and Water Regional Plan (pLWRP) guideline of a maximum water temperature of 20°C in spring-fed (plains) urban waterways.

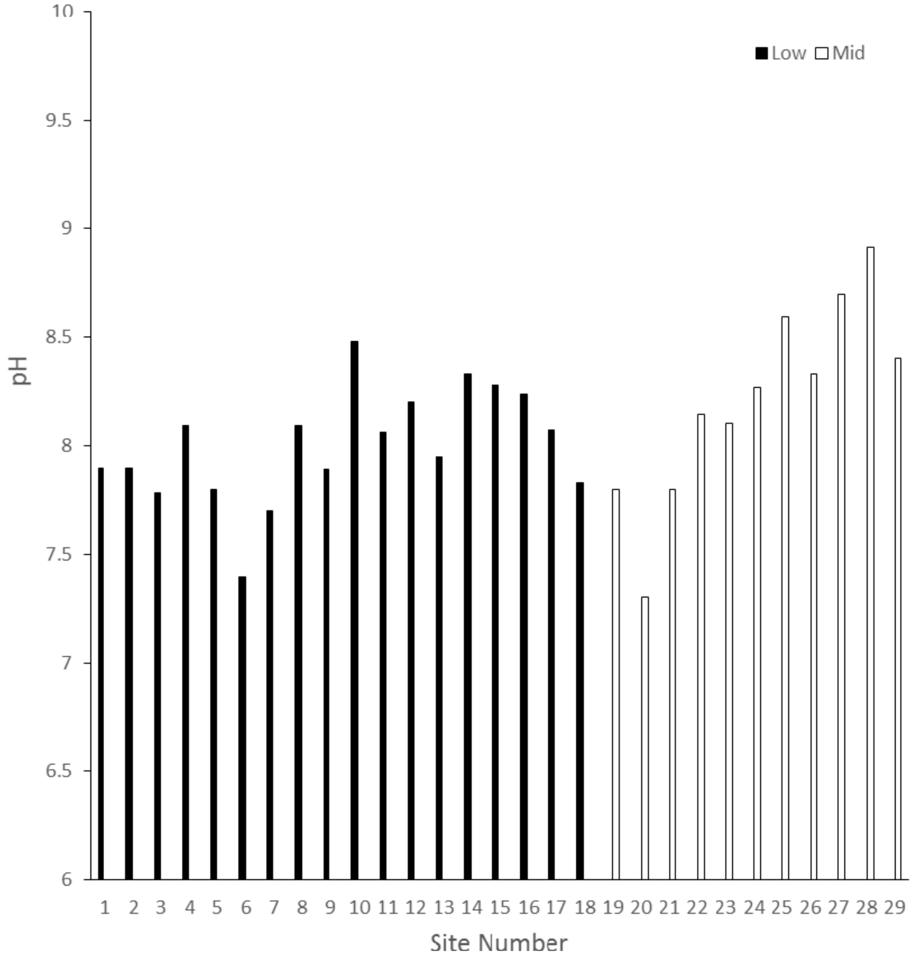
pH was relatively similar across the 29 sites, being circum-neutral in many of the sites but ranged from 7.3 to 8.9 across the catchment (Figure 3).

Velocity ranged from slow (0.01 m / s) to moderate (0.72 m / s), and was quite variable within low- and mid-order sites (Figure 3). Sites 2 (Ilam Stream at Waimairi Road), 4 (Wai-iti Stream at Clyde Road), and 16 (Shirley Stream Stapletons Road) had the slowest velocities, while Sites 7 (Avon River downstream of Clyde Road), 24 (Avon River downstream of Mona Vale weir), 29 (Avon River near Kilmore Street), 25 (Avon River at Carlton Mill Corner), 27 (Avon River near Durham Street) had the fastest velocities.

[5] Note, the dissolved oxygen probe was damaged and producing erroneous readings, so dissolved oxygen has not been presented in this report.



Low
Mid
Water Temperature (°C)
Site Number



Low
Mid
pH
Site Number

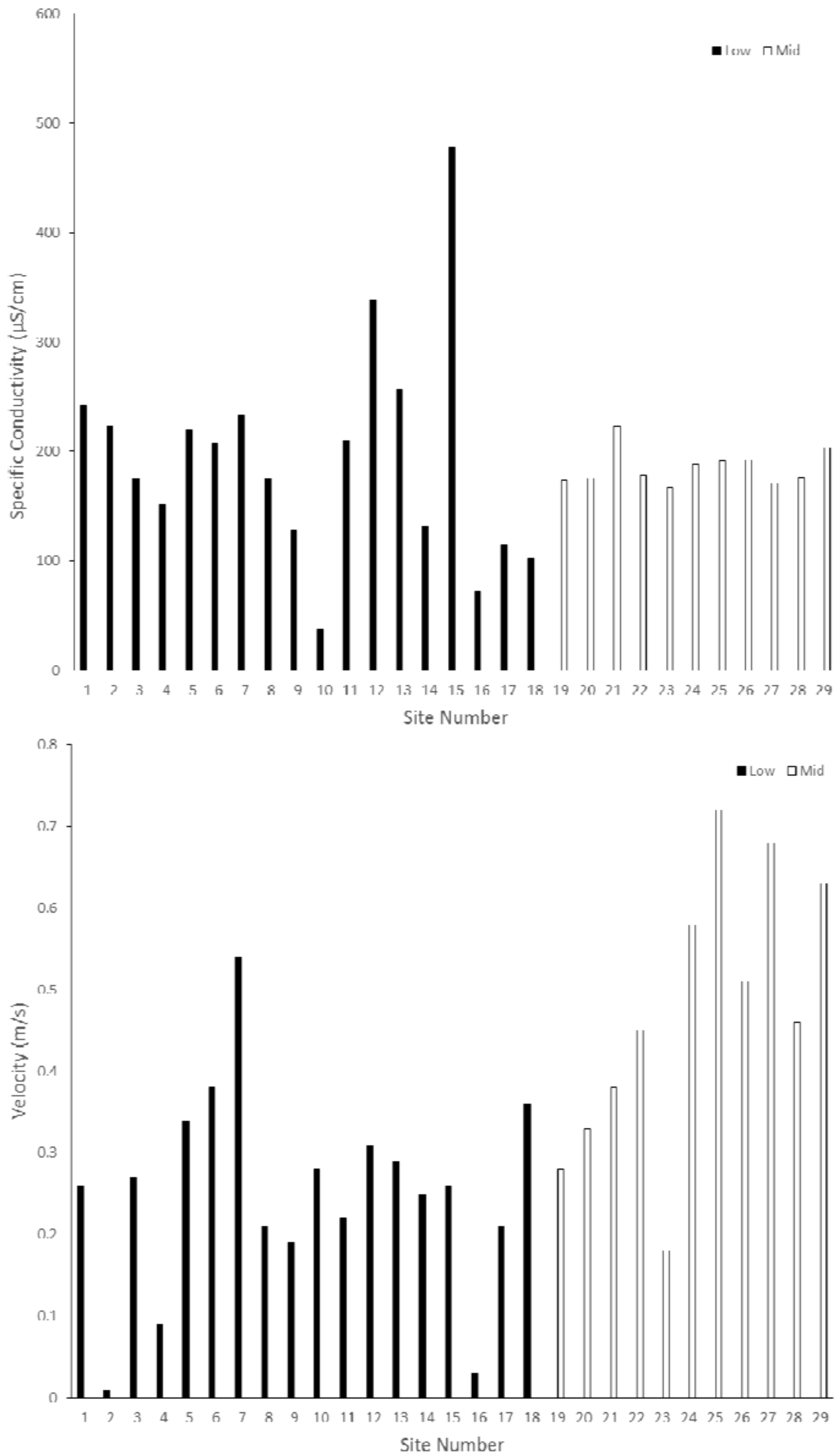


Figure 3. Basic water quality (physical and chemical) parameters of water temperature (top, previous page), pH (bottom, previous page), specific conductivity (top, this page) and velocity (bottom, this page), measured on one occasion in the 29 sites across the Avon River catchment. The 29 sites were categorised as low- (black) or mid-order (white) waterways according to the REC.

The 29 sites surveyed varied in their in-stream and riparian physical habitat conditions. Not surprisingly, sites in the upper catchment (i.e. the low order tributaries and headwaters of the Avon River; Sites 1-18) had significantly narrower channels, than sites in the mid-order reaches of the Avon River (Sites 19-29) (ANOVA: $F_{1, 85} = 10.04$; $P = 0.002$). Channel width ranged from 0.4 – 5.0 m in the low order sites (Sites 1 – 18), to 3.2 – 15.2 m in the mid order sites (Sites 19 – 29) (Figure 4).

Site 16, Shirley Stream Stapletons Road, was the narrowest site sampled (average wetted width 0.4 m), while Site 29, Avon River near Kilmore Street, was the widest (average wetted width 15.2 m) (Figure 4).

Water depth was highly variable among sites (ANOVA: $F_{28, 58} = 58.92$; $P < 0.001$; Figure 4) but there was no significant difference in water depth between low- and mid-order sites (ANOVA: $F_{1, 85} = 2.51$; $P = 0.117$). Water depth ranged from 1 – 44 cm and 17 – 49 cm in the low and mid order sites, respectively (Figure 4).

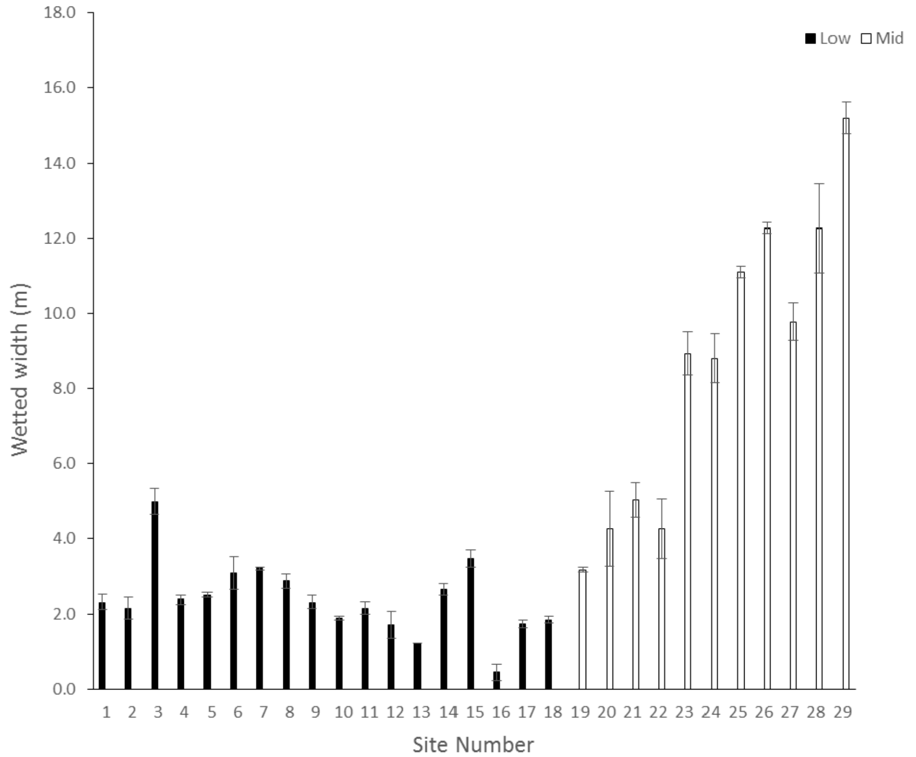
Site 16, Shirley Stream Stapletons Road, was the shallowest site surveyed (average water depth 1 cm), while Site 25, Avon River at Carlton Mill Corner, had the deepest channel (average depth 49 cm).

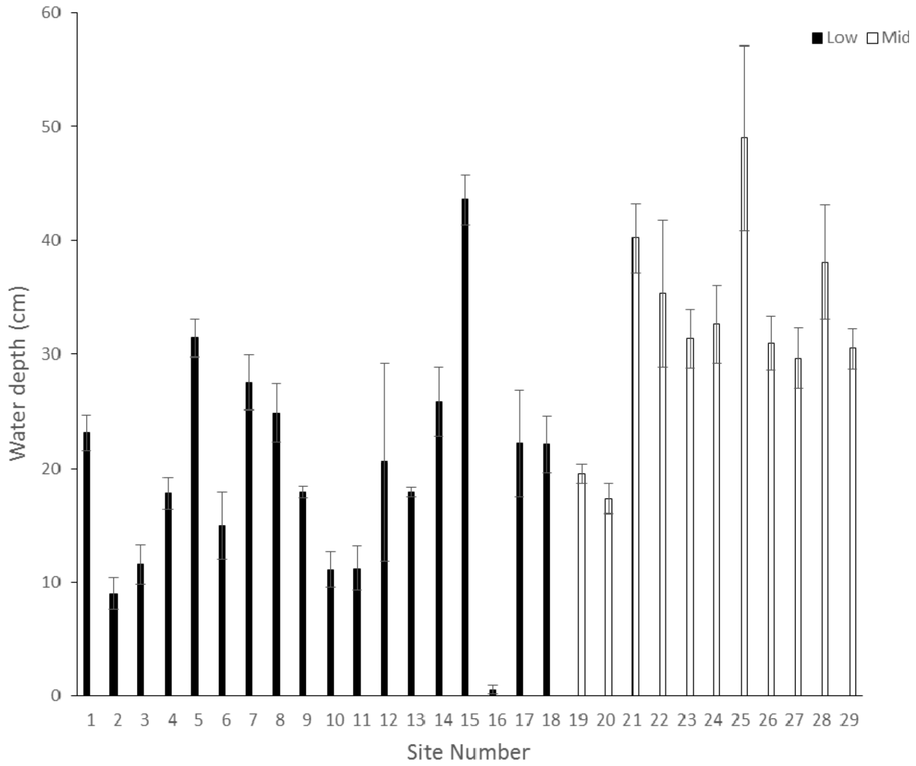
Fine sediment depth (i.e. the depth on top of coarser substrates) was also variable among sites (ANOVA: $F_{28, 58} = 5.92$; $P < 0.001$; Figure 4), but there was no difference between sediment depth at low- and mid-order sites (ANOVA: $F_{1, 85} = 1.82$; $P = 0.181$).

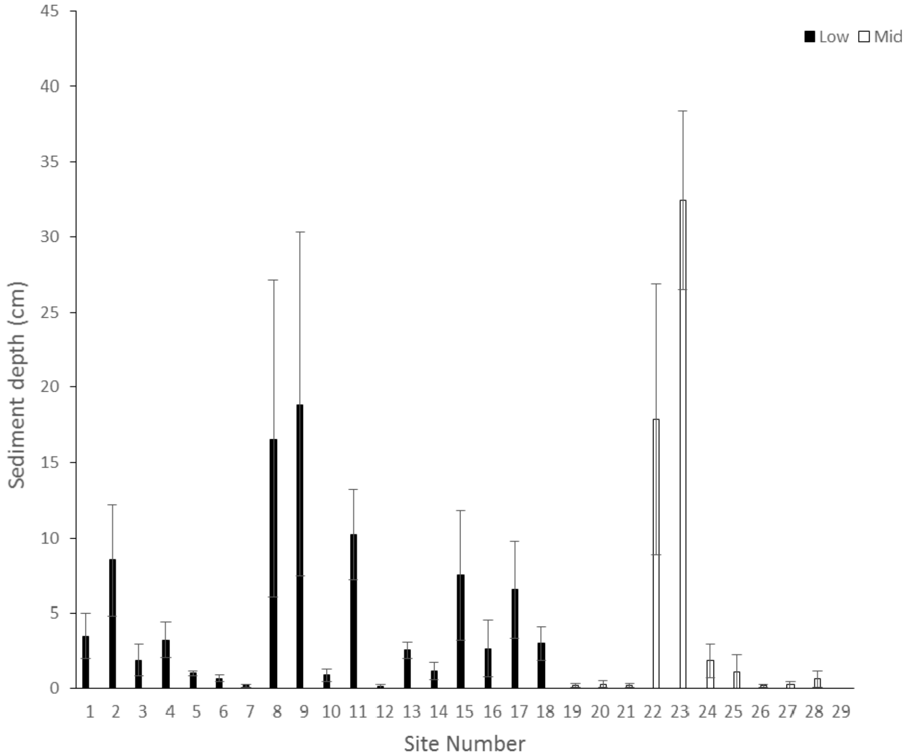
A number of sites had only a shallow covering of fine sediments, while Sites 8 (Taylors Drain at Heaton Street), 9 (Papanui Stream at Erica Reserve), 22 (Waimairi Stream downstream of railway), and 23 (Wairarapa Stream downstream of Fendalton Road) had a substantial covering (between 17 and 32 cm) of fine sediments covering the stream bed (Figure 4).

Low-order sites generally had finer substrates (dominated by sand, gravel, and pebbles), than the mid-order sites (dominated by pebbles and small cobbles, with generally less sand and gravels) ($F_{1, 85} = 6.60$; $P = 0.012$). However, substrate size was highly variable among sites (ANOVA: $F_{28, 58} = 8.35$; $P < 0.001$; Figure 4).

Sites 8 (Taylors Drain at Heaton Street), 11 (St Albans Creek at Abberley Park), 16 (Shirley Stream Stapletons Road), 17 (St Albans Creek downstream Slater Street), and 23 (Wairarapa Stream downstream Fendalton Road) had the lowest SIs, indicating the stream bed at these sites was dominated by finer substrates. Sites 3 (Wairarapa Stream at Jellie Park), 9 (Papanui Stream at Erica Reserve), 10 (Dudley Creek downstream Jameson Ave), 21 (Avon River above confluence with Wairarapa), and 27 (Avon River near Durham Street) had the greatest SIs, indicating the stream bed at these sites was dominated by coarser substrates. However, these SIs were still relatively low, given that an SI could range between 1 and 12. Therefore, all of the 29 sites surveyed were generally lacking in large boulder substrates.


■ Low □ Mid
Wetted width (m)
Site Number
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29


■ Low □ Mid
Water depth (cm)
Site Number
0
10
20
30
40
50
60
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29



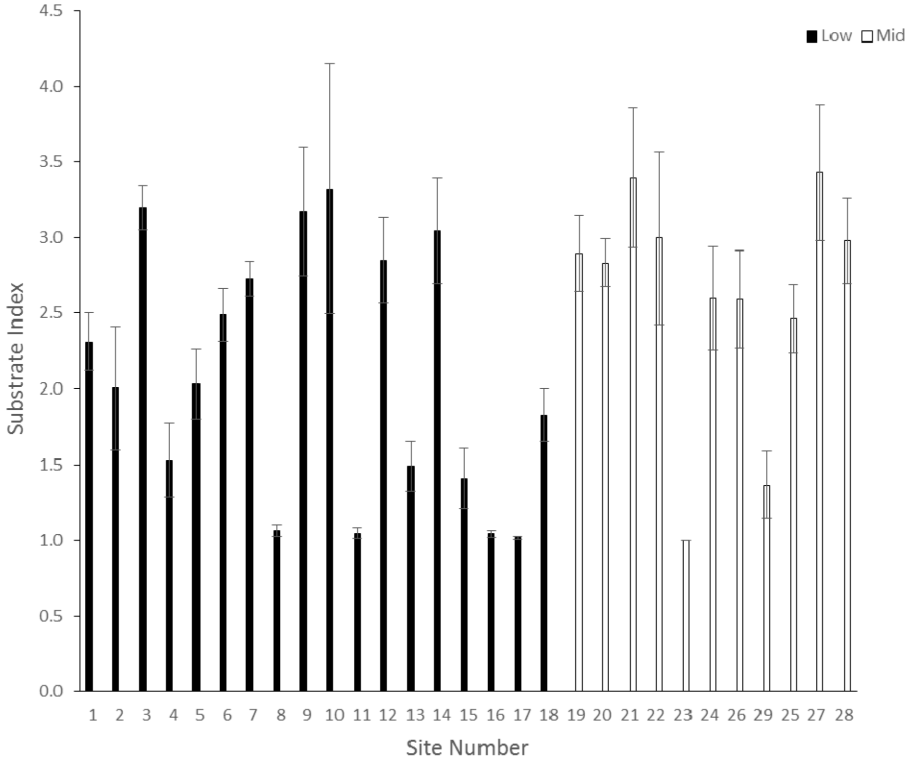


Figure 4. Average channel width (wetted width, m) (top, previous page), water depth (cm) (bottom, previous page), sediment depth (top, this page), and Substrate Index (bottom, this page) at each site. Error bars are 1±SE. The 29 sites were categorised as low- (black) or mid-order (white) waterways according to the REC.

Macrophyte cover was generally low, with many sites have few or very little macrophyte cover (Figure 5). The majority of macrophytes that did occur were submerged species, including *Potamogeton crispus*, *Elodea canadensis*, *Myriophyllum propinquum*, and *Nitella hookeri*, with occasional patches of the raft-forming *Nasturtium officinale*. The macrophyte community found at each site is explained in more detail in Appendix 3. Total macrophyte cover in the Avon River at Kilmore Street exceeded the pLWRP guideline of a maximum total cover of 60% for spring-fed (plains) urban waterways.

Periphyton cover (%) was variable across sites (Figure 6). Although filamentous green and brown algae were present at most sites (Figure 6), the percent cover of long filamentous green algae was below 30% at most sites. However, Riccarton Stream (Site 13) and Corsers Stream (Site 15) both had abundant long filamentous green algal growths, with total cover exceeding the pLWRP guidelines of 30% maximum total cover.

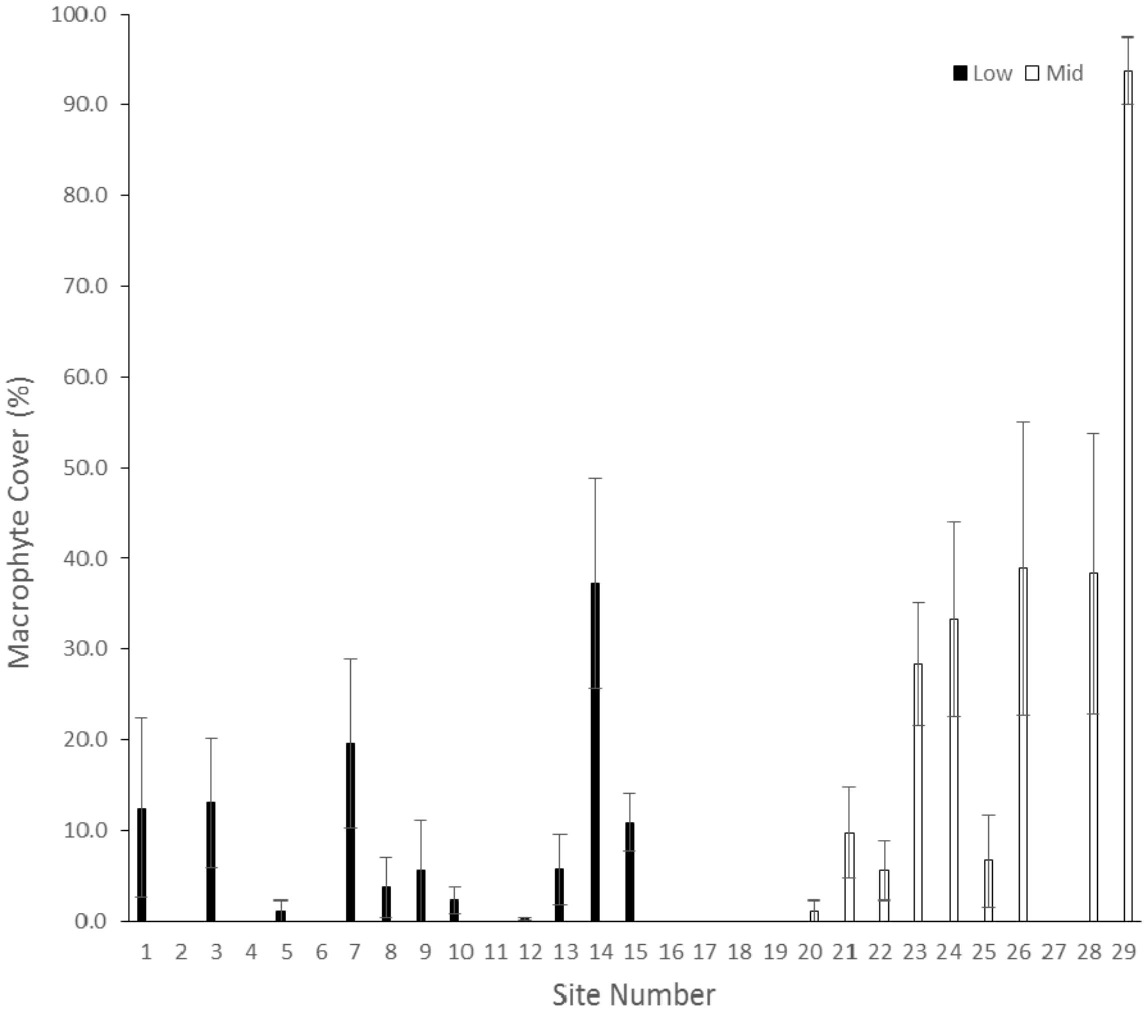


Figure 5. Macrophyte cover (%) estimated at each of the 29 survey sites in October and November 2013. Error bars are 1±SE. The 29 sites were categorised as low- (black) or mid-order (white) waterways according to the REC.

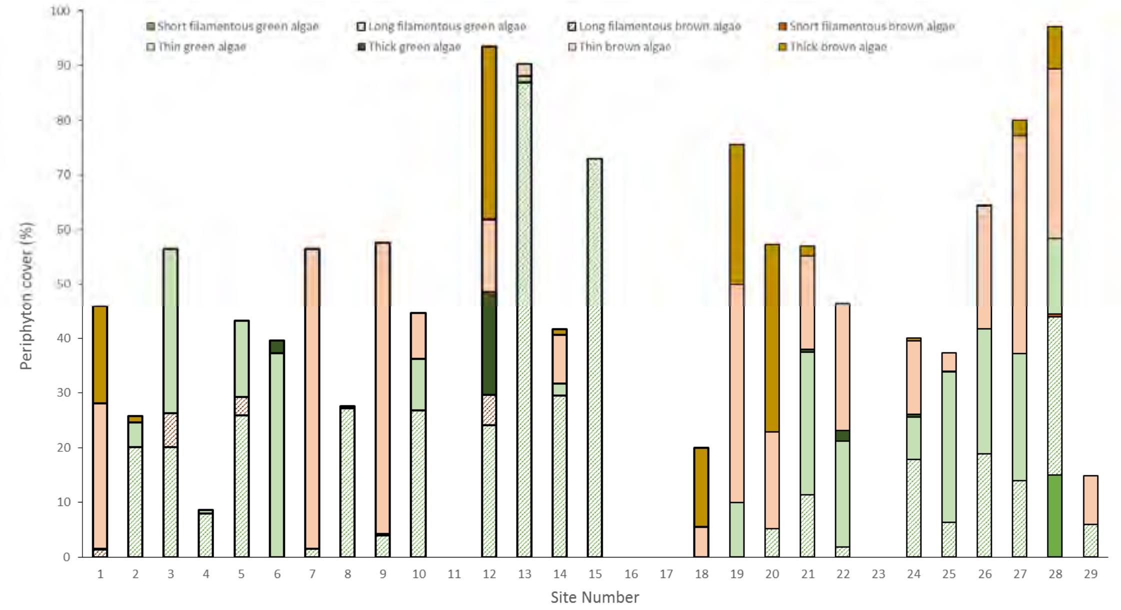


Figure 6. Periphyton cover (%) estimated at each of the 29 survey sites in October and November 2013.

Comparisons over Time

Habitat conditions were found to be generally similar at the 10 sites, changing very little between 2008 and 2013. As indicated above, the mid-order (described as 'mainstem sites' in EOS Ecology 2009) sites were generally wider and deeper than the low-order ('tributary sites' in EOS Ecology 2009) sites (also see Table 1 for a list of the 10 sites being compared). Velocity showed a similar trend with the mid-order sites having generally faster flows than the low-order or tributary sites.

It was more difficult to compare the Substrate Index (SI) calculated for each site between the 2008 and 2013 sampling periods. Although the SI values appear to have been calculated from the same equation (as modified from Jowett and Richardson (1990) and as reported in the data analyses section of the respective reports), the SI values for all 10 sites presented by EOS Ecology (2009) were below 1. In theory, the minimum SI value for any given site for both EOS Ecology's (2009) study and this study should have been 1. However, the SI values for the 10 sites as reported by EOS Ecology (2009) ranged from 0.26 – 0.41, while the SIs from this study ranged from 1.4 to 3.1 for the 10 sites.[6]

Nevertheless, EOS Ecology (2009) reported that there was a trend for slightly larger substrate size in the mainstem (mid-order) sites, when compared to the generally finer substrates found in the tributary (low-order) sites. This was consistent with the findings of this study, where low-order sites had significantly finer substrates (lower SI values), than mid-order sites ($F_{1, 85} = 6.60$; $P = 0.012$) (Figure 4).

[6] Communications with EOS Ecology in October 2015, after the final version of this report had been issued to the CCC, revealed that EOS Ecology had reported Substrate Index values (which can be less than one) rather than Substrate Index scores (which must have a minimum value of one) as was initially assumed. Nevertheless, the general comparisons and conclusions made in this Boffa Miskell report, comparing changes in substrate size over time, are correct.

Macroinvertebrate Community

Overview

A total of 16,331 macroinvertebrates, belonging to 35 taxonomic groups, was collected from the 29 sites surveyed within the Avon River catchment. The most diverse group was the caddisflies (Trichoptera), with ten different caddisfly taxa being recorded in the Avon River catchment. The true flies (or two-winged flies; Diptera) were the next most diverse group (9 taxa), followed by freshwater snails and bivalves (Mollusca: 5 taxa), crustaceans (Crustacea: 5 taxa), aquatic beetles (Coleoptera, 1 taxon), and aquatic worms (Oligochaeta: 1 taxon), polychaetes (Polychaeta: 1 taxon), leeches (Hirudinea: 1 taxon), springtails (Collembola: 1 taxon), and flatworms (Platyhelminthes: 1 taxon).

However, caddisflies did not numerically dominate the macroinvertebrate community, making up just 4% of all macroinvertebrates found in the entire Avon River catchment. Instead, the macroinvertebrate community of the Avon River catchment was dominated by molluscs (e.g. the ubiquitous native mud snail *Potamopyrgus antipodarium*, and the tiny freshwater clam *Sphaerium*; 40% of the community) and crustaceans (e.g. seed shrimp ostracods and the freshwater amphipod *Paracalliope fluviatilis*; 31%) together making up 71% of the macroinvertebrates found. True flies (e.g. chironomid midge larvae) contributed another 17% to the community. The remainder of the macroinvertebrates collected were oligochaete worms, flatworms, leeches, a single polychaete worm and a single beetle larva.

Oligochaete worms and chironomid midge larvae (family Orthocladiinae) were recorded at all of the 29 sites, while the seed shrimp ostracods (Crustacea: Ostracoda) and the ubiquitous native mud snail, *Potamopyrgus antipodarium*, was found at 28 of the 29 sites surveyed. The freshwater amphipod *Paracalliope fluviatilis*, the freshwater clam *Sphaerium*, the introduced snail *Physa* were also commonly encountered, being found at 24, 23, and 22 of the 29 sites, respectively. There were numerous rare taxa, which were only found at one or a few of the 29 sites, including the single polychaete worm and many of the dipteran (true fly) taxa.

Although a total of 10 caddisfly taxa were found in the Avon River catchment, many of these taxa were encountered at a limited number of sites (i.e. ≤55% of sites). For example, *Triplectides* was encountered at just one site, *Oecetis* and *Paroxyethira* were found at 2 and 3 of the 29 sites, respectively. The stony-cased caddis, *Pycnocentria* and *Pycnocentrodes* were more commonly encountered, but still only at 5 and 10 (out of 29) sites. The algal-piercing caddis *Oxyethira* and the cased-caddis *Hudsonema* (which usually builds its case from plant material) were the most commonly encountered of all the caddisfly taxa found, occurring at 52% (15) and 55% (16) of sites.

Biotic Indices

There was some variation among sites in many of the biotic indices calculated. For example, total abundance (i.e. the total number of macroinvertebrates collected in the kick-net sample from each site) varied among sites, ranging from 36 to 1,277 individuals collected at each site (Figure 7). However, there was no difference in average abundance between low- and mid-order sites (ANOVA: $F_{1, 27} = 0.75$; $P = 0.395$). Sites 1 (Avon River at Corfe Reserve) and 3 (Wairarapa Stream at Jellie Park) had the greatest total abundances of all the sites, with 1,227 and 1,110 individuals collected, respectively. This was due to high abundances of *Paracalliope fluviatilis*, *Potamopyrgus antipodarium* and orthoclad (chironomid midge) larvae. Site 17 (St Albans Creek downstream of Slater Street) had the lowest total abundance, with just 35 macroinvertebrates collected in the kick-net sample.

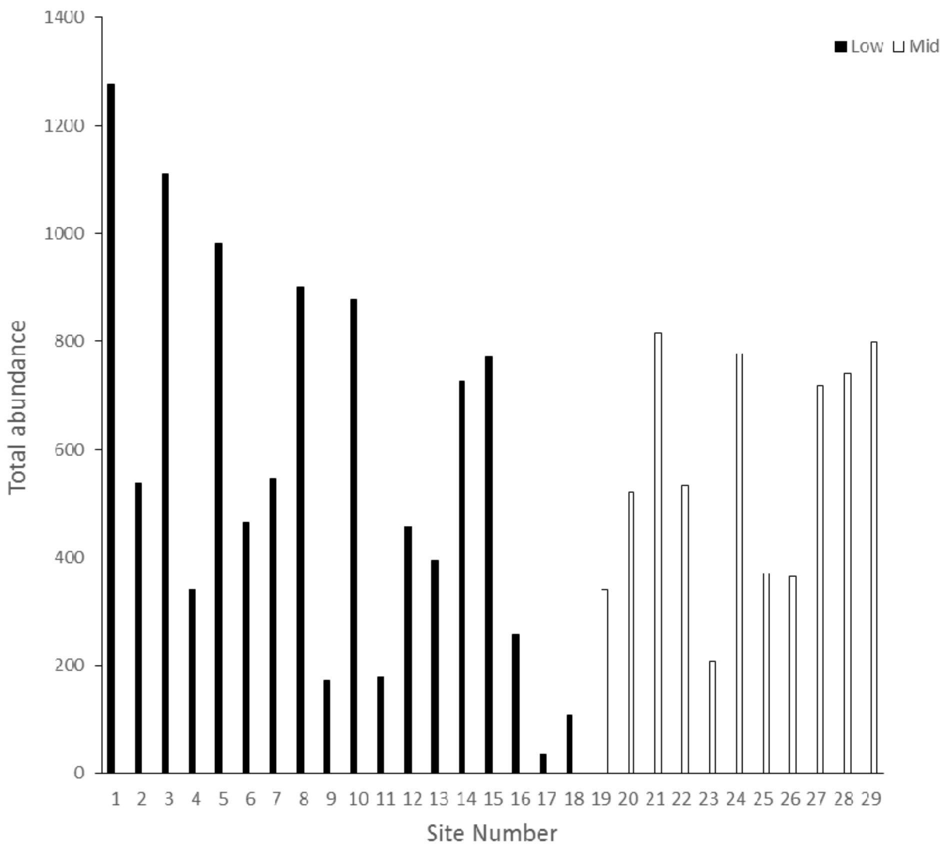


Figure 7. Total abundance of macroinvertebrates collected in a kick-net sample collected from each of the 29 sites surveyed. The 29 sites were categorised as low- (black) or mid-order (white) waterways according to the REC.

Taxonomic richness was less variable among sites, but still ranged between 5 and 17 macroinvertebrate taxa collected at each site. More than 79% of sites surveyed had a richness value of 10 or more, while at three sites richness was very low with only 5 or 6 taxa collected (Figure 8). Taxon richness was greater in the mid-, than low-order sites (average richness of 13.8 and 10.7, respectively) (ANOVA: $F_{1, 85} = 6.58$; $P = 0.016$) (i.e. sites within the larger waterways – the main stem of the Avon River and the downstream reaches of Wairarapa Stream – had greater taxonomic richness than the small, low-order tributaries and headwater sites of the Avon River). Sites 7 (Avon River downstream of Clyde Road), 22 (Waimairi downstream of railway bridge), 29 (Avon River near Kilmore Street) and 27 (Avon River near Durham Street) had the greatest taxonomic richness (16 & 17 taxa). Sites 11 (St Albans Creek at Abberley Park), 12 (Addington Brook upstream of Avon confluence), and 17 (St Albans Creek downstream of Slater Street) had the lowest taxonomic richness, with just 5-6 different macroinvertebrate taxa recorded (Figure 8).

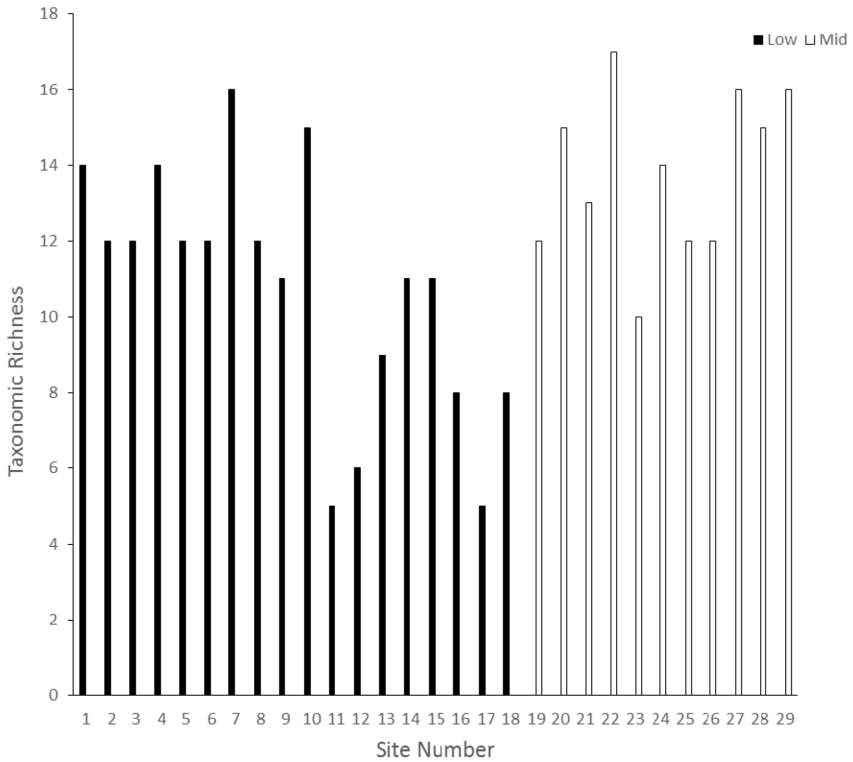


Figure 8. Taxonomic richness of macroinvertebrates collected in a kick-net sample collected from each of the 29 sites surveyed. The 29 sites were categorised as low- (black) or mid-order (white) waterways according to the REC.

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 richness was variable among sites, ranging from 0 to 7 (Figure 9). Mid-order sites (e.g. the main stem of the Avon River) had significantly higher EPT richness (average 3.5 EPT taxa), than low-order sites (e.g. tributary sites) (average 2.0 EPT taxa) (ANOVA: $F_{1,\,27} = 4.47$; $P = 0.044$). Caddisflies were the only group of the clean-water 'EPT taxa' present in the Avon River catchment; mayflies and stoneflies were absent from all sites. Sites 7 (Avon River downstream of Clyde Road), 22 (Waimairi Stream downstream of railway bridge), and 26 (Avon River in Hagley Park) had the greatest EPT diversity with 7, 6, and 6 EPT taxa, respectively. The EPT fauna at Sites 2, 4, and 13 consisted only of the generally pollution-tolerant *Oxyethira albiceps*. No caddisflies were found in Sites 11 (St Albans Creek at Abberley Park), 12 (Addington Brook upstream of Avon confluence), 17 (St Albans Creek downstream of Slater Street), and 18 (Dudley Creek at North Parade).

When the pollution-tolerant hydroptilids (e.g. *Oxyethira* and *Paroxyethira*) were excluded from EPT richness calculations (i.e. to only include the relatively pollution-intolerant or clean-water caddisfly taxa), a similar trend was seen (Figure 9). EPT richness, after excluding hydroptilid caddisflies, was variable among sites, with more EPT taxa found in the mid-order than low-order sites (average EPT, except hydroptilids: 3 and 1, respectively) (ANOVA: $F_{1,\,27} = 5.99$; $P = 0.021$). Sites 7 (Avon River downstream of Clyde Road), 22 (Waimairi Stream downstream of railway bridge), and 26 (Avon River in Hagley Park) still had the greatest EPT diversity even when hydroptilid caddisflies were excluded. When the pollution-tolerant hydroptilids were excluded from the calculations, ten of the 29 sites (Sites 2, 4, 11, 12, 13, 15, 16, 17, 18, 23) scored zero (i.e. hydroptilids were the only caddisflies found at these sites).

Caddisfly taxa made up only a small proportion of the macroinvertebrate richness at each site, with %EPT richness ranging from 0 – 50% (Figure 9). Although mid-order sites had slightly greater %EPT richness (25.6%) than low-order sites (16.6%), this difference was not statistically significant ($F_{1,\,27} = 3.21$; $P = 0.084$).

MCI and QMCI scores were less variable among sites, than many of the other biotic indices (Figure 10). There were no differences in average MCI and QMCI scores at low- and mid-order sites (ANOVA: $F_{1,\,27} = 2.31$; $P = 0.141$ and $F_{1,\,27} = 3.32$; $P = 0.08$, respectively). Moreover, the MCI and QMCI scores indicated that 20 to 21 of the 29 sites had poor stream health (based on the water quality categories of Stark and Maxted, 2007), with probable severe enrichment (Figure 10). The remainder of the sites had fair stream health, with probable moderate enrichment, while one site (Site 6: Okeover Stream at Canterbury University) was on the cusp between fair and good stream health (QMCI value of 5.1) (Figure 10).

QMCI scores for Ilam Stream (Site 2), Wairarapa Stream at Jellie Park and upstream of Glandovey Road (Sites 3 and 20), Papanui Stream (Site 9), both Dudley Creek sites (Sites 10 and 18), both St Albans Creek sites (Sites 11 and 17), Addington Brook (Site 12), Riccarton Stream (Site 13), Shirley Stream (Site 16), Waimairi Stream at Fendalton Park (Site 19), and the Avon River near Durham Street and at Kilmore Street (Sites 27 and 29) all fell below the pLWRP's minimum QCMI guideline of 3.5 for spring-fed (plains) urban waterways (Figure 10).

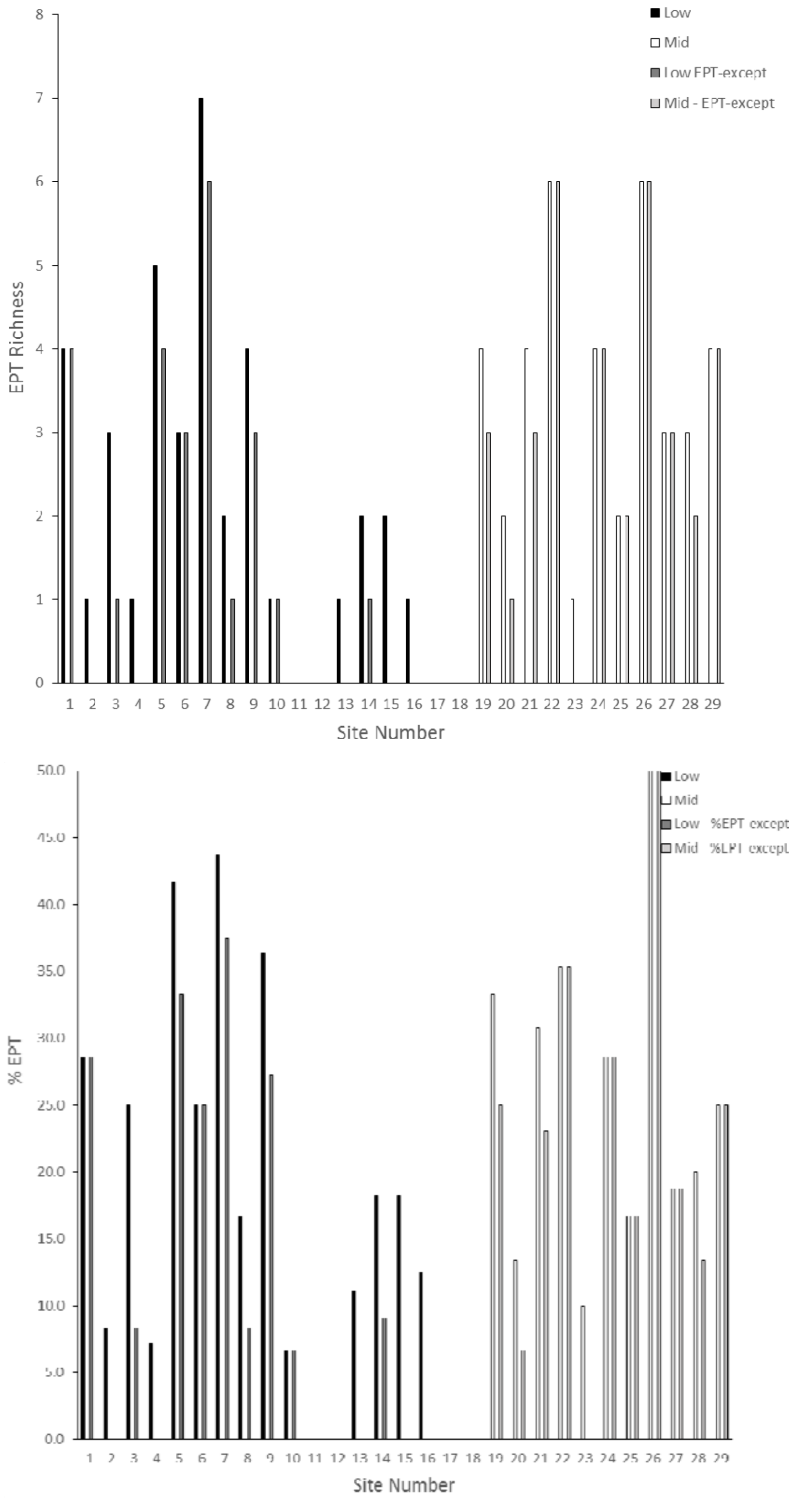


Figure 9. EPT (Ephemeroptera, mayfly; Plecoptera, stonefly; and Trichoptera, caddisfly) richness and EPT-except Hydroptilidae richness (top) and percent EPT (Ephemeroptera, mayfly; Plecoptera, stonefly; and Trichoptera, caddisfly) richness and %EPT-except Hydroptilidae richness (bottom) at each of the 29 sites surveyed. The 29 sites were categorised as low- (black) or mid-order (white) waterways according to the REC.

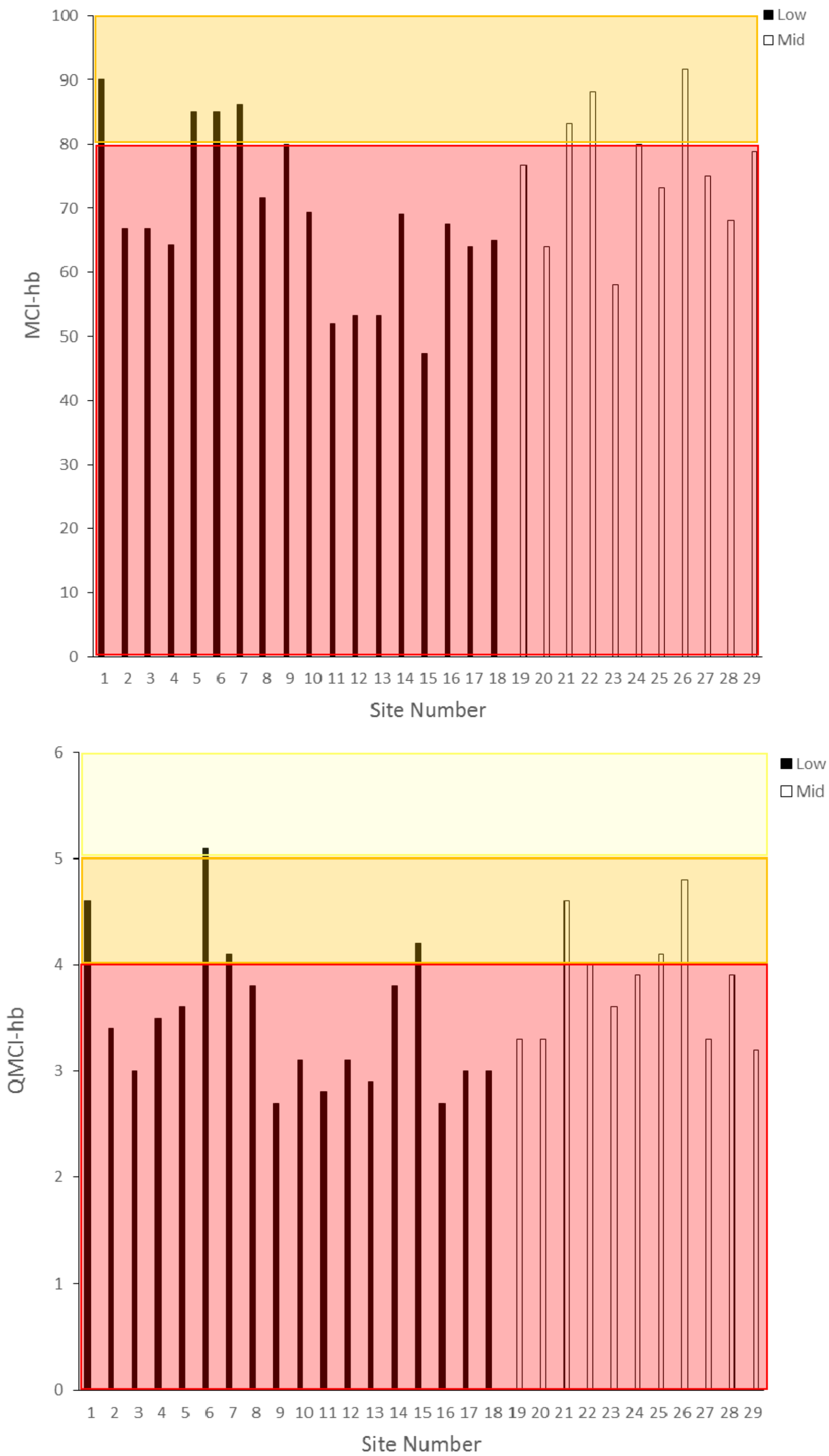


Figure 10. MCI-hb (Macroinvertebrate Community Index for hard-bottomed streams) scores (top) and QMCI-hb scores (bottom) for the 29 sites surveyed in October and November 2013. Sites within the red area fall within the 'poor' or 'probable severe enrichment' water quality category, within the orange area fall within the 'fair' or 'probable moderate enrichment' water quality category, and within the yellow area fall within 'good' or 'doubtful quality or possible mild enrichment' water quality category of Stark and Maxted (2007). The 29 sites were categorised as low- (black) or mid-order (white) waterways according to the REC.

When the biotic indices taxonomic richness, EPT richness, %EPT richness, MCI, and QMCI scores were ranked, from 1 (best) to 29 (worst) for each of the 29 sites, Site 7 (Avon River downstream of Clyde Road) was ranked as the best site overall (i.e. ranked first place across all of the sites). This site had the second greatest taxonomic richness, greatest EPT richness and scored 4th & 6th, respectively, in the MCI and QMCI values (Table 3).

Sites 1 (Avon River at Corfe Reserve), 21 (Avon River above confluence with Wairarapa), 22 (Waimairi Stream downstream of railway bridge), and 26 (Avon River in Hagley Park) were all within the top 5 sites surveyed (Table 3).

Site 11 (St Albans Creek at Abberley Park) was ranked as the worst site, while Sites 12 (Addington Brook upstream of Avon confluence), 13 (Riccarton Stream downstream of Deans Ave), 17 (St Albans Creek downstream Slater Street) and 18 (Dudley Creek at North Parade) were within the bottom 5 sites surveyed (Table 3).

Table 3. Taxonomic richness, EPT richness, %EPT richness, MCI, and QMCI values have been ranked, from 1 (best) to 29 (worst), for each of the 29 sites. These ranks were then summed to give a final rank, indicating the site that scored best out of these five biotic indices. Individual scores for the biotic indices at each site are given in parentheses.

Site	Site names	Taxonomic richness	EPT richness	%EPT richness	MCI	QMCI	Sum of ranks	Final rank
7	Avon River downstream of Clyde Road	2= (16)	1 (7)	2 (44)	4 (86.2)	6= (4.1)	15	1
26	Avon River in Hagley Park	12= (12)	2= (6)	1 (50)	1 (91.7)	2 (4.8)	18	2
22	Waimairi Stream downstream of railway bridge	1 (17)	2= (6)	5 (35)	3 (88.2)	8 (4.0)	19	3
1	Avon River at Corfe Reserve	8= (14)	5= (4)	8= (29)	2 (90.0)	3= (4.6)	26	4
21	Avon River above confluence with Wairarapa	11 (13)	5= (4)	7 (31)	7 (83.1)	3= (4.6)	33	5
5	Waimairi Stream at Barlow Street	12= (12)	4 (5)	3 (42)	5= (85.0)	13= (3.6)	37	6
24	Avon River downstream of Mona Vale weir	8= (14)	5= (4)	8= (29)	8= (80.0)	9= (3.9)	38	7
6	Okeover Stream at Canterbury University	12= (12)	11= (3)	10= (25)	5= (85.0)	1 (5.1)	39	8
29	Avon River near Kilmore Street	2= (16)	5= (4)	10= (25)	10 (78.8)	20 (3.2)	47	9
19	Waimairi Stream at Fendalton Park	12= (12)	5= (4)	6 (33)	11 (76.7)	17= (3.3)	51	10
28	Avon River at Victoria Park	5= (15)	11= (3)	13 (20)	17 (68.0)	9= (3.9)	55	11
27	Avon River near Durham Street	2= (16)	11= (3)	14 (19)	12 (75.0)	17= (3.3)	56	12
25	Avon River at Carlton Mill Corner	12= (12)	15= (2)	17= (17)	13 (73.3)	6= (4.1)	63	13
9	Papanui Stream at Erica Reserve	20= (11)	5= (4)	4 (36)	8= (80.0)	28= (2.7)	65	14
8	Taylors Drain at Heaton Street	12= (12)	15= (2)	17= (17)	14 (71.7)	11= (3.8)	69	15
3	Wairarapa Stream at Jellie Park	12= (12)	11= (3)	10= (25)	19= (66.7)	23= (3.0)	75	16
14	No. 2 Drain at Christchurch Golf Club	20= (11)	15= (2)	15= (18)	16 (69.1)	11= (3.8)	77	17
20	Wairarapa Stream upstream of Glandovey Road	5= (15)	15= (2)	19 (13)	23= (64.0)	17= (3.3)	79	18
15	Corsers Stream at Brooker Reserve	20= (11)	15= (2)	15= (18)	29 (47.3)	5 (4.2)	84	19
10	Dudley Creek downstream Jamesome Ave	5= (15)	20= (1)	25 (7)	15 (69.3)	21= (3.1)	86	20
4	Wai-iti Stream at Clyde Road	8= (14)	20= (1)	24 (7)	22 (64.3)	15 (3.5)	89	21
2	Ilam Stream at Waimairi Road	12= (12)	20= (1)	23 (8)	19= (66.7)	16 (3.4)	90	22
23	Wairarapa Stream downstream Fendalton Road	23 (10)	20= (1)	22 (10)	25 (58.0)	13= (3.6)	103	23
16	Shirley Stream Stapletons Road	25= (8)	20= (1)	20 (13)	18 (67.5)	28= (2.7)	111	24
13	Riccarton Stream downstream Deans Ave	24 (9)	20= (1)	21 (11)	26= (53.3)	26 (2.9)	117	25
18	Dudley Creek at North Parade	25= (8)	26= (0)	26= (0)	21 (65.0)	23= (3.0)	121	26
17	St Albans Creek downstream Slater Street	28= (5)	26= (0)	26= (0)	23= (64.0)	23= (3.0)	126	27=
12	Addington Brook upstream of Avon confluence	27 (6)	26= (0)	26= (0)	26= (53.3)	21= (3.1)	126	27=
11	St Albans Creek at Abberley Park	28= (5)	26= (0)	26= (0)	28 (52.0)	27 (2.8)	135	29

Community-level Assessments

Macroinvertebrate community composition was variable among the 29 sites, however, the majority of sites were dominated by molluscs, crustaceans, and / or oligochaete worms, while caddisflies contributed relatively little to the community except for at Sites 6 (Okeover Stream at Canterbury University) and 26 (Avon River in Hagley Park) (Figure 11).

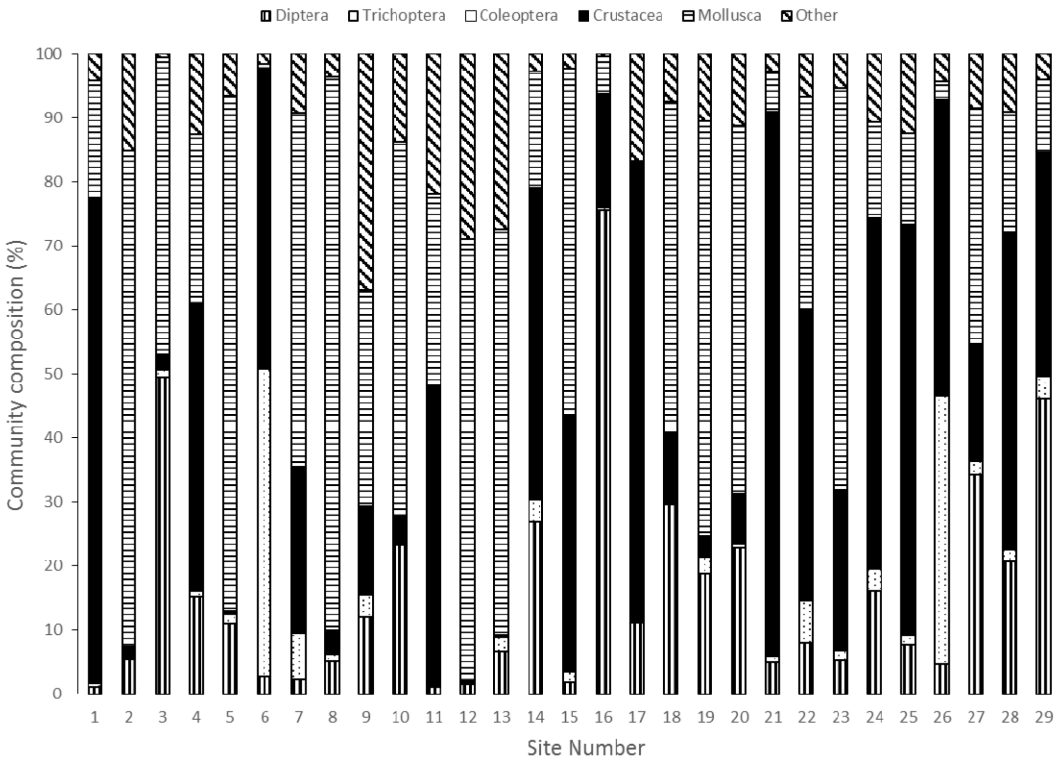


Figure 11. Macroinvertebrate community composition (%) at the 29 sites surveyed in October and November 2013. ‘Other’ includes oligochaete worms, leeches (Hirudinea), polychaete worms, springtails (Collembola), and flatworms (Platyhelminthes).

The NMDS ordination further indicated that the macroinvertebrate community composition was variable among sites. As shown by the NMDS ordination (Figure 12), and the ANOSIM results, there was no significant difference in the community composition found in low- and mid-order waterways (i.e. ANOSIM: R = -0.026[6]; P = 0.590). However, there were subtle differences in the macroinvertebrate community composition among the 15 waterways surveyed (i.e. ANOSIM: R = 0.417; P = 0.04) (Figure 12).

SIMPER indicated that these significant (albeit statistically weak) differences were largely due to the macroinvertebrate communities from sites within the Avon River being more similar to each other, than to those communities from other waterways. These differences were generally due to variation in the abundances of taxa among sites. For example, the freshwater amphipod *Paracalliope* was relatively abundant in the Avon River sites, but not as abundant in other waterways. The native mud snail *Potamopyrgus* was generally more abundant in Wairarapa, Waimairi and Ilam Streams, and less common in the Avon River sites, and Wai-iti and Okeover

[6] A negative *R* value indicates that dissimilarities within groups (i.e. within low- or mid-order waterways) are greater than between groups (Quinn and Keough 2002).

Streams. Some of the dissimilarity among waterways was also due to the absence of the caddisfly taxa, *Pycnocentrodes* and *Pycnocentria* in Wai-iti and Ilam Streams. *Pycnocentrodes* was also relatively abundant in Okeover Stream compared to the other waterways sampled.

See Appendix 4 for full SIMPER results.

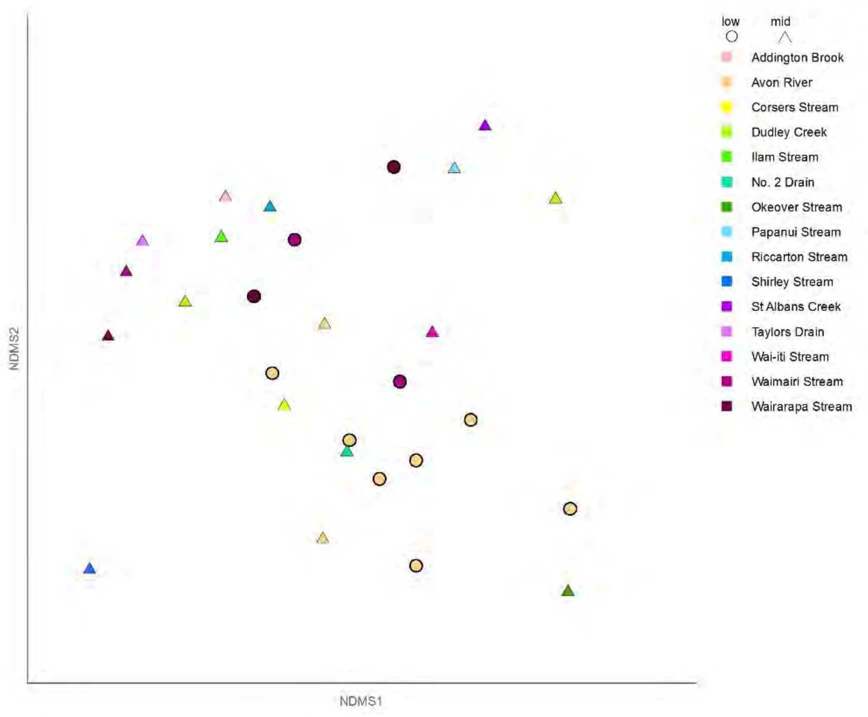


Figure 12. Non-metric multidimensional scaling (NMDS) ordination based on a Bray-Curtis matrix of dissimilarities calculated from macroinvertebrate abundance data collected in a kick net at each of 29 sites along the Avon River catchment. The NMDS ordination has been graphically shown where sites are categorised as low- or mid-order waterways (circles and triangles, respectively) according to the River Environment Classification (REC), while different colours show the different waterways surveyed. Note, the NMDS gave a good representation of the actual community dissimilarities between low- and mid-order waterways (two-dimensional stress = 0.16). Axes are identically scaled so that the sites closest together are more similar in macroinvertebrate community composition than those further apart.

Comparisons over Time

There was some variation in taxonomic richness, EPT richness, %EPT richness, and MCI and QMCI scores calculated for the 10 sites in 2008 and 2013 (Table 4). There was a general decrease in the total taxonomic richness from 2008 to 2013, however, this is likely to be due to differences in the level to which macroinvertebrates were identified, rather than marked changes in taxon richness at sites over time. EPT richness and EPT% richness also varied at sites between 2008 and 2013, however, there was no apparent overall trend of an increase or decrease from 2008 to 2013. MCI and QMCI scores showed slight changes in 'stream health' based on the macroinvertebrate community detected at a site in 2008 and 2013, with some sites apparently improving over time, while ecological condition appeared to decrease from 2008 to 2013 at other sites (Table 4). Stream health appeared to change the most from 2008 to 2013 in Papanui Stream and Avon River at Hagley Park, with macroinvertebrate communities indicating an increase from 'poor' to 'fair' condition.

Table 4. Comparison of five macroinvertebrate biotic indices (taxonomic richness, EPT richness, %EPT richness, and MCI and QMCI scores) calculated for the 10 sites in 2008 (EOS Ecology 2009) and 2013 (this study). ^{P} indicates a MCI or QMCI score within the 'Poor' water-quality category of Stark & Maxted (2007), while ^{F} indicates 'Fair', and ^{G} indicates 'Good'. Letters in bold, red font indicate sites that have changed water-quality categories between the 2008 and 2013 sampling occasions. Red arrows indicate the direction of change.

Site	Taxon richness		EPT		%EPT		MCI		QMCI	
	2008	2013	2008	2013	2008	2013	2008	2013	2008	2013
Okeover Stream at Canterbury University	20.0	12.0	8.0	3.0	40.0	25.0	88.4^{F}	85.0^{F}	4.5$^{\mathbf{F}}$	5.1$^{\mathbf{G}}$ ↑
Avon River downstream of Clyde Road	16.3	16.0	4.3	7.0	26.3	43.8	74.8$^{\mathbf{P}}$	86.2$^{\mathbf{F}}$ ↑	3.9$^{\mathbf{P}}$	4.1$^{\mathbf{F}}$ ↑
Papanui Stream at Erica Reserve	11.0	11.0	3.0	4.0	27.3	36.4	64.4$^{\mathbf{P}}$	80.0$^{\mathbf{F}}$ ↑	2.6^{P}	2.7^{P}
Waimairi Stream at Fendalton Park	20.3	12.0	5.0	4.0	24.6	33.3	80.7$^{\mathbf{F}}$	76.7$^{\mathbf{P}}$ ↓	3.1^{P}	3.3^{P}
Wairarapa Stream upstream of Glandovey Road	19.7	15.0	4.3	2.0	21.8	13.3	74.7^{P}	64.0^{P}	4.0$^{\mathbf{F}}$	3.3$^{\mathbf{P}}$ ↓
Avon River downstream of Mona Vale weir	16.3	14.0	5.7	4.0	34.9	28.6	75.0$^{\mathbf{P}}$	80.0$^{\mathbf{F}}$ ↑	4.5$^{\mathbf{F}}$	3.9$^{\mathbf{P}}$ ↓
Avon River in Hagley Park	23.0	12.0	7.3	6.0	31.7	50.0	76.0$^{\mathbf{P}}$	91.7$^{\mathbf{F}}$ ↑	4.0^{F}	4.8^{F}
Avon River near Durham Street	22.0	16.0	7.7	3.0	35.0	18.8	72.1^{P}	75.0^{P}	3.7^{P}	3.3^{P}
Avon River at Victoria Square	14.3	15.0	3.3	3.0	23.1	20.0	62.3^{P}	68.0^{P}	4.1$^{\mathbf{F}}$	3.9$^{\mathbf{P}}$ ↓
Avon River near Kilmore Street	13.7	16.0	3.3	4.0	24.1	25.0	70.8^{P}	78.8^{P}	4.4$^{\mathbf{F}}$	3.2$^{\mathbf{P}}$ ↓

However, the NMDS ordination, and the ANOSIM results, showed that there were only slight, albeit statistically significant, differences in the macroinvertebrate community composition found at the 10 sites between 2008 and 2013 (ANOSIM: $R = 0.45$; $P = 0.001$) (Figure 13).

SIMPER indicated that these significant, but subtle differences were largely due to the presence of some taxa in 2008 but not in 2013 (e.g. aquatic mites (Acarina), nematode worms, and the caddisfly *Triplectides*). Differences in community composition between sampling years were also driven by differences in the average number of occurrences of some species, rather than the absence of particular taxa from one sampling occasion. For example, empidid fly larvae were more commonly encountered in 2008 than in 2013, as were the chironomid midge larvae Tanytarsini.

See Appendix 5 for full SIMPER results.

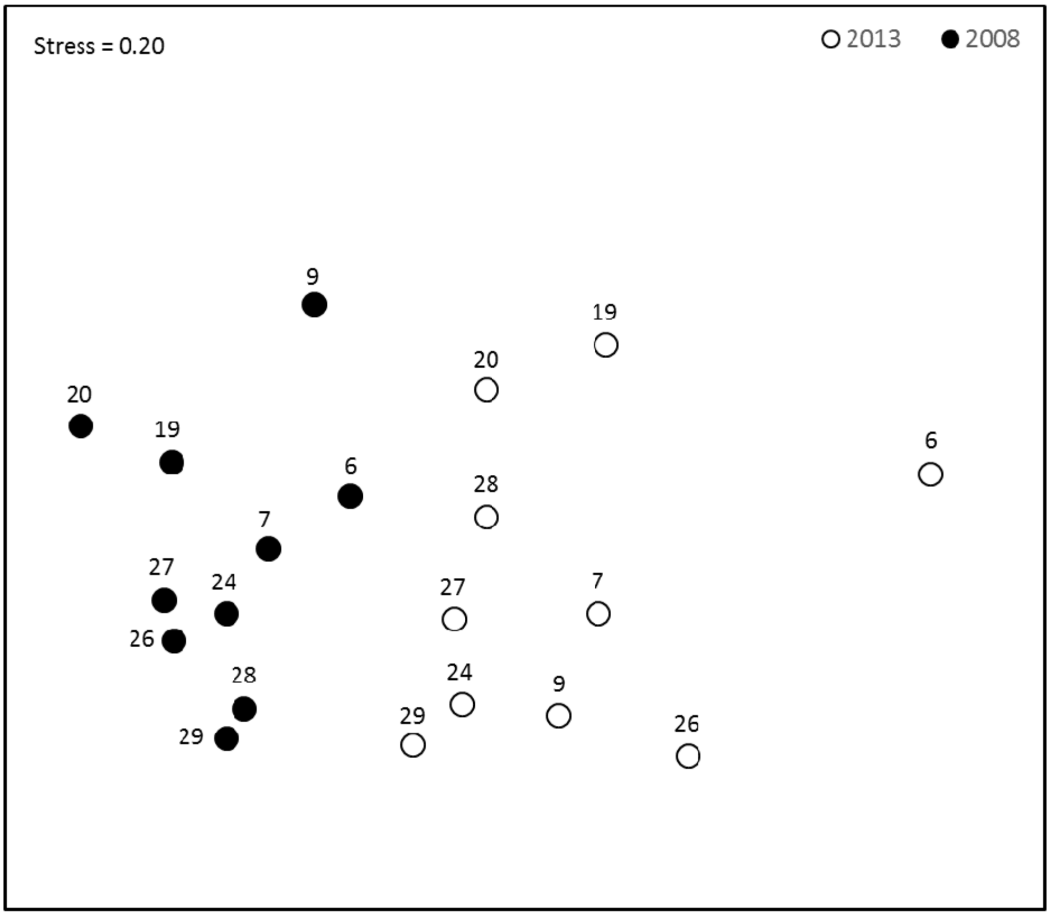


Figure 13. Non-metric multidimensional scaling (NMDS) ordination based on a Bray-Curtis matrix of dissimilarities calculated from macroinvertebrate presence data collected in kick-net samples at each of 10 sites in the Avon River catchment in 2008 (black circles) and 2013 (white circles). Note, the NMDS gave a good representation of the actual community dissimilarities between low- and mid-order waterways (two-dimensional stress = 0.18). Axes are identically scaled so that the sites closest together are more similar in macroinvertebrate community composition than those further apart.

Fish Community

A total of 705 fish, belonging to seven species, were captured in the 29 sites of the Avon River catchment. The seven species were, in descending order of total abundance (i.e. across all sites): common bully (*Gobiomorphus cotidianus*), brown trout (*Salmo trutta*), shortfin eel (*Anguilla australis*), longfin eel (*A. dieffenbachii*), upland bully (*G. breviceps*), bluegill bully (*G. hubbsi*), and inanga (*Galaxias maculatus*). Longfin eel, bluegill bully, and inanga are all listed as "declining", while common bullies, upland bullies, and shortfin eels are currently listed as 'not threatened' (Allibone et al. 2010). Brown trout is an introduced species.

Species richness was variable among sites with, on average, slightly more species captured in mid-, than low-order waterways (ANOVA: $F_{1, 27}$ = 644.9; P = 0.001). Six fish species (the maximum found at any site) were found at five of the sites (Sites 7, Avon River downstream Clyde Road; 24, Avon River downstream of Mona Vale weir; 29, Avon River near Kilmore Street; 27, Avon River near Durham Street; and 28, Avon River at Victoria Square) (Figure 14). No fish were captured at Sites 2 (Ilam Stream at Waimairi Road), 12 (Addington Brook upstream of Avon Confluence), and 16 (Shirley Stream Stapletons Road). A dead shortfin eel was seen at Site 2 on the day of sampling.

Shortfin eel was the most commonly encountered species, being captured at 76% of sites. Common bullies were found at 69% of sites, longfin eel at 65% of sites, while brown trout and upland bully were captured from around half of the sites (55% and 48%, respectively). Bluegill bullies and inanga were only found at 17% and 10% of the sites surveyed.

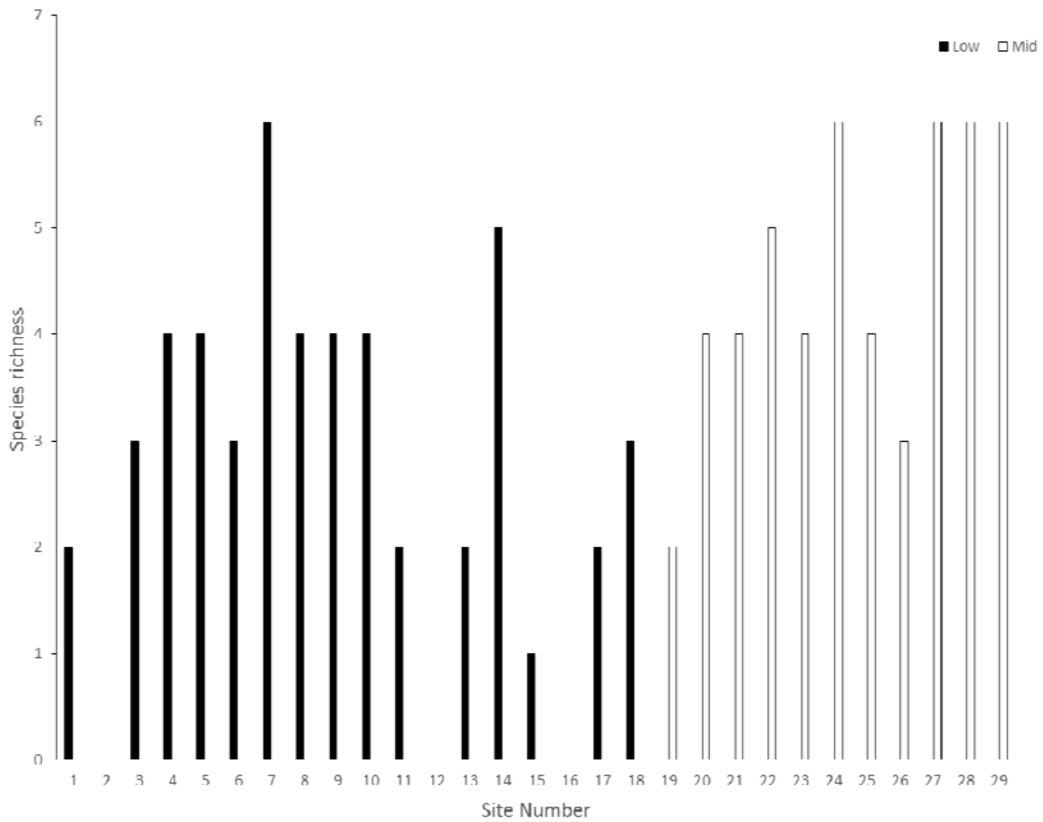


Figure 14. Species richness of fish captured during electro-fishing of 29 sites along the Avon River catchment. The 29 sites were categorised as low- (black) or mid-order (white) waterways according to the REC.

The total number of fish captured (expressed as number per 100 m^2) varied across the sites, ranging from 0 – 37.7 fish / 100 m^2. No fish were found in Ilam Stream at Waimairi Road (Site 2), Addington Brook upstream of Avon confluence (Site 12), or Shirley Stream Stapletons Road (Site 16). Wai-iti Stream at Clyde Road (Site 4), Dudley Creek downstream Jameson Ave (Site 10) and Taylors Drain at Heaton Street (Site 8) had the greatest fish densities. Figure 15 shows these fish catches categorised by the different species found at each site.

There was no significant difference in the number of fish found per 100 m^2 in low- versus mid-order waterways (ANOVA: $F_{1, 27} = 0.314$; $P = 0.580$).

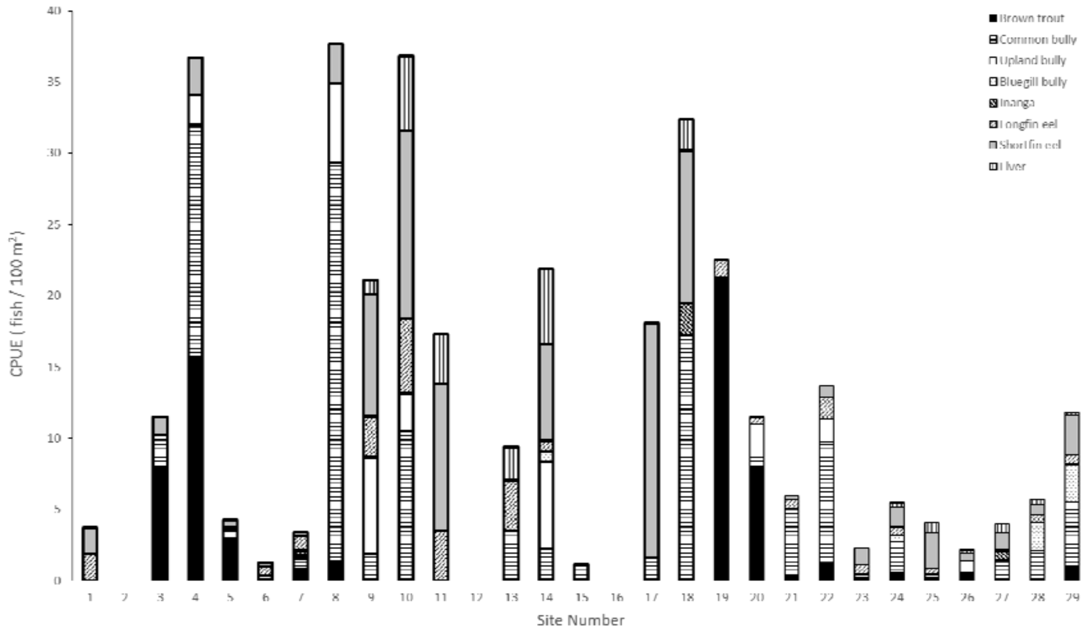


Figure 15. Fish abundance, expressed as number of fish captured per 100 m2 of area fished at each of 29 sites along the Avon River catchment in November 2013.

The relative abundances of fish species found at each of the sites also varied within the Avon River catchment (Figure 16). For example, only two fish species, shortfin and longfin eels, were found at Site 1 (Avon River at Corfe Reserve), and these species each made up 50% of the community at this site. Shortfin eel dominated the catch at some sites (e.g. Site 11, 17, and 27), as did common bullies (Sites 8, 15, 21, and 22). Although upland bully were found at over half of the sites surveyed, they never dominated the community (the greatest relative abundance of upland bully was at Site 26 in the Avon River at Hagley Park) (Figure 16).

Of the three species of greatest conservation interest (i.e. those with ‘declining’ status), bluegill bullies were only found at 5 of the 29 sites, and generally contributed only a small proportion to the fish catch at these sites. Bluegill bullies were found in the mainstem of the Avon River (downstream of the Mona Vale weir – Site 24; near Kilmore Street – Site 29; near Durham Street – Site 27; and at Victoria Square – Site 28) and in No. 2 Drain at the Christchurch Golf Club (Site 14). Inanga was also found at very few sites (3 in total), and never dominated the community (only contributing between 6.6 and 12.9%). Longfin eels only made up a substantial proportion of the community (i.e. >30%) at four of the 19 sites were they were found (i.e. Sites 1, 6, 13, and 23) (Figure 16).

The introduced brown trout made up a large portion of the fish community surveyed at a number of sites, including Sites 3 (Wairarapa Stream at Jellie Park), 4 (Wai-iti Stream at Clyde Road), 5 (Waimairi Stream at Barlow Street), 19 (Waimairi Stream at Fendalton Park), and 20 (Wairarapa Stream upstream of Glandovey Road) (Figure 16).

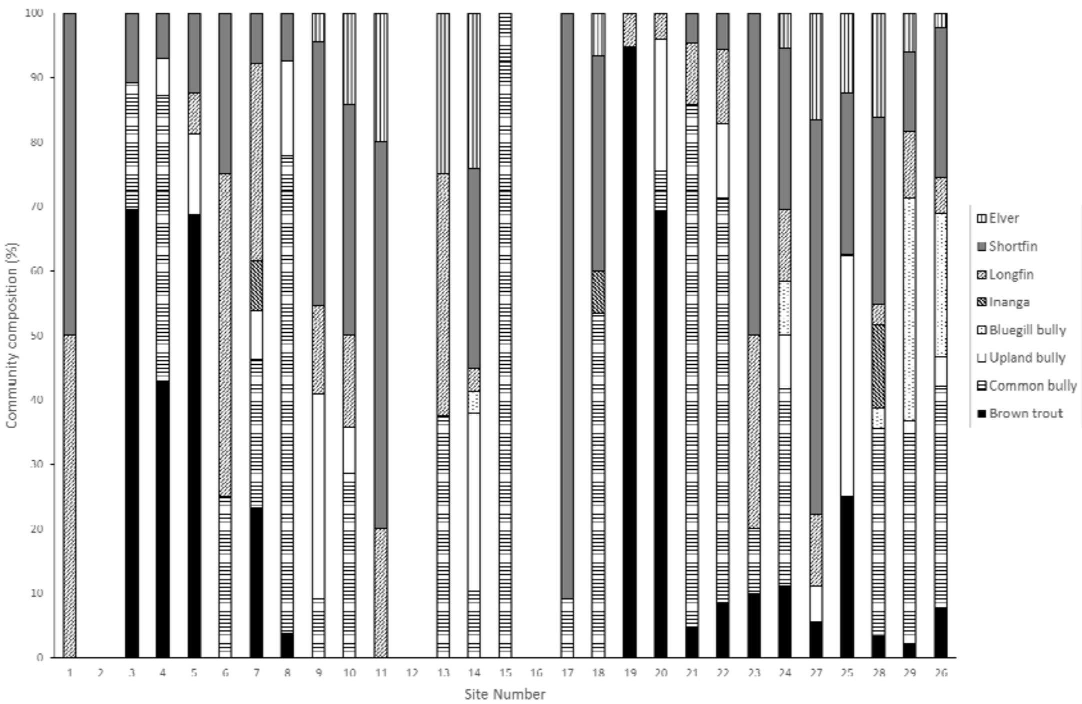


Figure 16. Community composition (%) of fish captured at the 29 sites surveyed using electro-fishing techniques in November 2013.

Table 5 summarises the size information on fish captured at the 29 sites. The largest shortfin eel captured at any site was 700 mm (Site 23, Wairarapa Stream downstream Fendalton Road), while a 1100 mm longfin eel was captured (in a fyke net) at this same site. The majority of the 'unidentified eels' were elvers (i.e. <180 mm), which are often more difficult to identify. However, a few eels were not captured, but were recorded and lengths estimated. These were included in as 'unidentified eels'.

Although trout made up a substantial proportion (>60%) of the fish community at Sites 3 (Wairarapa Stream at Jellie Park), 4 (Wai-iti Stream at Clyde Road), 5 (Waimairi Stream at Barlow Street), 19 (Waimairi Stream at Fendalton Park), and 20 (Wairarapa Stream upstream of Glandovey Road), the majority of trout were very small juvenile fish (average sizes of 64, 44, 40, and 52, respectively).

Table 5. Average length (mm) of fish (with ranges in parentheses) found at each site in November 2013.

Site	Shortfin eel	Longfin eel	Unidentified eel	Common bully	Upland bully	Bluegill bully	Inanga	Brown trout
1	377 (220-490)	537 (410-640)	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-
3	408 (300-580)	-	-	49 (38-65)	-	-	-	64 (33-320)
4	302 (250-400)	-	-	48 (25-70)	64 (45-72)	-	-	44 (28-60)
5	420 (280-560)	290 (290-290)	-	-	65 (60-70)	-	-	39 (30-45)
6	280 (280-280)	300 (300-300)	-	72 (72-72)	-	-	-	-
7	480 (480-480)	565 (260-800)	-	41 (35-45)	50 (-)	-	65 (-)	220 (40-420)
8	320 (300-340)	-	-	51 (40-72)	63 (51-72)	-	-	50 (-)
9	266 (140-480)	663 (330-900)	90 (-)	45 (44-45)	63 (45-85)	-	-	-
10	358 (160-590)	415 (240-590)	105 (90-120)	64 (51-92)	46 (46-46)	-	-	-
11	208 (110-350)	290 (170-510)	70 (60-80)	-	-	-	-	-
12	-	-	-	-	-	-	-	-
13	-	350 (180-520)	200 (150-250)	83 (79-89)	-	-	-	-
14	258 (120-520)	560 (560-560)	96 (80-130)	71 (41-116)	47 (42-57)	42 (-)	-	-
15	-	-	-	74 (65-82)	-	-	-	-
16	-	-	-	-	-	-	-	-
17	265 (140-450)	-	-	85 (85-85)	-	-	-	-
18	308 (170-570)	-	100 (-)	58 (39-104)	-	-	101 (-)	-
19	-	300 (250-350)	-	-	-	-	-	40 (20-60)
20	-	420 (400-440)	-	39 (35-41)	50 (38-58)	-	-	52 (33-270)
21	330 (330-330)	325 (210-440)	-	48 (33-68)	-	-	-	45 (45-45)
22	260 (120-400)	275 (150-420)	-	45 (33-58)	55 (44-70)	-	-	63 (43-75)
23	412 (210-700)	647 (300-1100)	-	66 (66-66)	-	-	-	200 (-)
24	276 (170-450)	290 (130-600)	105 (100-110)	61 (34-93)	54 (49-59)	58 (52-69)	-	45 (42-49)
25	263 (130-420)	380 (310-450)	383 (350-400)	-	66 (66-66)	-	-	300 (-)
26	400 (350-450)	-	500 (-)	-	54 (48-58)	-	-	41 (40-42)
27	156 (120-200)	130 (130-130)	115 (110-120)	70 (40-85)	-	65 (-)	50 (40-55)	45 (-)
28	180 (110-280)	256 (120-670)	150 (120-180)	47 (35-78)	50 (-)	55 (30-65)	-	60 (-)
29	207 (110-390)	262 (130-470)	120 (100-140)	38 (28-75)	38 (30-50)	40 (29-62)	-	44 (30-55)

Re-Survey of Macrophytes in the Avon River

A total of 65 macrophyte species, including 34 native species, was recorded in the 16 sites. A full list of these species found in the upper and lower sites is given in Appendix 6. Fennel-leaved pondweed (*Stuckenia pectinata*[7]), which was only found at one site, A191, was the only species with a conservation status of At Risk - Naturally Uncommon (de Lange et al. 2012). The exotic and invasive macrophyte *Iris pseudacorus* was found at 6 of the 11 non-wadeable sites. Of greatest interest, was the presence of the extremely invasive reed canary grass *Phalaris arundinacea* at one site (A186) in the non-wadeable reaches of the Avon River.

Macrophyte richness varied across the survey sites, with only 4 species found at the wadeable site A133, and 31 species found at the non-wadeable site A184. Although macrophyte richness was greatest at the three upstream-most non-wadeable sites (Sites A184, A185 and A186) (Figure 17), there was no significant difference in the average number of macrophytes found at wadeable and non-wadeable sites ($F = 0.191$; $P = 0.669$) (Figure 17).

The proportion of native species found at each site varied across the 16 survey locations, with %native species ranging from 31% at Site A134A (wadeable) to 100% at Site A193 (non-wadeable) (Figure 18). Native species made up a significantly greater proportion of the macrophyte community at non-wadeable sites, than wadeable sites ($F = 10.05$; $P = 0.007$) (Figure 18). In fact, the macrophyte community of the lower, non-wadeable sites was dominated by native species (Figure 18).

[7] *Stuckenia pectinata* was previously described as *Potamogeton pectinatus* and is referred to as *P. pectinatus* in van den Ende and Partridge (2008)

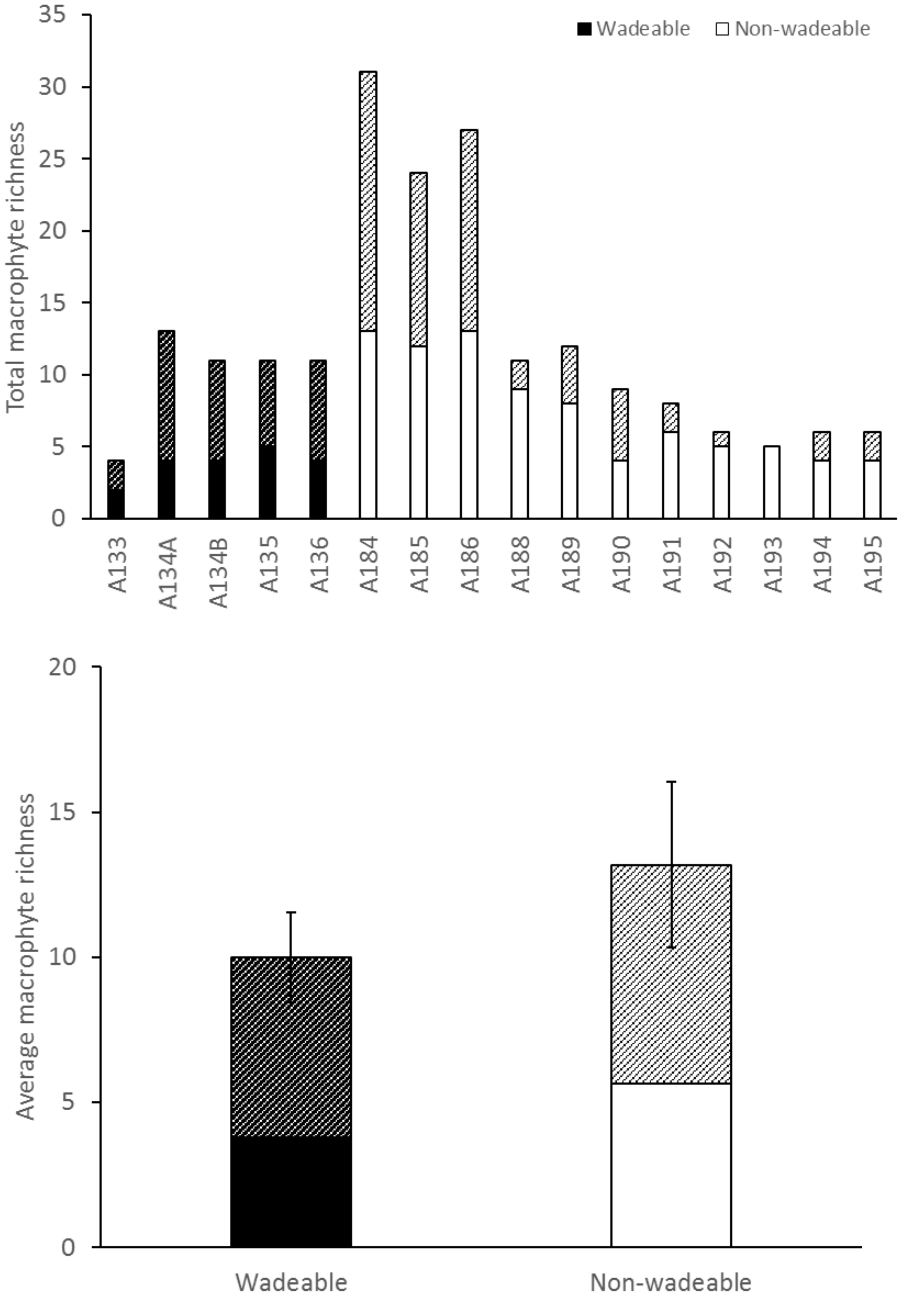


Figure 17. Total (top) and average (bottom) macrophyte species richness found at the 5 wadeable and 11 non-wadeable survey sites in November 2013. Solid black and white bars indicate native species, hatching indicates introduced species. Error bars are 1±SE.

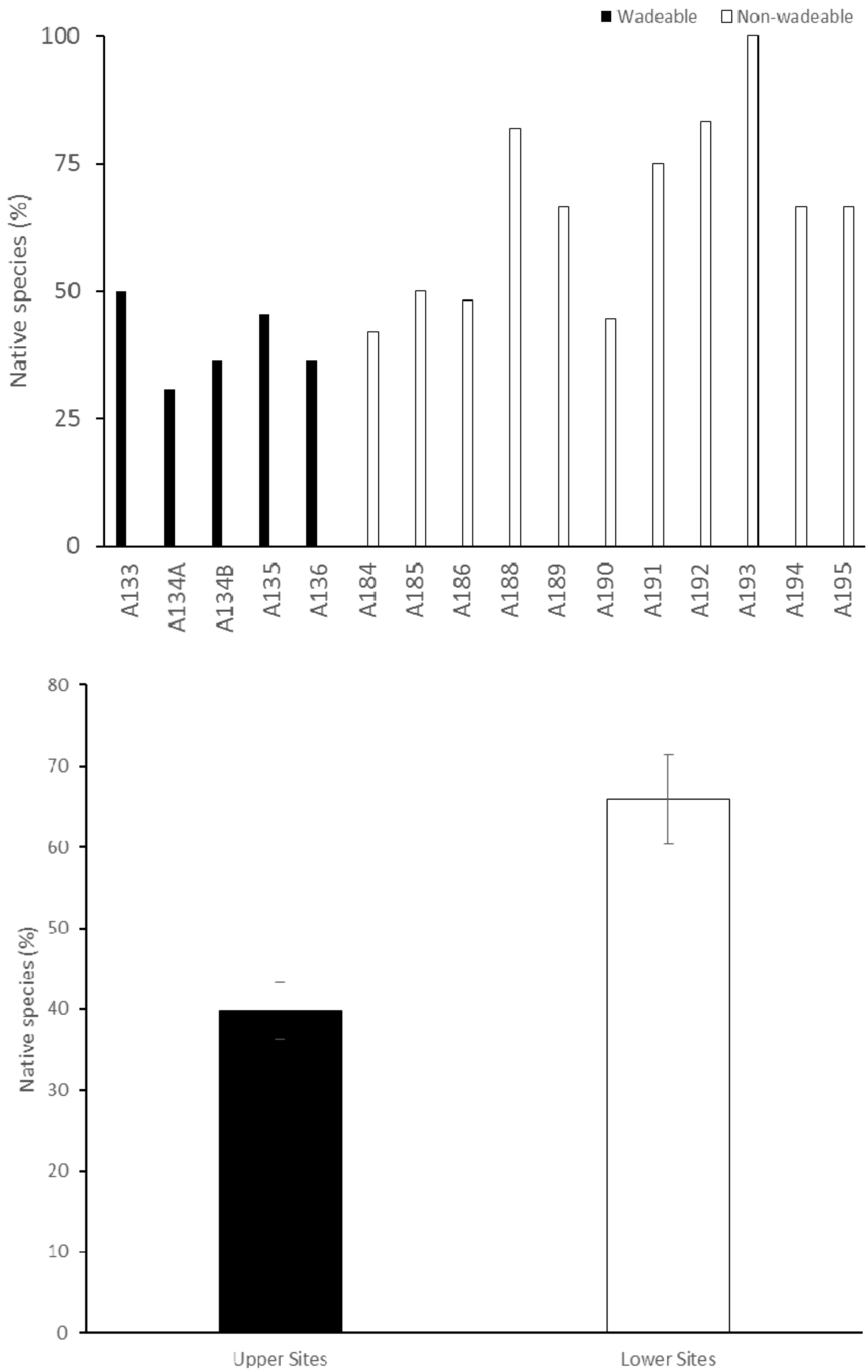


Figure 18. Total (top) and average (bottom) percentage of native macrophyte species found at the 5 wadeable and 11 non-wadeable survey sites in November 2013. Error bars are 1±SE.

The NMDS ordination indicated that the macrophyte community composition was generally variable among sites, with statistically significant differences in macrophyte community composition between wadeable and non-wadeable sites (Figure 19) (ANOSIM: $R = 0.843$, $P = 0.01$). There was no significant different in the community composition found at these sites over time (i.e. community composition did not change between the 2007 and 2013 sampling periods) (ANOSIM: $R = 0.210$; $P = 0.08$).

SIMPER indicated that the upper wadeable sites showed similarity in macrophyte composition largely due to the following species. The native macrophyte *Myriophyllum propinquum* was present at all of the upper wadeable sites, while the introduced species *Elodea canadensis*, *Agrostis stolonifera*, *Potamogeton crispus*, *Callitriche stagnalis* and *Nasturtium officinale*, and the native macrophytes *Nitella hookeri* and *Carex secta*, and filamentous green algae occurred relatively frequently in the upper sites.

Conversely, the lower non-wadeable sites were dominated by *Ruppia polycarpa* (native), *Potamogeton ochreatus* (native), *Schedonorus arundinaceaus* (introduced) and *Potamogeton crispus* (introduced). The native *Gracillaria* (estuarine brown algae), *Myriophyllum triphyllum* and *Cotula coronopifolia*, and the exotic species *Iris pseudacorus*, *Elytrigia repens*, *Elodea canadensis* and *Agrostis stolonifera* were all found in approximately 30% of the sites, and were all important contributors to similarity in community composition of the non-wadeable sites.

SIMPER further indicated that the differences in macrophyte community composition between wadeable and non-wadeable sites was due to the presence of saline tolerant species, such as *Ruppia polycarpa* (native), *Gracillaria* (estuarine brown algae), filamentous Enteromorpha, *Ulva*, *Cotula coronopifolia* (native) and *Apium prostratum* (native), which were present in the non-wadeable reaches, but not upstream at the wadeable sites. However, differences in macrophyte community composition between wadeable and non-wadeable sites were also due to variation in the average number of occurrences of some species, rather than their total absence from wadeable or non-wadeable sites. For example, the native macrophyte *Myriophyllum propinquum* was found at all of the upper wadeable sites, but occurred less frequently at the lower, non-wadeable sites. The native macrophyte *Potamogeton ochreatus* showed the reverse pattern, being commonly encountered in the non-wadeable sites, but occurring less frequently in the upper, wadeable sites. The exotic *Potamogeton crispus* occurred at, on average, approximately equal frequencies in the wadeable and non-wadeable sites. Nevertheless, none of the species identified by the SIMPER were particularly strong contributors to differences in community composition between the wadeable and non-wadeable sites (see Appendix 7 for full SIMPER results), with *Ruppia polycarpa*, *Myriophyllum propinquum*, *Potamogeton ochreatus*, and filamentous green algae together contributing just 22% of the differences in community composition (Appendix 7).

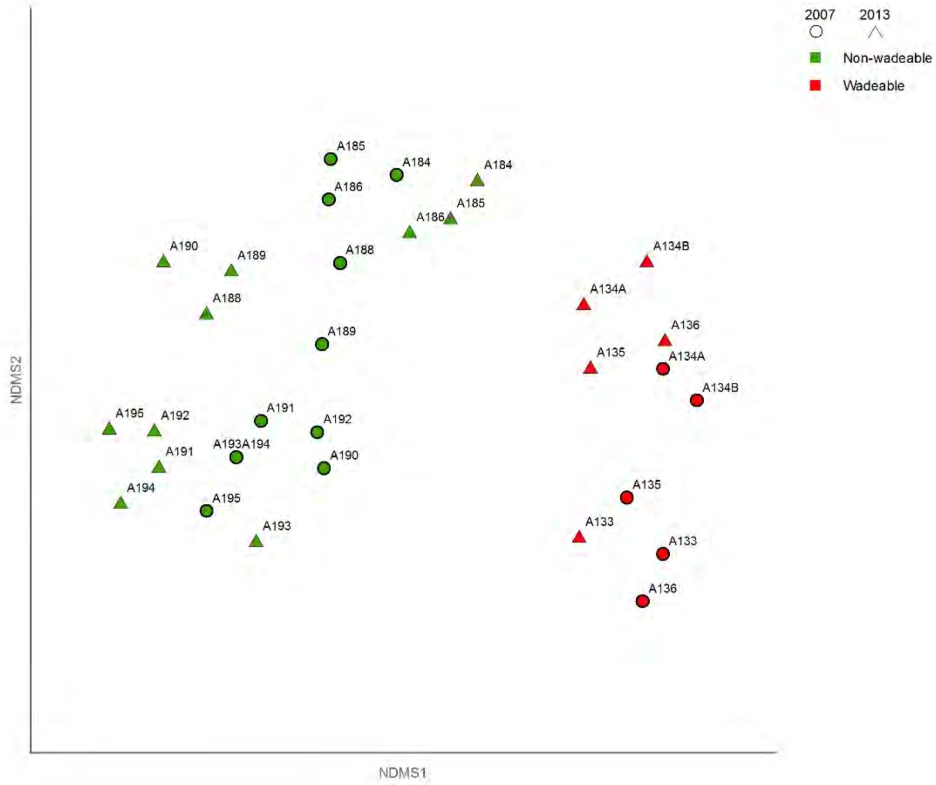


Figure 19. Non-metric multidimensional scaling (NMDS) ordination based on a Bray-Curtis matrix of dissimilarities calculated from macrophyte presence data recorded at 5 wadeable (red) and 11 non-wadeable (green) sites of the Avon River in 2013 (triangles) and by van den Ende and Partridge (2008) in 2007 (circles). The NMDS ordination has been graphically shown where sites are categorised as wadeable or non-wadeable sites as sampled in 2007 and 2013. Note, the NMDS gave a good representation of the actual community dissimilarities between wadeable and non-wadeable sites (two-dimensional stress = 0.13). Axes are identically scaled so that the sites closest together are more similar in macrophyte species composition than those further apart.

DISCUSSION

Wadeable Reaches of the Avon River catchment

This ecological assessment indicated that waterways within the Avon River catchment are generally of poor ecological health. Only 7 of the 29 sites surveyed were found to be within the fair water-quality category of Stark and Maxted (2007); while one site fell within the ‘good’ category, the majority (>70%) of the 29 sites surveyed fell within the ‘poor’ water quality category. The QMCI scores of nearly 50% (14 of 29) of the sites surveyed fell below the minimum score of 3.5 QMCI guideline of Canterbury’s proposed Land and Water Regional Plan (pLWRP). Moreover, in-stream conditions and macroinvertebrate and fish communities were typical of waterways in moderately urbanised catchments (e.g. Walsh et al 2005a).

In-stream and riparian habitat conditions, although variable among sites, were generally degraded, with low Substrate Indexes (i.e. stream beds dominated by finer substrates and generally lacking in boulders) and often very little in-stream shading, and modified channels with low habitat diversity. All of these in-stream physical characteristics are important determinants of macroinvertebrate and fish community composition. Jowett et al. (1991) found that, of the macroinvertebrate taxa studied, the majority preferred relatively shallow and faster-flowing water in gravel and coarser substrates. More importantly, Jowett et al. (1991) did not find any taxa that preferred fine substrates or deeper waters.

Macrophyte cover was generally low across the catchment, as was filamentous algal cover. However, the Avon River at Kilmore Street had extensive macrophyte beds, dominated by the exotic species *Potamogeton crispus* and *Elodea canadensis*. Here, macrophyte cover exceeded the pLWRP guideline of a maximum total macrophyte cover of 30% for spring-fed (plains) urban waterways. Long filamentous algal cover was also generally low, with only Riccarton Stream and Corsers Stream found to exceed the pLWRP guideline of maximum of 30% cover of long (>2 mm) filamentous algae.

The basic water-quality parameters of pH, dissolved oxygen, conductivity and temperature were within ranges expected in a spring-fed urban environment during base-flow conditions. The water temperatures recorded within the catchment are likely to be within the thermal tolerance limits of many of New Zealand’s freshwater fauna (Quinn et al. 1994). None of the water temperatures recorded in the Avon River catchment exceeded the maximum temperature guideline (20°C) of the pLWRP. However, it’s important to note that the temperature recordings consisted of a single spot measure and, therefore, would not pick up day-night fluctuations in temperature that can be common in urban environments, particularly in waterways that have little shading of the channel.

Although conductivity levels in the Avon River catchment were comparable to levels of urban systems more generally, some sites had particularly high conductivity readings indicating the level of pollutants and contaminants in the water column may be elevated. For example, conductivities of 256, 339, 210 and 478 µS / cm were recorded in Addington Brook, Riccarton Stream, St Albans Creek, and Corsers Stream respectively. These elevated conductivity levels in Addington Brook, Riccarton Stream and St Albans Creek are likely to indicate increased pollutant or contaminant levels in these waterways. However, the spot conductivity reading of 478 uS / cm at Corsers Stream (Site 15) is likely a reflection of a saline influence, due to the sites proximity to the river mouth, rather than pollutants and contaminants. These conclusions are consistent with those of a parallel study on the sediment quality of the Avon River catchment conducted by NIWA. NIWA found elevated concentrations of heavy metals and polycyclic aromatic hydrocarbons (PAHs) in Riccarton Stream, Addington Drain and St Albans Creek. Heavy metal and PAH levels were relatively low in Corsers Stream (Jennifer Gadd – NIWA, pers. comm.).

Nevertheless, water chemistry and temperature can vary markedly, both daily and seasonally, and because of this episodic events can be missed by spot sampling of basic water-quality parameters. Macroinvertebrates live almost continuously in freshwaters and are variously sensitive to environmental stressors, such as organic and inorganic pollutants, habitat availability and water quality. Thus, it is widely accepted that investigating the macroinvertebrate community at a site can be a more useful alternative tool to measure long-term water quality and ecosystem health, than spot measures of water chemistry.

In this study, the macroinvertebrate community of the Avon River catchment was found to be dominated by pollution-tolerant snails, crustaceans, oligochaete worms and chironomid midge larvae. The clean-water, or sensitive, EPT taxa were poorly represented in the Avon River catchment; only pollution-tolerant caddisfly taxa were present, while mayflies and stoneflies were absent. *Deleatidium* mayflies were still present in the Avon River, albeit appeared restricted to just a few locations, in Robb's 1989-1990 study (Robb 1992). Meredith et al. (2003) conducted a survey of a variety of waterways in Canterbury, and from this developed some 'reference site' comparisons for a variety of biotic indices to give an indication of the condition that should be expected in 'healthy' lowland streams in Canterbury. Many of the biotic indices we calculated indicated that sites within the Avon River catchment had poorer macroinvertebrate communities compared to the reference condition for Canterbury's lowland waterways (Meredith et al 2003).

Only six freshwater fish species were found in the Avon River catchment, however, this included three species listed as 'declining': longfin eel, bluegill bully and inanga. Many sites within the Avon River catchment were dominated by one or a few species, such as shortfin eel and the introduced brown trout. However, trout were never particularly abundant, except in smaller headwater tributaries where juvenile trout reached the greatest numbers. Of note, bluegill bullies were found at four sites in the mid reaches of the Avon River (from downstream of the Mona Vale weir and as far downstream as Kilmore Street). However, as part of its regular maintenance schedule, City Care had removed the macrophyte beds at Site 29, near Kilmore Street, a few weeks prior to the fish sampling. Bluegill bullies were not found at sites above the Mona Vale weir, even though habitat in the upper Avon River sites might be suitable for this species (e.g. Avon River at Clyde Road). Barriers to the upstream movement of this migratory species (e.g. weirs), which enter rivers as small juveniles and gradually migratre upstream as adults, may be impeding bluegill bullies from inhabiting areas further upstream in the Avon River catchment.

This shift towards pollution-tolerant, species-poor communities is a phenomenon common to urban streams around the world. Walsh et al. (2005a) coined the term as the "urban stream syndrome", used to describe the consistently observed ecological degradation of urban catchments. Urban waterways can be characterised as having altered hydrological regimes (e.g. reduced baseline water tables and exaggerated, 'flashy' flooding), elevated inputs of pollutants, chemicals and sediments, and reduced in-stream and riparian habitat complexity, resulting in the loss of 'clean-water' taxa and the dominance of species 'tolerant' to poor ecological conditions.

Non-Wadeable Reaches of the Lower Avon River

EOS Ecology (2012a) was commissioned by the CCC to assess the ecological conditions of the non-wadeable reaches of the lower Avon River. In this separate study, EOS Ecology (2012a) found that the habitat of the non-wadeable reaches of the lower Avon River was different from that in the remainder of the Avon River catchment. The lower Avon sites were wide and deep with generally greater depths of deposited fine sediments on the river bed, than in the wadeable reaches. The river generally became wider and deeper downstream towards Ihutai / the Avon-Heathcote Estuary.

The macroinvertebrate community, however, was similar to that found in the wadeable reaches of the catchment. The community was dominated by snails, oligochaete worms, chironomid midge larvae and crustaceans, with few 'clean-water' EPT taxa. Similar to the majority of sites in the upper reaches of the Avon River catchment, the MCI and QMCI scores (for soft-bottomed streams) indicated that these lower, non-wadeable reaches of the Avon River fell within the 'poor' water-quality category of Stark and Maxted (2007).

All of the species encountered in the upper reaches of the catchment, with the exception of brown trout, were also present in the non-wadeable reaches. However, there were some differences, where the fish community of the lower Avon River reaches was dominated by species that are typical of tidally influenced waters. For example, common smelt (*Retropinna retropinna*), yellow-eyed mullet (*Aldrichetta forsteri*), and estuarine triplefin (*Grahamina* sp.) were found in the non-wadeable reaches of the Avon River, but were not present in the wadeable reaches upstream of Fitzgerald Avenue.

Comparisons with Previous Studies

Although many areas of the Avon River catchment have been surveyed relatively recently (e.g. EOS Ecology 2009, 2012a & b), a survey of this number of sites within the Avon River catchment hasn't been conducted since the work by Jim Robb for the Christchurch Drainage Board (CDB) in the summer of 1989 & 1990 (Robb 1992). Robb (1992) found a greater macroinvertebrate diversity generally than was found in this study, with many more 'clean-water' EPT taxa represented in the catchment. The once ubiquitous mayfly *Deleatidium* species was still present in Avon River in 1989 & 1990, albeit only in a few locations. There were also notable changes in the macroinvertebrate community recorded by Robb (1992) compared with a survey also conducted by the CDB in 1978 - 1979 (Christchurch Drainage Board 1980). For example, Robb (1992) noted the loss of many species of caddisfly and a decline in *Deleatidium* presence throughout the Avon River. The ecological health of the Avon River catchment is likely to have been in decline for many years, as a result of the long history of urban development in this catchment. For example, the MCI scores based on the macroinvertebrate community present in the Avon River catchment in 1978 – 1979 ranged from 91 to 62, and 80 to 64 at the same sites in 1989 – 1990 (Robb 1992). A number of these sites were within the 'fair' water-quality category of Stark and Maxted (2007) in 1978 – 1979, but the communities declined over the following 10 years with the majority of sites falling within the 'poor' water-quality category in 1989 – 1990 (Robb 1992).

When only considering the 10 sites that are part of the CCC's long-term monitoring programme of Christchurch's waterways, there were subtle differences in some of the macroinvertebrate biotic indices between the survey conducted by EOS Ecology (2009) and this study. Of particular interest is the apparent change (both improvements and declines) in the likely ecological condition, or stream health, as determined by the MCI and QMCI scores. While the ecological condition of many sites appeared to be greater in 2013 compared to 2008, the relative change in the MCI / QMCI values was small (i.e. likely only very slight improvements, which may be due to the presence of a few rare and / or slightly more sensitive taxa). Similarly, the apparent decline in ecological condition over time in Waimairi Stream at Fendalton Park, Wairarapa Stream at Glandovey Road, Avon River downstream of Mona Vale, Avon River at Victoria Square and Avon River near Kilmore Street was again due to relatively small changes in MCI and QMCI values calculated in 2008 versus 2013. Papanui Stream and Avon River in Hagley Park saw the greatest changes in MCI values with an increase from 'poor' to 'fair' water-quality conditions, indicating the ecological condition may have improved over time. Okeover Stream was the only waterway found to be in the 'good' water-quality category in 2013, with an apparent improvement since 2008. However, there were only subtle differences detected in macroinvertebrate community composition over time. Therefore, it may be concluded that the macroinvertebrate community in the 10 long-term monitoring sites has not markedly changed over the 5 years since it was last surveyed by EOS Ecology (2009). It is not unusual for the MCI (and its derivatives) to fluctuate slightly between sampling occasions, even when the ecological condition or stream health hasn't changed markedly at a site. For example, in the long-term monitoring of Okeover Stream, MCI and QMCI scores have varied since 1980, and continue to fluctuate even after rehabilitation activities of the stream (Winterbourn et al. 2007). Despite these fluctuations found by Winterbourn et al. (2007) and in this study, these biotic indices certainly indicate degraded stream conditions in the Avon River catchment.

Today, the majority of the Avon River catchment falls within the 'poor' water-quality category. This shift in community composition is unsurprising given our knowledge on the effects of urbanisation (e.g. the Urban Stream Syndrome), and particularly a catchment's connectedness (via the stormwater system) to the surrounding urban environment. In fact, Walsh et al. (2005b) noted that stormwater impacts are likely to be the primary driver behind the often reported correlations between stream condition and catchment imperviousness. Walsh et al. (2007) and Walsh et al. (2005a) found that sensitive macroinvertebrate taxa (e.g. EPT taxa) rarely occurred in waterways with > 4 – 10% catchment imperviousness. They also found that there is often little change in macroinvertebrate composition in urban systems once they reach this level of connectedness via stormwater inputs to the surround urban environment.

Since Robb's (1992) study, the macroinvertebrate community has continued to shift towards a community consistent with that generally found in urban systems. *Deleatidium* mayflies are no longer present in the Avon River catchment, most likely due to continued stormwater, sediment and contaminant inputs into the waterways. Communities of the Avon River catchment have become more and more dominated by pollution-tolerant taxa, such as snails, oligochaete worms, and chironomid midge larvae, with few caddisfly taxa present. The results presented in this study are consistent with that found by EOS Ecology (2009), where a subset of the sites surveyed in this current study were examined. EOS Ecology (2009) found the overall health, as categorised by the MCI and QMCI scores, of the Avon River catchment was 'poor' or 'fair'. They also concluded that this was in contrast to the less developed (i.e. largely rural) Otukaikino and Styx catchments, which are more likely to be rated as having 'fair' or even 'good' water-quality conditions and ecological health (Boffa Miskell 2005; EOS Ecology 2008). Certainly these catchments support a more diverse EPT fauna (including the presence of mayflies), than the Avon River catchment. The Otukaikino and Styx catchments are today regarded as the best examples of lowland spring-fed stream systems within the greater Christchurch area (Boffa Miskell 2005).

Macrophyte Communities

The macrophyte community of the upper, wadeable sites was different from that found in the lower, non-wadeable sites. The community in the upper sites was dominated (60% on average) by exotic species, including the now ubiquitous introduced macrophytes *Elodea canadensis*, and *Potamogeton crispus.* However, the native macrophyte *Myriophyllum propinquum* was found at all of the upper wadeable sites intensively surveyed for macrophytes.

The lower, non-wadeable sites had slightly richer macrophyte communities, and a greater proportion of native species present (76% were native species). The native macrophytes *Ruppia polycarpa* and *Potamogeton ochreatus* were found at almost all of the 11 non-wadeable sites surveyed.

Interestingly, these differences in community composition of the wadeable and non-wadeable sites were also evident in 2007 (based on the findings of van den Ende and Partridge 2008), with the community composition being relatively unchanged over the 6 or so years between sampling periods.

Despite the higher proportion of native species in the lower non-wadeable reaches of the Avon River, there were a couple of species of concern

Of note was the occurrence of *Stuckenia pectinata* (an At Risk – Naturally Uncommon macrophyte; de Lange et al. 2012) at site A191, as well as the potentially concerning presence of two invasive, introduced species *Iris pseudacorus* and *Phalaris arundinacea* (site A186) in the non-wadeable reaches of the Avon River (Figure 2).

The upper and lower sites included in this 're-survey of macrophyte communities' are distinct site locations from those that have been surveyed for the Ecological Survey of the Avon River catchment. The results do, however, add value in indicating these areas of the Avon River add a valuable contribution to the ecological values of the Avon River catchment. This is particularly the case for the non-wadeable sites, where a greater proportion of native macrophyte species were found.

Ecological Health of the Catchment

The majority of sites surveyed within the Avon River catchment were found to be of poor ecological health, with 48% of sites surveyed below the proposed Land and Water Regional Plan's (LWRP) QMCI guidelines for spring-fed urban systems. The non-wadeable reaches of the Avon River were also found to be of poor ecological health. Despite this, when sites were ranked according to five of the macroinvertebrate biotic indices (total taxonomic richness, total and percent EPT richness, and MCI and QMCI scores) there was a clear pattern indicating some areas within the catchment are likely to be of greater ecological value than others (Figure 20: ranked overall ecological health is shown as a graduated colour scale from green – yellow – orange – red, where green indicates best and red indicates worst sites). For example, sites within the headwaters of the Avon River and Waimairi Stream, and downstream in the Avon River were ranked as the top sites, while ecological health appeared to generally decline downstream and waterways such as Addington Brook, Riccarton Stream, St Albans Creek, and Dudley Creek were ranked much lower in overall ecological health.

When the non-wadeable reaches of the lower Avon River, as surveyed by EOS Ecology (2012), were included in this ranking process, the reaches from the Fitzgerald Avenue bridge downstream to the Pages Road bridge scored some of the lowest values (i.e. ranks) in the overall ecological health of the Avon River catchment (Figure 20).

The sites that scored the highest in overall ecological health generally also had the best in-stream and riparian habitat conditions. For example, the headwater tributary sites of the Avon River often had faster flowing waters, and a diversity of in-stream habitats and coarser substrates. These in-stream conditions are particularly important for supporting healthier macroinvertebrate and fish communities. There are also likely to be marked, and likely biologically important, differences in stormwater and sediment conditions in the 'healthiest' sites versus sites located in poorer-scoring waterways such as Addington Brook, Riccarton Stream, St Albans Creek and Dudley Creek (as shown by NIWA's sediment quality data).

Importantly, five sites within the Avon River catchment were also important sites for the 'declining' bluegill bully. The location of these sites is shown on Figure 20. Bluegill bullies are benthic feeders, meaning that they feed on the macroinvertebrates (and mainly aquatic insect larvae) that live on the stream bed, and the presence of bluegill bully populations coincides with 'healthier' macroinvertebrate communities. However, these sites, and particularly those within the main stem of the Avon River, also contain areas of faster, riffle habitats. Bluegill bullies preferentially inhabit swift riffle sections in open rivers and streams, so tend to be found in the mid sections of fast-flowing waterways.

Despite many of the other headwater sites of the Avon River scoring as the best in overall ecological health, Ilam Stream (Site 2) scored very poorly in overall ecological health, with a ranking of 22nd out of all of the Avon River catchment sites (Figure 20). No fish were found at this site, but a dead eel was seen floating immediately downstream of the Waimairi Road culvert during the habitat and macroinvertebrate sampling in late October. The stream had negligible flow during the habitat sampling, and virtually no flow during the fishing. Ilam Stream had reduced dramatically in wetted width at Site 2 in the approximately two weeks between surveying habitat and macroinvertebrates, and the fish sampling. It's noteworthy that a piped input into Ilam Stream (entering the stream on the true left side), which may be piped spring waters from an upstream residential area, was flowing, or discharging, into Ilam Stream in late October (i.e. during the habitat and macroinvertebrate sampling) but was no longer discharging into Ilam Stream in early November (i.e. during the fish sampling). This is likely to be a contributing factor to the more ephemeral nature of Ilam Stream.

Some other waterways within the catchment also appear to be ephemeral, which almost certainly impacts on the ecology of these systems. Shirley Stream at Site 16 was not flowing when the habitat and macroinvertebrate surveys were conducted on 5 November 2013. The stream was a series of isolated pools, but our observations indicated that it had only recently dried as the stream bed was still very wet, with no visible drying and cracking of the soft sediments covering the stream bed, and patches of filamentous algae were still wet and pliable. Shirley Stream was flowing again when visited on 26 November 2013 to conduct the fishing survey. However, no fish were caught, seen or heard during electro-fishing of the sampling reach.

However, it's important to remember that even sites that score the lowest in the overall catchment health, may still provide some value (or potential value) to the ecology of the Avon River catchment. Addington Brook is a good example of this; even though this site was found to be one of the poorest in overall health, the in-stream physical habitat conditions were generally pretty good, with an abundance of coarse substrates (including submerged and emergent boulders) and high stream shading. If an assessment was based entirely on the physical habitat of this waterway, Addington Brook might be expected to support better macroinvertebrate and fish communities than was found in this study. However, the water was a murky grey, almost soapy, colour on the day of electrofishing (despite that the stream was surveyed during base-flow conditions), and NIWA's recent study has indicated that the sediments contain elevated concentrations of heavy metals and polycyclic aromatic hydrocarbons (PAHs), which are detrimental to biological and stream health. This is a good example of a waterway that, even though it scored poorly in overall ecological health, it has the potential (if long-term sediment and water quality can be improved) to make a valuable contribution to the ecology of the Avon River catchment.

Stormwater and sediment quality is likely to be a major contributing factor in the poor communities found at some other sites. For example, sites that scored poorly in ecological health also had poor fish communities (either low species richness or low abundances) (e.g. Riccarton Stream, Wairarapa Stream downstream of Fendalton Road, both St Albans Creek sites and Dudley Creek at North Parade). The NIWA data indicated these sites also had poor sediment quality, with high levels of heavy metal and PAH contaminants in the sediments. Ecological improvements in much of the catchment would require focusing not only on improving stormwater and sediment quality but also in-stream habitat conditions.

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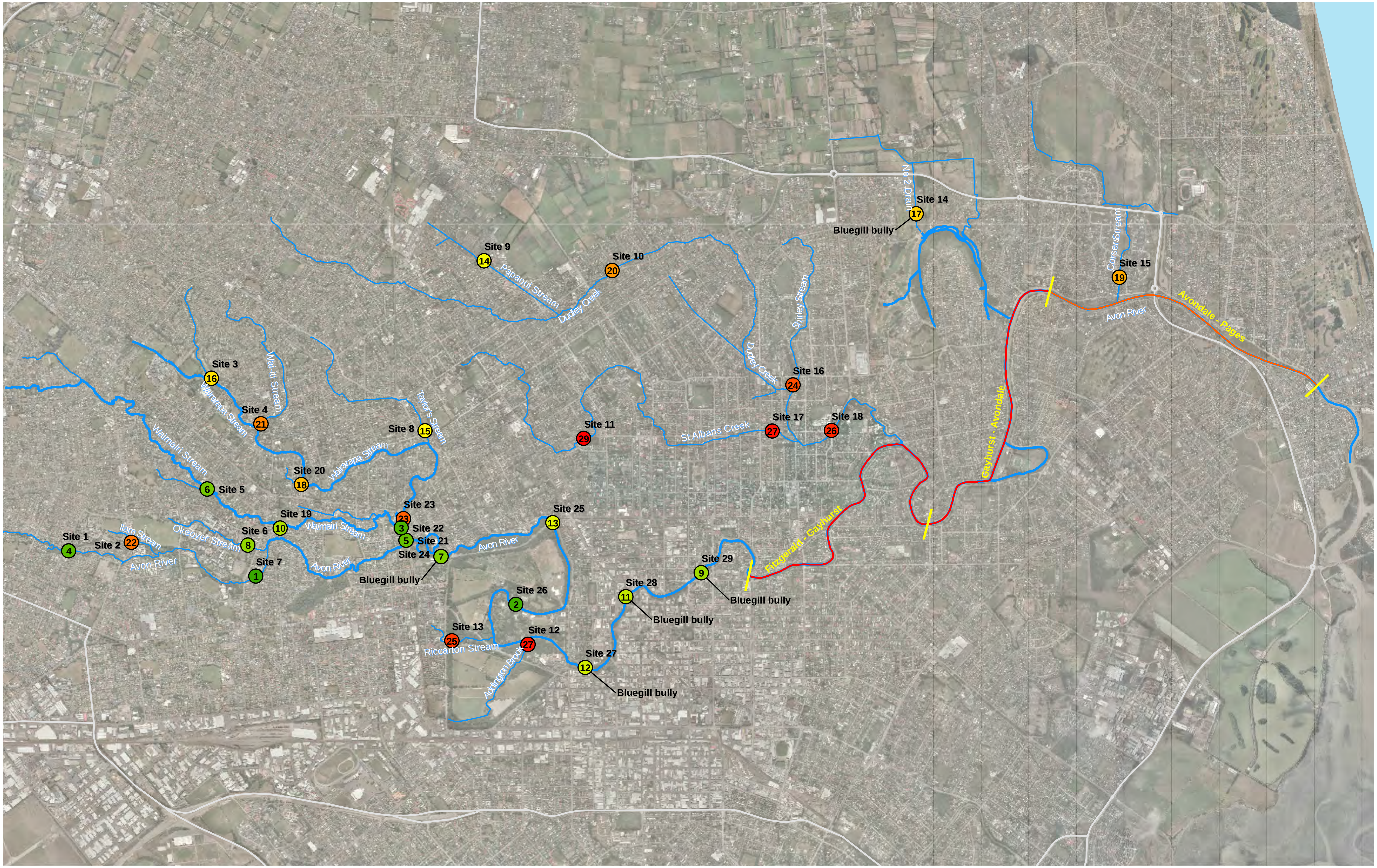

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Aerials Flown 2011 NZAM - Sourced from CERA.

Projection: NZGD 2000 New Zealand Transverse Mercator

Legend

Best Condition

Decreasing

Worst Condition

AVON RIVER ECOLOGY

Figure 20 : Overall Ecological Health

Date: 31 March 2014 | Revision: 0

Plan Prepared for CCC by Boffa Miskell Limited

Author: brian.mcauslan@boffamiskell.co.nz | *Checked:* TBl

Figure 20. Map showing the overall ecological health of the Avon River catchment, where the biotic indices taxonomic richness, EPT richness, %EPT richness, MCI and QMCI values for each site have been ranked, from best – green through to yellow, orange and red (worst). Numbers shown in the circles indicate a site's overall ranking. See Table 3 for further information.

Management Solutions

Although the overall ecological health of the Avon River catchment was found to be poor, a continuum along this health gradient was found, with some areas being better than others. For example, the headwaters and upper reaches of the Avon River and Waimairi and Okeover Streams scored highly overall, based on the resident macroinvertebrate communities. Some of these sites also supported bluegill bully populations; longfin eels were present throughout the catchment. Other waterways, such as Addington Brook, were found to have relatively good riparian and in-stream conditions, however, this was not reflected by healthy macroinvertebrate and fish communities.

These findings reflect the need for a multi-faceted approach to catchment management, whereby areas of greatest ecological health need to be maintained through appropriate management activities, but some of the lower / lowest ranked sites (i.e. Addington Brook, Riccarton Drain, St Albans Creek) may also be improved over time through more intensive management of stormwater and contaminated sediments, and in-stream and riparian habitat enhancement activities.

The effects of urbanisation on stream ecosystems are complex, and often there are multiple and interrelated stressors responsible for the loss of 'sensitive, clean-water' communities. It's therefore important to consider the possibility of further improvements to in-stream habitat, in conjunction with improved stormwater inputs (i.e. reducing the amount of fine sediments and contaminants transported into waterways), which would almost certainly improve the overall health of the Avon River catchment. For example, because urban waterways have historically been viewed as drainage systems, the in-stream habitats have been simplified to improve drainage capacity and efficiency. However, the straightening and channelizing of urban waterways and simplifying of in-stream substrates has marked consequences for freshwater macroinvertebrate and fish communities.

It is crucial to maintain the fast-flowing, riffle habitats of the Avon River, which support both diverse macroinvertebrate communities and bluegill bully populations. Similarly, future stormwater management activities should focus on reducing the levels of contaminants (e.g. suspended sediments, heavy metals, PAHs) that are likely to be entering the catchment via tributary waterways such as Dudley Creek, St Albans Creek, Addington Brook and Riccarton Stream. The loss of larger substrates, habitat and flow diversity not only limits the amount and variety of habitat available for 'habitat-specialists, such as bluegill bully, but likely limits recruitment of 'clean-water' macroinvertebrate taxa (Blakely and Harding 2005).

Aquatic insects, which generally have a winged adult stage, can populate waterways via three main pathways: downstream drift (where juveniles drift downstream with the current to colonise a new area); upstream migration (where juveniles crawl upstream); and aerial dispersal of a winged adult. Aerial dispersal can be a particularly important route for adult aquatic insects to access suitable oviposition (egg laying) sites, and this may be done either by flying upstream along a waterway, or laterally (overland dispersal) between streams. Aerial dispersal and oviposition is particularly important in recolonisation of waterways when an upstream, headwater source population is not available for colonisation via downstream drift (e.g. Okeover Stream, Papanui Stream and the headwaters of the Avon River, and Waimairi and Wairarapa Streams).

However, many freshwater insects have specific oviposition requirements. Some caddisfly species deposit eggs masses on the undersides of boulders in stream channels, while others specifically select emergent boulders, with specific downstream water velocities for oviposition sites. The size of the emergent boulder is important to some species, while others, it's the downstream water velocity that is most critical (Reich and Downes 2003). The successful recruitment of aquatic insect species, which in turn provide food sources for many of New Zealand's native freshwater fishes, is dependent on the availability of suitable oviposition habitat. There is a real lack of oviposition habitats in Christchurch's urban streams available for some of New Zealand's EPT taxa (Blakely and Harding 2005). The addition of emergent boulders, strategically placed in the channels, for example, would greatly improve the amount of egg-laying habitat available for some of the caddisfly species found in the Avon River catchment.

Studies have also shown that adult aquatic insects often face a number of anthropogenic barriers to dispersal in urban environments, which can all have implications for recruitment. For example, road crossings (i.e. culverts), light pollution (many of our caddisfly species are nocturnal), and the probable confusion of the built environment (e.g. concrete, which when wet reflects polarised light that confuses insects; tall buildings with few riparian 'markers' for species to navigate along and between waterways) may all disrupt adult aquatic insect flight (see discussion in Blakely et al. 2006).

Maintaining connectivity along a waterway is a crucial element for fish and macroinvertebrate communities. Many roads intersect waterways in urban environments and culverts are used as an alternative to bridges to pipe waterways under roads. While these piped sections are generally short (e.g. approximately 20 m long), culverts can still have a marked influence on the ability of both fish and macroinvertebrates to navigate through a stream network. A poorly constructed and placed road culvert can act as a barrier to fish passage, thereby preventing its migration along a waterway (Boubée et al. 1999). Road culverts are also known to impede the movement of crustaceans along a waterway (Resh 2005) and can limit the dispersal of the winged adult stages of aquatic insects, such as caddisflies (Blakely et al. 2006). It may be that aquatic insects cannot navigate through culverts, or that predation pressure is increased by a great number of spiders that often sit-and-wait inside road culverts. Or it could be that adult aquatic insects instead disperse overland, between waterways, and become disconnected from the stream and lost in the urban environment. These factors are important considerations in catchment management, particularly when source populations (i.e. potential colonists) of 'clean-water taxa' are generally absent from the Christchurch area.

Recommendations

- There needs to be a multi-faceted approach to the management of the Avon River catchment.
- Areas of greatest ecological health need to be maintained through appropriate management activities, while areas of lower health could be improved over time through intensive management of stormwater and contaminated sediments, and riparian and in-stream enhancements.
- Stormwater management needs to continue to focus on reducing the quantity of sediment and contaminant inputs into the catchment.
- Retrofitting existing drainage and stormwater connections, wherever possible, and therefore reducing the connectivity of the catchment with the impervious surface areas of the urban environment, is desirable.
- Reduce sediment and contaminant inputs, particularly deleterious heavy metals and PAHs, into key areas of the catchment.
- In areas where existing levels of contaminants and sediments are high, consider removing these contaminated sediments, through the use of a sand-wand, or similar device.
- Reduce the contaminant levels in areas of the catchment that otherwise have good in-stream habitat values. This may be an important first step to improving the macroinvertebrate and fish communities and overall ecological health.
- Replace deciduous trees in the immediate riparian margins with evergreen species, throughout the catchment, but particularly in the key ecological areas and smaller headwater and tributary sites. This will address the excessive amounts of leaf litter inputs into the waterways, and thereby improve the condition of the streams.
- Enhance riparian and in-stream habitat conditions, particularly in areas:
    - Where retrofitting of stormwater connections is undertaken; and
    - Of greatest ecological health.
- Maintain and enhance habitat for specialist species, such as bluegill bullies.
- Include the addition of a variety of larger substrates (e.g. emergent and submerged boulders) in habitat enhancement activities, particularly to increase the availability of oviposition habitats for freshwater fauna.
- Consider, and where possible, improve connectivity along the stream corridors, including impacts of in-stream structures such as culverts and low bridges on migrating freshwater fauna.
- Consider the inclusion of lighting systems that limit the effects of light pollution on freshwater fauna.
- All areas of the catchment, regardless of the local ecological health, should be considered as contributors to the Avon River, the overall health of the catchment, and the health of Ihutai / the Avon-Heathcote Estuary.

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Appendix 1: Site Locations Provided by the CCC

Sites for the Ecological Survey of the Avon River catchment – as provided by the CCC

Site number	Site name	Easting	Northing
1	Avon River at Corfe Reserve	2474875	5742550
2	Ilam Stream at Waimairi Road	2475509	5742636
3	Wairarapa Stream at Jellie Park	2476319	5744291
4	Wai-iti Stream at Clyde Road	2476816	5743832
5	Waimariri Stream at Barlow Street	2476274	5743174
6	Okeover Stream at Canterbury University	2476686	5742608
7	Avon River downstream of Clyde Road	2476765	5742294
8	Taylors Drain at Heaton Street	2478474	5743761
9	Papanui Stream at Erica Reserve	2479069	5745479
10	Dudley Creek downstream Jameson Ave	2480363	5745381
11	St Albans Creek at Abberley Park	2480075	5743683
12	Addington Brook upstream of Avon confluence	2479512	5741605
13	Riccarton Stream downstream of Deans Ave	2478744	5741641
14	No. 2 Drain at Christchurch Golf Club	2483431	5745954
15	Corsers Stream at Brooker Reserve	2485480	5745312
16	Shirley Stream Stapletons Road	2482185	5744223
17	St Albans Creek downstream Slater Street	2481978	5743759
18	Dudley Creek at North Parade	2482575	5743763
19	Waimariri Stream at Fendalton Park	2477010	5742780
20	Wairarapa Stream upstream of Glandovey Road	2477224	5743220
21	Avon River above confluence with Wairarapa	2478282	5742655
22	Waimairi Stream downstream of railway bridge	2478232	5742784
23	Wairarapa Stream downstream of Fendalton Road	2478254	5742874
24	Avon River downstream of Mona Vale weir	2478634	5742492
25	Avon River at Carlton Mill Corner	2479764	5742834
26	Avon River in Hagley Park	2479390	5742010
27	Avon River near Durham Street	2480089	5741371
28	Avon River at Victoria Square	2480483	5741998[9]
29	Avon River near Kilmore Street	2481261	5742329

[9] Note that Site 28 (Hagley Park at Victoria Square) was moved approximately 70 m upstream of the location (easting: 2480498; northing: 5742085) issued by the CCC. See Appendix 3 for details.

Sites for the Re-survey of Macrophytes in the Avon River – as provided by the CCC

Site	Site description	East	North
A133	20-40m downstream of site 31 (Confluence of Wairarapa stream and Avon river).	2478317	5742656
A134A	30-50m downstream of Fendalton Rd.	2478611	5742665
A134B	20m at end of Wood Lane.	2478608	5742517
A135	0-20m downstream of Fendalton Rd.	2478770	5742544
A136	50-70 m downstream of Helmores Lane.	2479038	5742666
A184	Upstream of Barker's Rd. opposite church.	2485684	5745143
A185	Half way between Anzac drive bridge and confluence of Kate Sheppard Stream.	2485901	5745135
A186	Opposite Culver Place. Middle ± 10m.	2486172 2486189	5744989 5745011
A188	100m down from Palmer's Rd. in Cockayne Reserve.	2486718 2486709	5744591 5744556
A189	Opposite Rawson St. Middle ± 10m.	2487066 2487074	5744411 5744450
A190	Opposite Pratt St. Middle ± 10m.	2487250 2487233	5744392 5744356
A191	Downstream of Seaview Rd. Beresford St. ± 10m.	2487536 2487507	5744158 5744146
A192	Opposite Collongwood St. Middle ± 10m.	2487655 2487645	5744053 5744015
A193	20-40m downstream of New Brighton Power Boat Slipway.	2487856 2487819	5743941 5743919
A194	Opposite drain, 100-120m down from site 193	2487904 2487890	5743836 5743829
A195	Opposite intersection of Evan's Ave. & Admiral Way. 0-20m past end of Gabions.	2487913 2487870	5743729 5743746

Appendix 2: Ryder Consulting – Macroinvertebrate Processing

Boffa Miskell

C13035, October/November 2013

Summary of Freshwater Macroinvertebrate Sample Processing & Results

Prepared by Katie Blakemore, BSc.(Hons)

Reviewed by Ben Ludgate, MSc.

November 2013

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Background

Preserved benthic macroinvertebrate samples were provided to Ryder Consulting by Boffa Miskell. Boffa Miskell staff collected these samples in October/November 2013. Ryder Consulting Ltd was engaged to process the C13035 samples, and report the results of taxonomic composition.

Laboratory Analysis

Samples were passed through a 500 μm sieve to remove fine material. Contents of the sieve were then placed in a white tray and macroinvertebrates were counted and identified by eye and under a dissecting microscope (10-40x) using criteria from Winterbourn *et al.* (2006).

Results

The macroinvertebrate results have been forwarded to Boffa Miskell in electronic form.

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Appendix 3: General Site Conditions

Site 1: Avon River at Corfe Reserve

This site was located in the headwaters of the Avon River flowing through Corfe Reserve. Here the river was approximately 2.3 m wide with an average water depth of 23 cm. The velocity on the day of sampling was 0.26 m / s. The true left (TL) side of the bank was lined by a wooden-box channel with residential housing and approximately 70-80 % cover of native and exotic vegetation (primarily garden shrubs). The Corfe Reserve was on the true right (TR) side of the bank and the riparian vegetation was dominated by native shrubs and exotic willows; willow roots encroached into the waterway forming much of the TR bank. The river bed had a moderate Substrate Index (2.3), indicating substrates were dominated by cobbles and pebbles. However, there was a reasonable level of fine sediment deposition on these coarser substrates and the site had an average fine sediment depth of 4 cm. Macrophytes were generally uncommon (<5% cover) and dominated by moss. Thin brown periphtyon was relatively abundant on the cobble substrates (approx. 25% cover).

Avon River at Corfe Reserve (Site 1), looking upstream.

Site 2: Ilam Stream at Waimairi Road

This site was located in the headwaters of Ilam Stream immediately downstream of the Waimairi Road culvert. Here the stream was 2.2 m wide with an average water depth of 9 cm. There was negligible flow on the day of sampling. The TL side of the stream had a covering of native and exotic trees and shrubs including a large specimen of *Gunnera tinctoria.* An input into Ilam Stream on the TL, which may originate from a spring piped in the residential area upstream, intermittently flows into Ilam Stream at this site. This input was flowing on the day of the habitat and macroinvertebrate sampling, but was not flowing during the fish sampling approximately 2 weeks later. This may have accounted, in part, for the marked difference in water levels and flow during the two visits to this site. No visible macrophytes were present at the site, however, long filamentous green algae and other periphyton were found.

The TR side of the channel is lined with a stone wall and residential properties have mown, manicured lawns with scattered *Carex secta* and garden shrubs to the water's edge. The TL bank at this site was highly organic, and presumably quite anoxic (based on the smell observed when standing and disturbing these sediments), due to a number of deciduous trees in the riparian zone.

Ilam Stream at Waimairi Road (Site 2) facing downstream (top) during the habitat and macroinvertebrate sampling, and (bottom) approximately 2 weeks later during the fish sampling.

Site 3: Wairarapa Stream at Jellie Park

This site was located in Wairarapa Stream where it flows through Jellie Park. Here the stream was approximately 5 m wide with an average water depth of 12 cm. The velocity on the day of sampling 0.27 m / s. Jellie Park lies on the TR of the stream, with the TR bank being a wood-lined channel with mown grass and scattered *Carex secta* and native shrubs down to the water's edge. The substrate was dominated by coarser substrates, with an abundance of relatively loose large cobbles and pebbles. Macrophyte beds were limited at this site, but a few strands of *Nitella hookeri* were observed. Long filamentous green algae and thin green periphyton were present (approximately 20-30% cover).

Wairarapa Stream at Jellie Park (Site 3) looking downstream.

Site 4: Wai-iti Stream at Clyde Road

Site 4 was located in Wai-iti Stream amongst residential housing, just above its confluence with Wairarapa Stream. Here the stream was approximately 2.4 m wide, with slow flowing (0.09 m / s) waters of an average depth of 18 cm. Although a cobble-pebble bottom was present at this site, the stream bed was dominated by fine deposited sediments giving a Substrate Index of 1.5. Both TR and TL banks had scattered plantings of native and exotic shrubs including some overhanging *Carex secta*, but were otherwise mown grass to the water's edge at much of the site. A recently planted willow sapling was noted at one property on the TL bank at the site. Parts of the stream channel were lined with wood or corrugated boards, which were in various states of disrepair with submerged gaps and nooks present in the banks at much of the site. No macrophytes were observed at the site, and algal cover was sparse (<10% cover) with thin green and long filamentous green algae present.

Wai-iti Stream at Clyde Road (Site 4) looking downstream towards its confluence with Wairarapa Stream.

Site 5: Waimairi Stream at Barlow Street

This site consisted of areas both upstream and downstream of the footbridge at Barlow Street. Here Waimairi Stream was approximately 2.5 m wide with an average water depth of 31 cm, and included areas of relatively fast flowing waters (velocity on the day of sampling was 0.34 m / s). The stream bed was dominated by cobbles and pebbles, with a Substrate Index of 2.0. The stream (both TR and TL banks) was relatively consistently contained within a wooden-box channel with overhanging native and exotic vegetation. Macrophytes were rare, with only moss being observed at the site. Long filamentous green algae was visible on approx. 25% of the stream bed.

Waimairi Stream at Barlow Street (Site 5) looking upstream.

Site 6: Okeover Stream at University of Canterbury

Site 6 was located within Okeover Stream upstream of its confluence with the Avon River and within the University of Canterbury (UOC) grounds. The stream was approximately 3.1 m wide with an average water depth of 15 cm. The banks of Okeover Stream at Site 6 have been planted with a mixture of native scrubs and small trees (e.g. *Carex secta*, hebes and cabbage trees) during rehabilitation activities by the CCC and UOC in the 1990s, which provide variable canopy cover and stream shading at the site. Thin green and thick green periphyton was visible on approximately 20% of the cobbles and pebbles at the site.

This site included some areas of swift shallow riffle-like sections with cobble dominated substrates (Substrate Index, 2.5). However, fine sediments were also abundant on the stream bed.

Okeover Stream at the University of Canterbury (Site 6) looking downstream.

Site 7: Avon River downstream of Clyde Road

This site was located in the Avon River, downstream of the Clyde Road culvert but upstream of the Okeover Stream and Avon River confluence. Here the river was approximately 3.2 m wide, with an average water depth of 28 cm. The water was relatively fast flowing here (0.38 m / s) due to being situated downstream of a weir. The river bed substrates at this site consisted of a variety of pebbles, cobbles and some larger substrates (Substrate Index, 2.7). The channel was constricted and lined with a variety of materials including concrete, rock and wooden walls. Some of the channel linings were quite degraded, with slumping of the banks and vegetation increasing the variety of in-stream habitat available in places. Both banks included a mixture of native and exotic garden plants as well as some creeping weeds, all of which provided shading, albeit patchy, to the river channel. Moss was present at the site, but no other macrophytes were observed. Periphyton, primarily thin brown algae, covered approximately 50% of the stream bed, with scattered long filamentous green algae.

Avon River downstream of Clyde Road (Site 7), looking downstream.

Site 8: Taylors Stream at Heaton Street

Site 8 was located within Taylors Stream, a rock walled ‘drain’ flowing through residential housing and Elmwood Park. The stream was highly channelised, with an abundance of sediment-laden long filamentous green algae, and patches of the macrophyte *Myriophyllum propinquum* covering the sand / silt, with scattered gravel-pebble substrates (Substrate Index, 1.1). As a result of only scattered flax bushes and otherwise grassed riparian edges, very little stream shading was observed on the day of sampling.

Taylors Stream at Heaton Street (Site 8), looking upstream.

Site 9: Papanui Stream at Erica Reserve

Site 9 was located in Papanui Stream at Erica Reserve. This approximately 2.3 m wide stream had an average water depth of around 18 cm and parts were well shaded as a result of the overhanging and stream side rehabilitation plantings of *Carex*, hebes, cabbage trees and other native plants. Patches of *Nasturtium* were present along the stream margins throughout the site. The stream bed was dominated by quite clean (i.e. not sediment laden) cobble substrates, with approximately 50% cover of thin brown periphyton. Long filamentous green algae was also present, but not abundant.

Papanui Stream at Erica Reserve (Site 9), looking upstream.

Site 10: Dudley Creek downstream of Jameson Ave

Site 10 was located in Dudley Creek downstream of Jameson Avenue. Here the creek was approximately 1.9 m wide with an average water depth of 11 cm. Large cobbles and boulders were present at the site, added during previous rehabilitation activities, giving the site a Substrate Index of 3.3. The macrophyte *Nitella* was present along the site, but never common in the site, while long filamentous green algae was relatively abundant (approx. 25% cover). The riparian areas have been planted with scattered *Carex secta*, flaxes and cabbage trees, however, much of the bank (particularly the TL) was dominated by long grasses. As a result, stream shading was variable along the site.

Dudley Creek at Jameson Ave (Site 10), looking upstream.

Site 11: St Albans Creek at Abberley Park

St Albans Creek at Abberley Park (Site 11) was approximately 2.2 m wide with an average water depth of 11 cm, with relatively slow flowing waters (0.22 m / s). The creek where it flows through Abberley Park had riparian margins dominated by exotic deciduous trees. As a result the cobble bottom had a thick layer of organic-rich sediments. The Substrate Index of 1.0 further indicated the stream bed was dominated by fine substrates. No macrophytes or periphyton were visible at the site on the day of sampling.

St Albans Creek at Abberley Park, looking upstream.

Site 12: Addington Brook upstream of Avon confluence

Site 12 was located in Addington Brook upstream of its confluence with the Avon River. Addington Brook had an approximate width of 1.7 m with an average water depth of 21 cm. The water was relatively fast flowing in areas (0.31 m / s), flowing over substrates dominated by large cobbles (Substrate Index, 2.9). The sides of the creek had been 'reinforced' in places with large boulders, and riparian plantings (including *Carex*, native grasses and ferns and native and exotic trees and shrubs) provided a high level of shading in some places. Patches of perennial rye grass (*Lolium perenne*) and starwort (*Callitriche stagnalis*) were present in and along the stream.

Addington Brook upstream of Avon confluence (Site 12), looking downstream.

Site 13: Riccarton Stream downstream of Deans Ave

Riccarton Stream, downstream of Deans Avenue, was a highly modified concrete ‘drain’ with steep grassed banks. The uniform channel was 1.2 m along the entire site, with a generally constant water depth of 18 cm. Patches of cocksfoot *Dactylis glomerata* and jointed rush *Juncus articulatus* were present in the stream channel, with the stream bed otherwise being dominated by small cobbles and filamentous green algae. The Substrate Index was 1.5.

Riccarton Stream downstream of Deans Ave (Site 13), looking downstream.

Site 14: No. 2 Drain at Christchurch Golf Club

Site 14 was located in No. 2 Drain at Christchurch Golf Club, within an area that had been rehabilitated in 2007, including naturalising of the channel and extensive riparian plantings. The waterway at this site was approximately 2.7 m wide with an average water depth of 26 cm. The stream bed was dominated by coarse substrates, such as large cobbles. Macrophytes were common in places along the site, including duckweed (*Lemna minor*), red azolla (*Azolla rubra*), curly pondweed (*Potamogeton crispus*), Canadian pondweed (*Elodea canadensis*), stonewort (*Nitella hookeri*).

Overhanging plantings of *Carex* provided stream shading along much of the site.

No. 2 Drain at Christchurch Golf Course.

Site 15: Corsers Stream at Brooker Reserve

Site 15 was located in Corsers Stream at Brooker Reserve. Here the stream was approximately 3.5 m wide and 44 cm deep with moderately slow flowing waters (0.26 m / s). The Substrate Index was 1.4, indicating the stream bed was dominated by finer substrates such as gravels and pebbles and an abundance of fine particles. There was an abundance of filamentous green algae on the day of sampling, as well as patches of the macrophytes *Veronica anagallis-aquatica*, *Agrostis stolonifera*, and *Potamogeton crispus*. Macrophytes were never particularly abundant, however.

Corsers Stream at Brooker Reserve (Site 15), looking downstream.

Site 16: Shirley Stream Stapletons Road

Site 16 was located in Shirley Stream at Stapletons Road. This muddy-bottomed waterway was not flowing on the day of the habitat and macroinvertebrate sampling and the wetted width was a maximum of 0.4 m along the site with approximately 1 cm water depth.

Shirley Stream at Stapletons Road (Site 16).

Site 17: St Albans Creek downstream Slater Street

Site 17 was within the channelised (block walled) St Albans Creek downstream of Slater Street (and downstream of Site 11, also in St Albans Creek). Here the waterway was relatively slow flowing (0.21 m / s), with a relatively uniform width (1.7 m wide) and an approximate depth of 22 cm. The stream bed had a substantial covering of highly organic soft sediments, and the Substrate Index was very low (SI = 1.0) indicating the substrates were dominated by finer materials such as sand and silt / mud.

There was relatively little vegetation overhanging the channel so much of the waterway was without shading.

St Albans Creek downstream Slater Street (Site 17).

Site 18: Dudley Creek at North Parade

Site 18 was located in Dudley Creek at North Parade, downstream of Sites 16 (Shirley Stream) and downstream of the two sites (11 and 17) in St Albans Creek. Here, Dudley Creek was approximately 1.8 m wide with an average depth of 22 cm. The banks at this site were heavily eroded with substantial areas of slumping and fine sediments covering the stream bed. The stream channel had very little shading, and the stream bed was dominated by sand, mud and fine gravels. Riparian vegetation was limited, particularly on the TL where areas of grass and bare ground were abundant.

Dudley Creek at North Parade (Site 18), facing downstream.

Site 19: Waimairi Stream at Fendalton Park

Waimairi Stream at Fendalton Park (Site 19) was approximately 3.2 m wide with an average water depth of 20 cm. The velocity was 0.28 m / s on the day of sampling. At Site 19, Waimairi Stream flows through Fendalton Park (TL) and residential housing and roads near the University of Canterbury campus in Ilam. Although there were some plantings of *Carex secta* along and overhanging the stream, much of the banks' vegetation was covered in long grass. The TR bank was reinforced with wooden-box lining, while the TL (i.e. Fendalton Park side) was grassed to the water's edge. The stream bed was dominated by coarse substrates, including large cobbles and a few scattered emergent boulders (Substrate Index, 2.9); however the boulders were experimentally added to the stream by TJ Blakely in 2003 (Blakely et al. 2006). No macrophytes were observed in the stream, however, periphyton (thin green, thin brown and thick brown) covered approximately 20% of the cobble substrates at the site.

Waimairi Stream at Fendalton Park (Site 19), looking downstream.

Site 20: Wairarapa Stream upstream of Glandovey Road

Site 20 was located in Wairarapa Stream upstream of Glandovey Road. Here the Wairarapa Stream was channelised with a rock wall reinforcing the TR bank, while exotic and native garden plants covered the bank right down the water's edge. The stream was approximately 4.3 m wide, on average 17 cm deep at Site 20 and relatively swift (0.33 m / s) on the day of sampling. Macrophytes were uncommon in the channel (monkey musk, *Erythranthe guttata*, was present along the margins), but short and long filamentous green algae was relatively abundant. The stream bed was dominated by coarse pebble and cobble substrates, as reflected by the Substrate Index of 2.8.

Wairarapa Stream upstream of Glandovey Road (Site 20), looking downstream towards the Glandovey Road culvert.

Site 21: Avon River above confluence with Wairarapa

Site 21 was located in the Avon River upstream of where Wairarapa Stream joins the Avon, within the gardens of Mona Vale. This site was located upstream of the Mona Vale weir (located near Site 24). The river was variable in width here, with an average wetted width of 5.0 m, and an average water depth of 40 cm. The velocity, on the day of sampling, was 0.38 m / s. The stream bed was dominated by large cobbles (Substrate Index, 3.4), with moderate coverage (10-40%) of macrophytes, including *Myriophyllum propinquum, Elodea Canadensis* and moss. There were patches of long filamentous green algae and thick green algae; approximately 20% of the substrates were covered with thin green and thin brown periphyton. The river was channelised at this site, and the river banks reinforced with wooden-box lining. Much of the TR bank was mown grass to the stream edge, whereas the TL bank was vegetated with shrubs and creepers such as ferns, rhododendrons and ivy.

Avon River above confluence with Wairarapa (Site 21), facing downstream.

Site 22: Waimairi Stream downstream of railway bridge

Site 22 was located in Waimairi Stream, downstream of the railway bridge and in the Mona Vale gardens. The stream was swift (0.45 m /s), approximately 4.3 m wide and on average 35 cm deep on the day of sampling. With a Substrate Index of 3.0, the stream bed at this site was dominated by coarse substrates, including large cobbles and boulders. Moss occurred on the large, more stable boulders, but otherwise macrophytes were generally limited at this site. The banks were lined with either wood or rock and the riparian vegetation generally consisted of exotic plantings with some native grasses overhanging the channel. Both the riparian vegetation, which included some large trees, and the rail bridge provided in-stream shading. However, there were also areas along both the TR and TL banks where there was little riparian vegetation (either mown grass or leaf litter and bare ground).

Waimairi Stream downstream of railway bridge (Site 22), looking downstream towards the Avon River.

Site 23: Wairarapa Stream downstream of Fendalton Road

Site 23 was located in Wairarapa Stream downstream of the Fendalton Road culvert and upstream of its confluence with the Avon River. The stream was highly channelised, very wide (approximately 8.9 m wide) and quite uniform in depth (on average 31 cm) at this site. The stream bed was almost entirely composed of sand / silt, with a Substrate Index of 1.0 (indicating 100% silt / sand). Few macrophytes were present on the day of sampling; there was evidence of *Myriophyllum propinquum* and *Elodea canadensis*, however, it appeared that the macrophytes had been recently cleared from the stream. The TR bank was within the Mona Vale gardens and the riparian vegetation was sparsely planted exotic garden plants or mown grass, with an occasional *Carex secta* overhanging the stream. The TL bank was within manicured residential gardens with mown lawn or exotic shrubs, including a large willow tree, up to the water's edge.

Wairarapa Stream downstream of Fendalton Road (Site 23), looking downstream.

Site 24: Avon River downstream of Mona Vale weir

This site was located in the Avon River downstream of the Mona Vale weir. Here the river was approximately 8.8 m wide and on average 33 cm deep. The velocity on the day of sampling was 0.58 m / s. The TR bank was well vegetated with *Carex secta*, flaxes and other native plantings in the Girls' High School grounds; however, these appeared to have slumped into the waterway as a result of the Canterbury earthquakes. *Erythranthe guttata* was abundant, albeit in patches, along the margins of the site. The TL bank was within residential housing and gardens, including mown grasses and shrubs to the water's edge, with scattered *Carex secta* and flaxes. The retaining wall along the TL had slumped greatly due to the Canterbury earthquakes. The river bed had a moderate Substrate Index (2.6), indicating substrates were dominated by pebbles and larger cobbles.

Avon River downstream of Mona Vale weir (Site 24), looking downstream.

Site 25: Avon River at Carlton Mill Corner

The Avon River at Carlton Mill Corner (Site 25) was approximately 11 m wide with an average water depth of 49 cm and a velocity of 0.72 m / s on the day of sampling. Both banks were predominantly covered with long grass, with a few Carex secta planted along the TL side. Erythranthe guttata was present along much of the TR side and macrophyte beds (of approx. 50% cover in parts of the site) were dominated by *Elodea Canadensis* and *Potamogeton crispus*, with *Nitella hookeri* and filamentous green algae also present. The substrates were largely comprised of cobbles and pebbles, with a Substrate Index of 2.5.

Avon River at Carlton Mill Corner (Site 25), looking upstream.

Site 26: Avon River in Hagley Park

Site 26 was also located in the Avon River, within Hagley Park. Here the river was approximately 12 m wide with an average depth of 31 cm. The river was quite swift, with a velocity of 0.51 m / s on the day of sampling. The TL bank at this site was mostly grassed, with longer grasses along the stream margin, and well established trees providing a substantial amount of shading to the channel throughout the day. The TR bank was also grassed with established trees, but also had some *Carex secta* and flax plantings right on the water's edge, which provided abundant overhanging vegetation to the river in parts of the site. Macrophyte beds were abundant (sometimes covering almost all of the river channel, approx. 50-100% cover) and were dominated by *Myriophyllum propinquum*, *Potamogeton crispus*, *Nitella hookeri* and filamentous green algae. The substrates were dominated by pebble and cobbles, with a Substrate Index of 2.6.

Avon River in Hagley Park (Site 26), looking downstream.

Site 27: Avon River near Durham Street

Site 27 was within the Avon River near Durham Street, encompassing an area where in-stream physical remediation works were undertaken in 2013 and now often referred to as 'Watermark'. The river at this site was approximately 9.8 m wide with an average water depth of 30 cm and a velocity of 0.68 m / s on the day of sampling. Both banks of the river at this site were grassed, with plantings of Carex secta along the margins, particularly on the TR bank. Macrophytes were not particularly common in the river at this site, but there was the occasional patch dominated by *Myriophyllum propinquum* and filamentous green algae. The Substrate Index of 3.4 indicated the bed was dominated by larger substrates, and there were aggregations of boulders and large cobbles throughout the site.

Avon River near Durham Street (Site 27), looking upstream towards the Antigua Boatsheds.

Site 28: Avon River at Victoria Square

The Avon River at Victoria Square (Site 28) was approximately 12 m wide with an average depth of 38 cm and a velocity of 0.46 m / s on the day of sampling. This site was located upstream of the Armagh Street bridge, approximately 70 m upstream of the original Avon River at Victoria Square site. During discussions with Belinda Whyte (CCC), it was determined that moving the sampling site upstream would make it a better long-term monitoring site, given that in-stream works as part of the Avon River Precinct project are anticipated to include this reach upstream of the Armagh Street bridge.

The TR banks of the Avon at this site were tightly planted with *Carex secta* overhanging the river. Otherwise, grass and exotic ornamental trees covered the river bank (TR) for approx. 5 m from the water's edge, then roads and commercial buildings dominated the wider riparian zone. There was a narrow (approx. 3 m), but well vegetated area on the TL bank between the river and the Provincial Court buildings and Durham Street. The river bed was dominated by larger substrates, including large cobbles and some boulders (Substrate Index, 3.0). In the shallower areas, macrophyte beds were growing on finer substrates of sand, gravel and pebbles. The dominant macrophyte at this site was *Potamogeton crispus* with long filamentous green algae.

Avon River at Victoria Square (Site 28), located upstream of the Armagh Street bridge (facing upstream).

Site 29: Avon River near Kilmore Street

The Avon River near Kilmore Street (Site 29) was the downstream most sampling site in this study. At this site, the river was approximately 15 m wide with an average water depth of 31 cm and a velocity of 0.63 m / s on the day of sampling. The TL bank had *Carex secta* planted along the edge of the river, while grass and scattered trees were within 5-8 m of the water's edge, and a road and residential apartments were within 20-50 m of the river. Macrophyte beds dominated the river bed, almost entirely covering the bed in parts of the site. These were dominated by *Potamogeton crispus*, *Elodea canadensis* and filamentous green algae. *Erythranthe guttata* was present along the TR banks in between *Carex secta* overhanging the river channel. However, the macrophyte beds and marginal *Erythranthe guttata* were mechanically removed by City Care immediately after the macroinvertebrate and habitat sampling. The substrates were dominated by smaller cobbles, pebbles and sand (Substrate Index, 1.4).

Avon River near Kilmore Street (Site 29), looking downstream

Appendix 4: SIMPER results – macroinvertebrate community of the Avon River catchment

Species	Average abundance		Contribution to total dissimilarity (%)
	Avon	**Ilam**	**Average dissimilarity = 66.18**
Paracalliope	358.22	4	39.89
Potamopyrgus	121.78	377	33.09
Orthocladiinae	101.67	24	9.89
OLIGOCHAETA	46.44	79	4.35
Physa	8	34	3.43
	Avon River	**Wairarapa Stream**	**Average dissimilarity = 66.38**
Paracalliope	358.22	19	38.75
Potamopyrgus	121.78	302.67	23.16
Orthocladiinae	101.67	221.67	21.34
OLIGOCHAETA	46.44	23.67	4.15
Ostracoda	20.78	20.67	2.92
	Ilam Stream	**Wairarapa Stream**	**Average dissimilarity = 43.78**
Potamopyrgus	377	302.67	37.46
Orthocladiinae	24	221.67	31.76
OLIGOCHAETA	79	23.67	12.19
Physa	34	7.33	6.31
Ostracoda	6	20.67	4.63
	Avon River	**Wai-iti Stream**	**Average dissimilarity = 47.72**
Paracalliope	358.22	112	42.7
Potamopyrgus	121.78	81	16.44
Orthocladiinae	101.67	48	16.24
Ostracoda	20.78	40	5.81
Pycnocentrodes	17.78	0	4.72
OLIGOCHAETA	46.44	42	3.55
Sphaeriidae	10.22	5	1.89
	Ilam Stream	**Wai-iti Stream**	**Average dissimilarity = 62.23**
Potamopyrgus	377	81	54.11
Paracalliope	4	112	19.74
OLIGOCHAETA	79	42	6.76
Ostracoda	6	40	6.22
Physa	34	1	6.03
	Wairarapa Stream	**Wai-iti Stream**	**Average dissimilarity = 56.22**
Potamopyrgus	302.67	81	35.98
Orthocladiinae	221.67	48	28.75
Paracalliope	19	112	20.44
OLIGOCHAETA	23.67	42	6.29
	Avon River	**Waimairi Stream**	**Average dissimilarity = 57.57**
Paracalliope	358.22	69.67	37.65

Species	Average abundance		Contribution to total dissimilarity (%)
Potamopyrgus	121.78	381.67	34.97
Orthocladiinae	101.67	67.67	11.46
Pycnocentrodes	17.78	5	2.92
OLIGOCHAETA	46.44	44.33	2.89
Ostracoda	20.78	16.67	2.34
	Ilam Stream	**Waimairi Stream**	**Average dissimilarity = 43.32**
Potamopyrgus	377	381.67	51.87
Paracalliope	4	69.67	15.27
Orthocladiinae	24	67.67	8.32
OLIGOCHAETA	79	44.33	7.91
Physa	34	5.67	5.89
Ostracoda	6	16.67	2.5
	Wairarapa Stream	**Waimairi Stream**	**Average dissimilarity = 49.99**
Potamopyrgus	302.67	381.67	40.96
Orthocladiinae	221.67	67.67	26.56
Paracalliope	19	69.67	14.62
OLIGOCHAETA	23.67	44.33	5.59
Ostracoda	20.67	16.67	3.76
	Wai-iti Stream	**Waimairi Stream**	**Average dissimilarity = 49.36**
Potamopyrgus	81	381.67	54.03
Paracalliope	112	69.67	24.3
Ostracoda	40	16.67	5.12
Orthocladiinae	48	67.67	4.79
OLIGOCHAETA	42	44.33	2.63
	Avon River	**Okeover Stream**	**Average dissimilarity = 57.86**
Paracalliope	358.22	216	24.38
Pycnocentrodes	17.78	171	22.95
Potamopyrgus	121.78	3	17.05
Orthocladiinae	101.67	11	12.95
Pycnocentria	2.78	51	7.32
OLIGOCHAETA	46.44	7	5.84
	Ilam Stream	**Okeover Stream**	**Average dissimilarity = 94.42**
Potamopyrgus	377	3	39.45
Paracalliope	4	216	22.36
Pycnocentrodes	0	171	18.04
OLIGOCHAETA	79	7	7.59
Pycnocentria	0	51	5.38
	Wairarapa Stream	**Okeover Stream**	**Average dissimilarity = 91.49**
Potamopyrgus	302.67	3	28.53
Paracalliope	19	216	22.56
Pycnocentrodes	0	171	19.52
Orthocladiinae	221.67	11	16.09
Pycnocentria	0	51	5.82
	Wai-iti Stream	**Okeover Stream**	**Average dissimilarity = 66.54**

Species	Average abundance		Contribution to total dissimilarity (%)
Pycnocentrodes	0	171	31.84
Paracalliope	112	216	19.37
Potamopyrgus	81	3	14.53
Pycnocentria	0	51	9.5
Ostracoda	40	1	7.26
Orthocladiinae	48	11	6.89
OLIGOCHAETA	42	7	6.52
	Waimairi Stream	**Okeover Stream**	**Average dissimilarity = 80.46**
Potamopyrgus	381.67	3	39.09
Pycnocentrodes	5	171	20.21
Paracalliope	69.67	216	17.57
Orthocladiinae	67.67	11	6.36
Pycnocentria	0.67	51	6.1
OLIGOCHAETA	44.33	7	4.14
	Avon River	**Taylors Drain**	**Average dissimilarity = 74.26**
Potamopyrgus	121.78	771	56.03
Paracalliope	358.22	5	27.66
Orthocladiinae	101.67	41	6.72
	Ilam Stream	**Taylors Drain**	**Average dissimilarity = 36.62**
Potamopyrgus	377	771	74.76
OLIGOCHAETA	79	30	9.3
Physa	34	7	5.12
Ostracoda	6	29	4.36
	Wairarapa Stream	**Taylors Drain**	**Average dissimilarity = 52.33**
Potamopyrgus	302.67	771	67.49
Orthocladiinae	221.67	41	20.89
OLIGOCHAETA	23.67	30	3.31
	Wai-iti Stream	**Taylors Drain**	**Average dissimilarity = 68.92**
Potamopyrgus	81	771	80.61
Paracalliope	112	5	12.5
	Waimairi Stream	**Taylors Drain**	**Average dissimilarity = 41.14**
Potamopyrgus	381.67	771	72.56
Paracalliope	69.67	5	12.06
Orthocladiinae	67.67	41	4.09
Ostracoda	16.67	29	2.49
	Okeover Stream	**Taylors Drain**	**Average dissimilarity = 95.90**
Potamopyrgus	3	771	58.58
Paracalliope	216	5	16.09
Pycnocentrodes	171	0	13.04
Pycnocentria	51	0	3.89
	Avon River	**Papanui Stream**	**Average dissimilarity = 70.75**
Paracalliope	358.22	1	53.15
Orthocladiinae	101.67	9	14.29
Potamopyrgus	121.78	54	13.51

Species	Average abundance		Contribution to total dissimilarity (%)
OLIGOCHAETA	46.44	64	4.13
Pycnocentrodes	17.78	0	4.08
Ostracoda	20.78	23	2.66
	Ilam Stream	**Papanui Stream**	**Average dissimilarity = 59.55**
Potamopyrgus	377	54	76.18
Physa	34	5	6.84
Ostracoda	6	23	4.01
OLIGOCHAETA	79	64	3.54
	Wairarapa Stream	**Papanui Stream**	**Average dissimilarity = 65.47**
Potamopyrgus	302.67	54	44.21
Orthocladiinae	221.67	9	28.59
OLIGOCHAETA	23.67	64	10.26
Ostracoda	20.67	23	4.62
Paracalliope	19	1	4.08
	Wai-iti Stream	**Papanui Stream**	**Average dissimilarity = 47.96**
Paracalliope	112	1	44.94
Orthocladiinae	48	9	15.79
Potamopyrgus	81	54	10.93
OLIGOCHAETA	42	64	8.91
Ostracoda	40	23	6.88
Tanypodinae	2	12	4.05
	Waimairi Stream	**Papanui Stream**	**Average dissimilarity = 64.15**
Potamopyrgus	381.67	54	55.67
Paracalliope	69.67	1	15.41
Orthocladiinae	67.67	9	11.68
OLIGOCHAETA	44.33	64	5.33
Ostracoda	16.67	23	2.83
	Okeover Stream	**Papanui Stream**	**Average dissimilarity = 93.44**
Paracalliope	216	1	35.95
Pycnocentrodes	171	0	28.6
OLIGOCHAETA	7	64	9.53
Potamopyrgus	3	54	8.53
Pycnocentria	51	0	8.53
	Taylors Drain	**Papanui Stream**	**Average dissimilarity = 75.81**
Potamopyrgus	771	54	87.98
OLIGOCHAETA	30	64	4.17
	Avon River	**Dudley Creek**	**Average dissimilarity = 71.58**
Paracalliope	358.22	2	43.03
Potamopyrgus	121.78	244.5	22.68
Orthocladiinae	101.67	103.5	12.35
OLIGOCHAETA	46.44	62	6.58
Pycnocentrodes	17.78	0	3.2
Sphaeriidae	10.22	29	2.78
	Ilam Stream	**Dudley Creek**	**Average dissimilarity = 51.17**

Species	Average abundance		Contribution to total dissimilarity (%)
Potamopyrgus	377	244.5	56.17
OLIGOCHAETA	79	62	13.3
Orthocladiinae	24	103.5	11.56
Physa	34	3.5	7.01
Sphaeriidae	6	29	3.84
	Wairarapa Stream	**Dudley Creek**	**Average dissimilarity = 57.45**
Potamopyrgus	302.67	244.5	43.01
Orthocladiinae	221.67	103.5	29.22
OLIGOCHAETA	23.67	62	8.09
Ostracoda	20.67	23	4.93
Sphaeriidae	3.33	29	3.4
Paracalliope	19	2	3.4
	Wai-iti Stream	**Dudley Creek**	**Average dissimilarity = 61.03**
Potamopyrgus	81	244.5	32.49
Paracalliope	112	2	27.36
Orthocladiinae	48	103.5	11.71
OLIGOCHAETA	42	62	11.18
Ostracoda	40	23	5.86
Sphaeriidae	5	29	3.73
	Waimairi Stream	**Dudley Creek**	**Average dissimilarity = 59.18**
Potamopyrgus	381.67	244.5	51.61
Paracalliope	69.67	2	13.49
Orthocladiinae	67.67	103.5	10.6
OLIGOCHAETA	44.33	62	8.52
Sphaeriidae	7.33	29	3.86
Ostracoda	16.67	23	2.47
	Okeover Stream	**Dudley Creek**	**Average dissimilarity = 93.61**
Paracalliope	216	2	28.37
Pycnocentrodes	171	0	22.71
Potamopyrgus	3	244.5	21.13
Orthocladiinae	11	103.5	8.42
Pycnocentria	51	0	6.77
OLIGOCHAETA	7	62	4.43
	Taylors Drain	**Dudley Creek**	**Average dissimilarity = 59.05**
Potamopyrgus	771	244.5	76.72
Orthocladiinae	41	103.5	7.27
OLIGOCHAETA	30	62	5.94
Sphaeriidae	1	29	2.74
	Papanui Stream	**Dudley Creek**	**Average dissimilarity = 60.26**
Potamopyrgus	54	244.5	35.68
OLIGOCHAETA	64	62	20.58
Orthocladiinae	9	103.5	19.66
Sphaeriidae	0	29	5.23
Ostracoda	23	23	5.22

Species	Average abundance		Contribution to total dissimilarity (%)
Gyraulus	0	7	4.12
	Avon River	**St Albans Creek**	**Average dissimilarity = 84.40**
Paracalliope	358.22	2.5	48.52
Potamopyrgus	121.78	23	15.38
Orthocladiinae	101.67	2	14.17
Ostracoda	20.78	52.5	6.05
OLIGOCHAETA	46.44	22.5	4.65
Pycnocentrodes	17.78	0	3.93
	Ilam Stream	**St Albans Creek**	**Average dissimilarity = 82.71**
Potamopyrgus	377	23	67.61
OLIGOCHAETA	79	22.5	11.06
Ostracoda	6	52.5	8.16
Physa	34	0	6.45
	Wairarapa Stream	**St Albans Creek**	**Average dissimilarity = 78.48**
Potamopyrgus	302.67	23	50.27
Orthocladiinae	221.67	2	27.34
Ostracoda	20.67	52.5	8.64
OLIGOCHAETA	23.67	22.5	5.02
	Wai-iti Stream	**St Albans Creek**	**Average dissimilarity = 65.07**
Paracalliope	112	2.5	38.36
Potamopyrgus	81	23	21.68
Orthocladiinae	48	2	16.17
Ostracoda	40	52.5	10.38
OLIGOCHAETA	42	22.5	7.78
	Waimairi Stream	**St Albans Creek**	**Average dissimilarity = 81.35**
Potamopyrgus	381.67	23	55.15
Paracalliope	69.67	2.5	13.71
Orthocladiinae	67.67	2	11.75
Ostracoda	16.67	52.5	7.05
OLIGOCHAETA	44.33	22.5	4.5
	Okeover Stream	**St Albans Creek**	**Average dissimilarity = 95.04**
Paracalliope	216	2.5	39.73
Pycnocentrodes	171	0	31.87
Pycnocentria	51	0	9.5
Ostracoda	1	52.5	8.87
Potamopyrgus	3	23	3.82
	Taylors Drain	**St Albans Creek**	**Average dissimilarity = 86.16**
Potamopyrgus	771	23	86.71
Orthocladiinae	41	2	4.51
	Papanui Stream	**St Albans Creek**	**Average dissimilarity = 53.60**
OLIGOCHAETA	64	22.5	32.37
Potamopyrgus	54	23	26.1
Ostracoda	23	52.5	17.01
Tanypodinae	12	1	7.61

Species	Average abundance		Contribution to total dissimilarity (%)
Orthocladiinae	9	2	4.96
Physa	5	0	3.54
	Dudley Creek	**St Albans Creek**	**Average dissimilarity = 74.08**
Potamopyrgus	244.5	23	39.51
Orthocladiinae	103.5	2	22.2
Ostracoda	23	52.5	13.72
OLIGOCHAETA	62	22.5	10.64
Gyraulus	7	0	4.93
	Avon River	**Addington Brook**	**Average dissimilarity = 69.01**
Paracalliope	358.22	0	41.37
Potamopyrgus	121.78	308	25.24
Orthocladiinae	101.67	7	11.42
OLIGOCHAETA	46.44	132	11.32
Pycnocentrodes	17.78	0	2.83
	Ilam Stream	**Addington Brook**	**Average dissimilarity = 18.79**
Potamopyrgus	377	308	36.9
OLIGOCHAETA	79	132	28.34
Physa	34	2	17.11
Orthocladiinae	24	7	9.09
	Wairarapa Stream	**Addington Brook**	**Average dissimilarity = 46.65**
Orthocladiinae	221.67	7	32.23
Potamopyrgus	302.67	308	29.53
OLIGOCHAETA	23.67	132	24.54
Ostracoda	20.67	2	5.16
	Wai-iti Stream	**Addington Brook**	**Average dissimilarity = 65.41**
Potamopyrgus	81	308	43.49
Paracalliope	112	0	21.46
OLIGOCHAETA	42	132	17.24
Orthocladiinae	48	7	7.85
	Waimairi Stream	**Addington Brook**	**Average dissimilarity = 47.54**
Potamopyrgus	381.67	308	43.32
OLIGOCHAETA	44.33	132	18.85
Paracalliope	69.67	0	14.79
Orthocladiinae	67.67	7	11.69
Ostracoda	16.67	2	3.2
	Okeover Stream	**Addington Brook**	**Average dissimilarity = 95.88**
Potamopyrgus	3	308	34.46
Paracalliope	216	0	24.41
Pycnocentrodes	171	0	19.32
OLIGOCHAETA	7	132	14.12
	Taylors Drain	**Addington Brook**	**Average dissimilarity = 48.45**
Potamopyrgus	771	308	70.36
OLIGOCHAETA	30	132	15.5
Orthocladiinae	41	7	5.17

Species	Average abundance		Contribution to total dissimilarity (%)
	Papanui Stream	**Addington Brook**	**Average dissimilarity = 59.11**
Potamopyrgus	54	308	68.1
OLIGOCHAETA	64	132	18.23
Ostracoda	23	2	5.63
	Papanui Stream	**Addington Brook**	**Average dissimilarity = 59.11**
Potamopyrgus	54	308	68.1
OLIGOCHAETA	64	132	18.23
Ostracoda	23	2	5.63
	Dudley Creek	**Addington Brook**	**Average dissimilarity = 56.50**
Potamopyrgus	244.5	308	51.55
OLIGOCHAETA	62	132	20.48
Orthocladiinae	103.5	7	14.97
Sphaeriidae	29	6	3.72
	St Albans Creek	**Addington Brook**	**Average dissimilarity = 83.03**
Potamopyrgus	23	308	62.43
OLIGOCHAETA	22.5	132	24.2
Ostracoda	52.5	2	10.08
	Avon River	**Riccarton Stream**	**Average dissimilarity = 65.56**
Paracalliope	358.22	0	46.04
Potamopyrgus	121.78	225	18.25
Orthocladiinae	101.67	21	11.38
OLIGOCHAETA	46.44	108	9.2
Pycnocentrodes	17.78	0	3.21
Ostracoda	20.78	1	2.56
	Ilam Stream	**Riccarton Stream**	**Average dissimilarity = 27.82**
Potamopyrgus	377	225	58.69
Physa	34	2	12.36
OLIGOCHAETA	79	108	11.2
Sphaeriidae	6	21	5.79
Oxyethira	1	9	3.09
	Wairarapa Stream	**Riccarton Stream**	**Average dissimilarity = 48.36**
Orthocladiinae	221.67	21	32.08
Potamopyrgus	302.67	225	28.46
OLIGOCHAETA	23.67	108	19.98
Ostracoda	20.67	1	5.7
Paracalliope	19	0	4.32
	Wai-iti Stream	**Riccarton Stream**	**Average dissimilarity = 57.77**
Potamopyrgus	81	225	33.96
Paracalliope	112	0	26.42
OLIGOCHAETA	42	108	15.57
Ostracoda	40	1	9.2
Orthocladiinae	48	21	6.37
	Waimairi Stream	**Riccarton Stream**	**Average dissimilarity = 43.47**
Potamopyrgus	381.67	225	39.31

Species	Average abundance		Contribution to total dissimilarity (%)
Paracalliope	69.67	0	17.29
OLIGOCHAETA	44.33	108	16.3
Orthocladiinae	67.67	21	10.24
Ostracoda	16.67	1	4
Sphaeriidae	7.33	21	3.45
	Okeover Stream	**Riccarton Stream**	**Average dissimilarity = 94.41**
Potamopyrgus	3	225	27.37
Paracalliope	216	0	26.63
Pycnocentrodes	171	0	21.09
OLIGOCHAETA	7	108	12.45
Pycnocentria	51	0	6.29
	Taylors Drain	**Riccarton Stream**	**Average dissimilarity = 55.49**
Potamopyrgus	771	225	76.04
OLIGOCHAETA	30	108	10.86
Ostracoda	29	1	3.9
	Papanui Stream	**Riccarton Stream**	**Average dissimilarity = 53.44**
Potamopyrgus	54	225	56.44
OLIGOCHAETA	64	108	14.52
Ostracoda	23	1	7.26
Sphaeriidae	0	21	6.93
Orthocladiinae	9	21	3.96
Tanypodinae	12	0	3.96
	Dudley Creek	**Riccarton Stream**	**Average dissimilarity = 55.27**
Potamopyrgus	244.5	225	49.61
OLIGOCHAETA	62	108	18.63
Orthocladiinae	103.5	21	12.85
Sphaeriidae	29	21	5.67
Ostracoda	23	1	4.01
	St Albans Creek	**Riccarton Stream**	**Average dissimilarity = 81.12**
Potamopyrgus	23	225	51.62
OLIGOCHAETA	22.5	108	22.09
Ostracoda	52.5	1	11.82
Orthocladiinae	2	21	4.78
	Addington Brook	**Riccarton Stream**	**Average dissimilarity = 17.88**
Potamopyrgus	308	225	54.61
OLIGOCHAETA	132	108	15.79
Sphaeriidae	6	21	9.87
Orthocladiinae	7	21	9.21
Oxyethira	0	9	5.92
	Avon River	**No. 2 Drain**	**Average dissimilarity = 38.71**
Paracalliope	358.22	318	34.34
Orthocladiinae	101.67	179	23.26
Potamopyrgus	121.78	131	16.11
OLIGOCHAETA	46.44	20	4.9

Species	Average abundance		Contribution to total dissimilarity (%)
Ostracoda	20.78	35	4.3
Oxyethira	0.44	23	4.18
Pycnocentrodes	17.78	0	3.88
	Ilam Stream	**No. 2 Drain**	**Average dissimilarity = 69.94**
Paracalliope	4	318	35.52
Potamopyrgus	377	131	27.83
Orthocladiinae	24	179	17.53
OLIGOCHAETA	79	20	6.67
Physa	34	0	3.85
	Wairarapa Stream	**No. 2 Drain**	**Average dissimilarity = 57.46**
Paracalliope	19	318	41.98
Orthocladiinae	221.67	179	25.61
Potamopyrgus	302.67	131	19.08
OLIGOCHAETA	23.67	20	2.99
Oxyethira	3.33	23	2.79
	Wai-iti Stream	**No. 2 Drain**	**Average dissimilarity = 43.21**
Paracalliope	112	318	44.69
Orthocladiinae	48	179	28.42
Potamopyrgus	81	131	10.85
OLIGOCHAETA	42	20	4.77
Oxyethira	3	23	4.34
	Waimairi Stream	**No. 2 Drain**	**Average dissimilarity = 51.86**
Paracalliope	69.67	318	36.7
Potamopyrgus	381.67	131	30.33
Orthocladiinae	67.67	179	17.12
OLIGOCHAETA	44.33	20	3.23
Oxyethira	3.33	23	2.96
	Okeover Stream	**No. 2 Drain**	**Average dissimilarity = 60.07**
Pycnocentrodes	171	0	23.88
Orthocladiinae	11	179	23.46
Potamopyrgus	3	131	17.88
Paracalliope	216	318	14.25
Pycnocentria	51	0	7.12
Ostracoda	1	35	4.75
	Taylors Drain	**No. 2 Drain**	**Average dissimilarity = 70.50**
Potamopyrgus	771	131	55.8
Paracalliope	5	318	27.29
Orthocladiinae	41	179	12.03
	Papanui Stream	**No. 2 Drain**	**Average dissimilarity = 72.89**
Paracalliope	1	318	48.32
Orthocladiinae	9	179	25.91
Potamopyrgus	54	131	11.74
OLIGOCHAETA	64	20	6.71
	Dudley Creek	**No. 2 Drain**	**Average dissimilarity = 65.64**

Species	Average abundance		Contribution to total dissimilarity (%)
Paracalliope	2	318	43.84
Potamopyrgus	244.5	131	23.56
Orthocladiinae	103.5	179	13.66
OLIGOCHAETA	62	20	5.66
Oxyethira	0	23	3.19
Sphaeriidae	29	0	2.89
	St Albans Creek	**No. 2 Drain**	**Average dissimilarity = 83.89**
Paracalliope	2.5	318	45.42
Orthocladiinae	2	179	25.5
Potamopyrgus	23	131	15.84
Ostracoda	52.5	35	4.32
	Addington Brook	**No. 2 Drain**	**Average dissimilarity = 72.95**
Paracalliope	0	318	36.85
Potamopyrgus	308	131	20.51
Orthocladiinae	7	179	19.93
OLIGOCHAETA	132	20	12.98
	Riccarton Stream	**No. 2 Drain**	**Average dissimilarity = 67.29**
Paracalliope	0	318	42.23
Orthocladiinae	21	179	20.98
Potamopyrgus	225	131	12.48
OLIGOCHAETA	108	20	11.69
Ostracoda	1	35	4.52
	Avon River	**Corsers Stream**	**Average dissimilarity = 47.59**
Potamopyrgus	121.78	393	40.46
Paracalliope	358.22	303	26.61
Orthocladiinae	101.67	9	12.82
OLIGOCHAETA	46.44	17	4.18
Pycnocentrodes	17.78	0	3.04
Sphaeriidae	10.22	24	2.84
Ostracoda	20.78	5	2.17
	Ilam Stream	**Corsers Stream**	**Average dissimilarity = 35.98**
Paracalliope	4	303	63.48
OLIGOCHAETA	79	17	13.16
Physa	34	0	7.22
Sphaeriidae	6	24	3.82
Potamopyrgus	377	393	3.4
	Wairarapa Stream	**Corsers Stream**	**Average dissimilarity = 54.95**
Paracalliope	19	303	40.14
Potamopyrgus	302.67	393	24.75
Orthocladiinae	221.67	9	22.02
Sphaeriidae	3.33	24	2.93
Ostracoda	20.67	5	2.91
	Wai-iti Stream	**Corsers Stream**	**Average dissimilarity = 58.09**
Potamopyrgus	81	393	48.3

Species	Average abundance		Contribution to total dissimilarity (%)
Paracalliope	112	303	29.57
Orthocladiinae	48	9	6.04
Ostracoda	40	5	5.42
OLIGOCHAETA	42	17	3.87
	Waimairi Stream	**Corsers Stream**	**Average dissimilarity = 48.03**
Potamopyrgus	381.67	393	40.11
Paracalliope	69.67	303	35.92
Orthocladiinae	67.67	9	8.56
OLIGOCHAETA	44.33	17	3.85
Sphaeriidae	7.33	24	2.56
	Okeover Stream	**Corsers Stream**	**Average dissimilarity = 61.68**
Potamopyrgus	3	393	51.11
Pycnocentrodes	171	0	22.41
Paracalliope	216	303	11.4
Pycnocentria	51	0	6.68
	Taylors Drain	**Corsers Stream**	**Average dissimilarity = 47.61**
Potamopyrgus	771	393	47.49
Paracalliope	5	303	37.44
Orthocladiinae	41	9	4.02
Ostracoda	29	5	3.02
	Papanui Stream	**Corsers Stream**	**Average dissimilarity = 81.38**
Potamopyrgus	54	393	44.08
Paracalliope	1	303	39.27
OLIGOCHAETA	64	17	6.11
Sphaeriidae	0	24	3.12
	Dudley Creek	**Corsers Stream**	**Average dissimilarity = 64.72**
Paracalliope	2	303	40.53
Potamopyrgus	244.5	393	33.79
Orthocladiinae	103.5	9	9.76
OLIGOCHAETA	62	17	5.43
Sphaeriidae	29	24	3.3
	St Albans Creek	**Corsers Stream**	**Average dissimilarity = 89.56**
Potamopyrgus	23	393	47.58
Paracalliope	2.5	303	38.42
Ostracoda	52.5	5	5.75
	Addington Brook	**Corsers Stream**	**Average dissimilarity = 44.63**
Paracalliope	0	303	55.29
OLIGOCHAETA	132	17	20.99
Potamopyrgus	308	393	15.51
	Riccarton Stream	**Corsers Stream**	**Average dissimilarity = 51.37**
Paracalliope	0	303	50.67
Potamopyrgus	225	393	28.09
OLIGOCHAETA	108	17	15.22
	No. 2 Drain	**Corsers Stream**	**Average dissimilarity = 36.27**

Species	Average abundance		Contribution to total dissimilarity (%)
Potamopyrgus	131	393	48.25
Orthocladiinae	179	9	31.31
Ostracoda	35	5	5.52
Sphaeriidae	0	24	4.42
Paracalliope	318	303	2.76
	Avon River	**Shirley Stream**	**Average dissimilarity = 79.72**
Paracalliope	358.22	1	43
Orthocladiinae	101.67	192	18.72
Potamopyrgus	121.78	11	14.08
Cladocera	0	45	6.25
OLIGOCHAETA	46.44	1	6.04
Pycnocentrodes	17.78	0	3.17
	Ilam Stream	**Shirley Stream**	**Average dissimilarity = 88.94**
Potamopyrgus	377	11	51.69
Orthocladiinae	24	192	23.73
OLIGOCHAETA	79	1	11.02
Cladocera	0	45	6.36
	Wairarapa Stream	**Shirley Stream**	**Average dissimilarity = 75.88**
Potamopyrgus	302.67	11	41.99
Orthocladiinae	221.67	192	33.54
Cladocera	0	45	8.23
Ostracoda	20.67	0	4.78
OLIGOCHAETA	23.67	1	4
	Wai-iti Stream	**Shirley Stream**	**Average dissimilarity = 78.30**
Orthocladiinae	48	192	30.7
Paracalliope	112	1	23.67
Potamopyrgus	81	11	14.93
Cladocera	1	45	9.38
OLIGOCHAETA	42	1	8.74
Ostracoda	40	0	8.53
	Waimairi Stream	**Shirley Stream**	**Average dissimilarity = 80.03**
Potamopyrgus	381.67	11	47.16
Orthocladiinae	67.67	192	20.16
Paracalliope	69.67	1	11.04
Cladocera	0	45	7.01
OLIGOCHAETA	44.33	1	6.15
	Okeover Stream	**Shirley Stream**	**Average dissimilarity = 95.58**
Paracalliope	216	1	31.07
Orthocladiinae	11	192	26.16
Pycnocentrodes	171	0	24.71
Pycnocentria	51	0	7.37
Cladocera	0	45	6.5
	Taylors Drain	**Shirley Stream**	**Average dissimilarity = 89.47**
Potamopyrgus	771	11	73.29

Species	Average abundance		Contribution to total dissimilarity (%)
Orthocladiinae	41	192	14.56
Cladocera	0	45	4.34
	Papanui Stream	**Shirley Stream**	**Average dissimilarity = 86.57**
Orthocladiinae	9	192	48.93
OLIGOCHAETA	64	1	16.84
Cladocera	0	45	12.03
Potamopyrgus	54	11	11.5
Ostracoda	23	0	6.15
	Dudley Creek	**Shirley Stream**	**Average dissimilarity = 70.44**
Potamopyrgus	244.5	11	32.89
Orthocladiinae	103.5	192	32.23
Cladocera	0	45	11.54
OLIGOCHAETA	62	1	8.55
Ostracoda	23	0	4.06
Sphaeriidae	29	0	4.02
	St Albans Creek	**Shirley Stream**	**Average dissimilarity = 94.76**
Orthocladiinae	2	192	57.04
Ostracoda	52.5	0	13.91
Cladocera	0	45	13.51
Potamopyrgus	23	11	6.2
	Addington Brook	**Shirley Stream**	**Average dissimilarity = 94.13**
Potamopyrgus	308	11	44.13
Orthocladiinae	7	192	27.49
OLIGOCHAETA	132	1	19.47
	Riccarton Stream	**Shirley Stream**	**Average dissimilarity = 89.25**
Potamopyrgus	225	11	36.83
Orthocladiinae	21	192	29.43
OLIGOCHAETA	108	1	18.42
Cladocera	0	45	7.75
	No. 2 Drain	**Shirley Stream**	**Average dissimilarity = 60.37**
Paracalliope	318	1	53.37
Potamopyrgus	131	11	20.2
Cladocera	0	45	7.58
Ostracoda	35	0	5.89
Oxyethira	23	0	3.87
	Corsers Stream	**Shirley Stream**	**Average dissimilarity = 95.53**
Potamopyrgus	393	11	38.86
Paracalliope	303	1	30.72
Orthocladiinae	9	192	18.62
Cladocera	0	45	4.58

Appendix 5: SIMPER results – macroinvertebrate community of the CCC's long-term monitoring of 10 sites: 2008 versus 2013

2008 sampling	Average similarity: 71.84	
Taxon	**Average occurrence**	**Contribution to total similarity (%)**
Oligochaeta	1.0	6.79
Ostracoda	1.0	6.79
Empididae	1.0	6.79
Orthocladiinae	1.0	6.79
Physa	1.0	6.79
Potamopyrgus	1.0	6.79
Hudsonema	1.0	6.79
Hydroptilidae	1.0	6.79
Sphaeriidae	0.9	5.35
Acarina	0.9	5.21
Paracalliope	0.9	5.21
Tanytarsini	0.8	4.09
Pycnocentrodes	0.7	3.14
Nematoda	0.7	2.99
Hydrobiosis	0.7	2.93
Triplectides	0.6	2.24
Psilochorema	0.6	2.02
Gyraulus	0.5	1.54
Tanypodinae	0.5	1.50

2013 sampling	Average similarity: 45.04	
Taxon	**Average occurrence**	**Contribution to total similarity (%)**
Oligochaeat	1.0	10.96
Ostracoda	1.0	10.96
Orthocladiinae	1.0	10.96
Potamopyrgus	1.0	10.96
Paracalliope	0.9	8.63
Hudsonema	0.8	6.77
Physa	0.8	6.59
Sphaeriidae	0.8	6.52
Hydrobiosis	0.7	4.97
Pycnocentrodes	0.7	4.91
Psilochorema	0.5	2.6
Hydroptilidae	0.5	2.45
Tanypodinae	0.5	2.35
Platyhelminthes	0.5	2.31

2008 versus 2013 sampling		**Average dissimilarity: 38.61**	
Taxon	**Average occurrence**		**Contribution to total similarity (%)**
	2008	2013	
Acarina	0.9	0.0	6.64
Nematoda	0.7	0.0	5.12
Tanytarsini	0.8	0.2	5.11
Empididae	1.0	0.4	4.60
Triplectides	0.6	0.0	4.52
Gyraulus	0.5	0.4	3.80
Tanypodinae	0.5	0.5	3.79
Psilochorema	0.6	0.5	3.78
Hydroptilidae	1.0	0.5	3.78
Platyhelminthes	0.5	0.5	3.78
Muscidae	0.4	0.4	3.62
Nemertea	0.5	0.0	3.60
Mischoderus	0.3	0.4	3.45
Chironomidae	0.4	0.0	3.38
Hydrobiosis	0.7	0.7	3.30
Pycnocentria	0.1	0.4	3.24
Pycnocentrodes	0.7	0.7	3.23
Oeconesidae	0.4	0.2	3.22
Collembola	0.4	0.2	3.14
Lymnaeidae	0.4	0.0	3.05
Hydra	0.4	0.0	2.83
Oecetis	0.2	0.2	2.33
Ferrissia	0.3	0.0	2.11
Sphaeriidae	0.9	0.8	2.09
Stratyomyidae	0.3	0.0	2.06
Physa	1.0	0.8	1.60

Appendix 6: List of scientific and common names of macrophytes found in the Avon River

Common name	Scientific name	Conservation status[8]
Batchelors button	*Cotula coronopifolia*	Not Threatened
Bergamot mint	*Mentha x piperita var. citrata*	Introduced and Naturalised
Bittersweet	*Solanum dulcamara*	Introduced and Naturalised
Blunt pondweed	*Potamogeton ochreatus*	Not Threatened
Broad-leaved dock	*Rumex obtusifolius*	Introduced and Naturalised
Broad-leaved plantain	*Plantago major*	Introduced and Naturalised
Buck's horn plantain	*Plantago coronopus*	Introduced and Naturalised
Canadian pondweed	*Elodea canadensis*	Introduced and Naturalised
Celery-leaved buttercup	*Ranunculus sceleratus*	Introduced and Naturalised
Common alder	*Alnus glutinosa*	Introduced and Naturalised
Common water milfoil	*Myriophyllum propinquum*	Not Threatened
Couch	*Elytrigia repens*	Introduced and Naturalised
Crack willow	*Salix fragilis*	Introduced and Naturalised
Creeping bent	*Agrostis stolonifera*	Introduced and Naturalised
Creeping buttercup	*Ranunculus repens*	Introduced and Naturalised
Curled dock	*Rumex crispus*	Introduced and Naturalised
Curly pondweed	*Potamogeton crispus*	Introduced and Naturalised
Cutty grass	*Carex coriacea*	Not Threatened
Duckweed	*Lemna disperma*[9]	Not Threatened
Estuarine brown algae	*Gracillaria* sp.	
Fennel-leaved pondweed	*Stuckenia pectinata*[10]	Naturally Uncommon
Floating sweetgrass	*Glyceria fluitans*	Introduced and Naturalised
Giant rush	*Juncus pallidus*	Not Threatened
Glasswort	*Sarcocornia quinqueflora subsp. quinqueflora*	Not Threatened
Filamentous green algae		
Horses mane weed	*Ruppia polycarpa*	Not Threatened
Jointed wire rush	*Apodasmia similis*	Not Threatened
Leafless rush	*Juncus effusus*	Introduced and Naturalised
Lowland flax	*Phormium tenax*	Not Threatened
Male fern	*Dryopteris filix-mas*	Introduced and Naturalised

[8] Revised conservation assessments based on the New Zealand Threat Classification System manual (Townsend et al. 2008) are not available for non-vascular plants.

[9] *Lemna disperma* was previously described as *Lemna minor* and is referred to as *L. minor* in van den Ende and Partridge (2008)

[10] *Stuckenia pectinata* was previously described as *Potamogeton pectinatus* and is referred to as *P. pectinatus* in van den Ende and Partridge (2008)

Monkey musk	*Erythranthe guttata*[11]	Introduced and Naturalised
Moss sp.		
New Zealand celery	*Apium prostratum subsp. prostratum var. filiforme*	Not Threatened
New Zealand sea spurrey	*Spergularia media*	Introduced and Naturalised
Orache	*Atriplex prostrata*	Introduced and Naturalised
Pacific azolla	*Azolla filiculoides*	Not Threatened
Raupo	*Typha orientalis*	Not Threatened
Red pondweed	*Potamogeton cheesemanii*	Not Threatened
Reed canary grass	*Phalaris arundinacea*	Introduced and Naturalised
Salt marsh ribbonwood	*Plagianthus divaricatus*	Not Threatened
Sea lettuce	*Ulva* sp.	
Selliera	*Selliera radicans*	Not Threatened
Sharp spike sedge	*Eleocharis acuta*	Not Threatened
Slender clubrush	*Isolepis cernua var. cernua*	Not Threatened
Stonewort	*Nitella hookeri*	
Swamp kiokio	*Blechnum minus*	Not Threatened
Swamp sedge	*Carex virgata*	Not Threatened
Tall fescue	*Schedonorus arundinaceus*	Introduced and Naturalised
Three-square	*Schoenoplectus pungens*	Not Threatened
Toetoe	*Austroderia richardii*	Not Threatened
Umbrella sedge	*Cyperus eragrostis*	Introduced and Naturalised
Wandering Jew	*Tradescantia fluminensis*	Introduced and Naturalised
Water forget-me-not	*Myosotis scorpioides*	Introduced and Naturalised
Water milfoil	*Myriophyllum triphyllum*	Not Threatened
Water speedwell	*Veronica anagallis-aquatica*	Introduced and Naturalised
Starwort	*Callitriche stagnalis*	Introduced and Naturalised
Watercress	*Nasturtium officinale*	Introduced and Naturalised
Willow weed	*Polygonum persicaria*	Introduced and Naturalised
Wiwi	*Juncus edgariae*	Not Threatened
Yellow flag iris	*Iris pseudacorus*	Introduced and Naturalised
Yorkshire fog	*Holcus lanatus*	Introduced and Naturalised
	Carex secta	Not Threatened
	Crassula sinclairii	Not Threatened
	Enteromorpha	
	Lilaeopsis novae-zelandiae	Not Threatened

[11] *Erythranthe guttata* was previously described as *Mimulus guttatus* and is referred to as *M. guttatus* in van den Ende and Partridge (2008)

Appendix 7: SIMPER results – macrophyte community

Upper, wadeable sites	**Average similarity: 50.08**	
Species	**Average occurrence**	**Contribution to total similarity (%)**
Myriophyllum propinquum	1.00	26.55
Elodea canadensis	0.70	13.92
Agrostis stolonifera	0.60	10.39
Nitella hookeri	0.60	9.01
Potamogeton crispus	0.60	6.64
Callitriche stagnalis	0.60	6.47
Filamentous green algae	0.50	6.41
Nasturtium officinale	0.60	6.13
Carex secta	0.40	5.22

Upper, wadeable sites	**Average similarity: 45.04**	
Species	**Average occurrence**	**Contribution to total similarity (%)**
Ruppia polycarpa	0.95	19.18
Potamogeton ochreatus	0.86	14.56
Enteromorpha (filamentous)	0.59	9.97
Schedonorus arundinaceau	0.68	9.07
Potamogeton crispus	0.68	8.95
Gracillaria (estuarine brown algae)	0.55	8.58
Filamentous green algae	0.59	7.28
Iris pseudacorus	0.50	3.01
Myriophyllum triphyllum	0.36	3.00
Elytrigia repens	0.32	2.48
Elodea canadensis	0.36	1.75
Cotula coronopifolia	0.27	1.25
Agrostis stolonifera	0.32	1.16

Wadeable sites vs. non-wadeable sites	**Average dissimilarity: 85.51**		
Species	**Average occurrence**		**Contribution to total similarity (%)**
	Wadeable	Non-wadeable	
Ruppia polycarpa	0.00	0.95	6.22
Myriophyllum propinquum	1.00	0.18	5.63
Potamogeton ochreatus	0.10	0.86	5.28
Filamentous green algae	0.50	0.59	4.57
Gracillaria (estuarine brown algae)	0.00	0.55	4.38

Enteromorpha (filamentous)	0.00	0.59	4.21
Elodea canadensis	0.70	0.36	3.78
Schedonorus arundinaceus	0.00	0.68	3.71
Potamogeton crispus	0.60	0.68	3.7
Callitriche stagnalis	0.60	0.27	3.38
Nasturtium officinale	0.60	0.14	3.12
Nitella hookeri	0.60	0.18	3.1
Agrostis stolonifera	0.60	0.32	2.73
Iris pseudacorus	0.00	0.5	2.42
Elytrigia repens	0.00	0.32	2.41
Glyceria fluitans	0.40	0.00	2.29
Myriophyllum triphyllum	0.00	0.36	2.14
Carex secta	0.40	0.05	2.05
Mimulus guttatus	0.40	0.05	2.02
Ulva	0.00	0.23	1.86
Isolepis cernua	0.00	0.32	1.38
Leptodictyum riparium	0.20	0.00	1.33
Stuckenia pectinata	0.00	0.23	1.3
Periphyton	0.20	0.00	1.28
Rumex crispus	0.00	0.32	1.27
Cotula coronopifolia	0.00	0.27	1.25
Cyperus eragrostis	0.20	0.09	1.13
Apium prostratum	0.00	0.18	1.06
Tradescantia fluminensis	0.20	0.00	1.03
Juncus effusus	0.20	0.00	1.01
Phormium tenax	0.00	0.18	0.99
Holcus lanatus	0.20	0.00	0.96
Rumex obtusifolius	0.00	0.23	0.9
Potamogeton cheesmanii	0.00	0.23	0.89

Schoenoplectus tabernmontanii	0.00	0.18	0.84
Schoenoplectus pungens	0.00	0.14	0.68
Riccia sp.	0.10	0.00	0.62
Lilaeopsis novae-zelandiae	0.00	0.18	0.61
Polygonum persicaria	0.00	0.14	0.55
Alnus glutinosa	0.10	0.00	0.54
Austroderia richardii	0.10	0.00	0.54
Blechnum minus	0.10	0.00	0.54
Carex coriacea	0.10	0.00	0.54