Avon River Precinct

Baseline Conditions of the Avon River
Prepared for the Christchurch City Council

9 May 2014

Document Quality Assurance

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

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EXECUTIVE SUMMARY

The Christchurch Earthquake Recovery Authority and the Christchurch City Council commissioned Boffa Miskell Ltd to undertake an assessment of the freshwater ecology of the Avon River between Mona Vale and Kilmore Street, including upstream reference sites and downstream sites within the Avon River Precinct area.

Investigations of the in-stream and riparian habitat conditions and macroinvertebrate and fish communities showed that the current health of these parts of the Avon River is generally poor, with probable severe pollution.

This information will provide Christchurch Earthquake Recovery Authority and the Christchurch City Council with robust information on the existing ecological conditions of the river. This baseline information collected prior to rehabilitation works taking place in the river within the Avon River Precinct will provide a useful resource for later comparisons in which improvements in habitat and in-stream communities post-rehabilitation can be measured against.

SCOPE

The CERA and CCC commissioned Boffa Miskell to conduct an ecological survey of the Avon River in December 2013 and prior to the rehabilitation works of the ARP project. The survey sites included sites where rehabilitation activities will occur in 2014, and upstream ‘reference’ sites where no rehabilitation activities will be undertaken as part of the ARP project. The purpose of this brief report is to:

- Describe the existing ecological values found at the survey sites along the Avon River, with respect to riparian and in-stream physical habitat conditions, periphyton and macrophyte cover, and macroinvertebrate and fish communities;
- Provide baseline information of these sites, which may be used to determine if the ecological values of the river are improving over time and after rehabilitation activities are carried out.

SURVEY METHODS

Site Locations

In consultation with Dr Belinda Whyte (CCC), Boffa Miskell Ecologists Dr Tanya Blakely and Ms Barbara Risi surveyed 8 sites along the Avon River, including 3 'reference' sites upstream of the ARP, and 5 'rehabilitation' sites within the ARP (Figure 1; Table 1). All sites included a riffle or fast-flowing run; upstream reference sites were selected to be representative of the 'rehabilitation' sites downstream.

At each site, 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. All of the reference sites and 3 of the 5 rehabilitation sites were concurrently surveyed by Boffa Miskell as part of CCC's Avon River catchment Stormwater Management Plan project (hereafter referred to as the Avon SMP project).

Table 1. Site name, number and co-ordinates of each of the sites surveyed in this study.

Site name	Site number	Northing	Easting
Avon River downstream of Mona Vale weir	Reference Site 1	5742492	2478634
Avon River at Carlton Mill Corner	Reference Site 2	5742834	2479764
Avon River in Hagley Park	Reference Site 3	5742010	2479390
Avon River near Durham Street	Rehabilitation Site 1	5741371	2480089
Avon River at Rhododendron Island	Rehabilitation Site 2	5741385	2480253
Avon River at Hereford Street	Rehabilitation Site 3	5741648	2480397
Avon River at Victoria Square	Rehabilitation Site 4	5742085	2480498
Avon River near Kilmore Street	Rehabilitation Site 5	5742329	2481261

Habitat Assessment

A variety of in-stream and riparian habitat parameters were recorded at each site between 22 October and 7 November 2013, as part of the Avon SMP project.

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 Table 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).

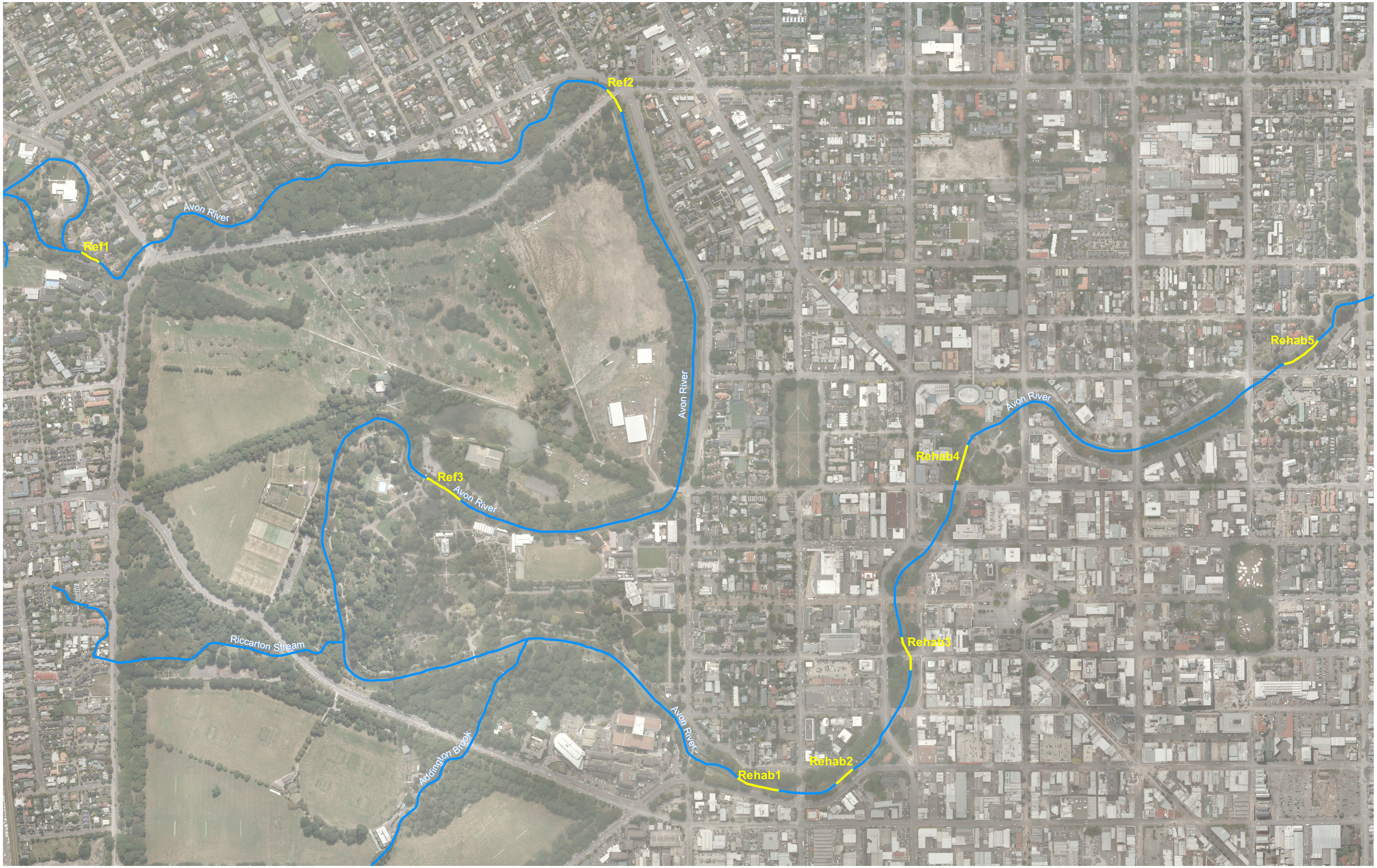
Further riparian and in-stream habitat assessments were made at each site on 12 and 13 November using the following standard protocols of Harding et al. (2009) and Clapcott et al. (2011):

- Protocol 3 (P3) Quantitative protocol of Harding et al. (2009):
    - P3b: Hydrology and morphology procedure, carried out by an Environment Canterbury hydrologist[1]
    - P3c: In-stream habitat procedure, conducted by Boffa Miskell ecologists; and
    - P3d: Riparian procedure, conducted by Boffa Miskell ecologists;
- Sediment Assessment Methods of Clapcott et al. (2011):
    - Sediment Assessment Method 2 – in-stream visual estimate of % sediment cover; and
    - Sediment Assessment Method 6 – sediment depth.

These additional habitat assessment methods involved measuring a range of in-stream and riparian physical habitat conditions at 6 equally spaced cross-sections in each survey reach. Full details of these methods are provided in Appendix 1.

Photographs and GPS locations were also taken at each site.

[1] The information gathered in this hydrological survey will allow any small-scale changes in bed, channel and hydrological characteristics due to in-stream rehabilitation works to be assessed.



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Aerials Flown 2011 NZAM - Sourced from CERA.

Projection: NZGD 2000 New Zealand Transverse Mercator

Legend
Survey Reach

AVON RIVER PRECINCT BASELINE SURVEY

Figure 1: Site Locations

Date: 3 April 2014 | Revision: 0

Plan Prepared for CCC by Boffa Miskell Limited

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

Figure 1. Locations of the 5 rehabilitation and 3 reference sites for the Baseline Ecological Survey of the Avon River Precinct project.

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[2]) using two complimentary methods.

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.

In addition to the kick-net samples, 5 replicate Surber samples (0.05 m^2, 500 µm mesh) were collected at each of the 8 sites. Surber samples were randomly collected from shallow riffles or fast-flowing runs, and the substrate was disturbed to an approximate depth of 5 cm.

All 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 at that site (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.

The habitat where fish were found was noted (e.g. under overhanging Carex plants, in macrophyte beds, in mid-channel fast riffles).

[2] The macroinvertebrate 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).

Data Analyses

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 habitat conditions among sites and between reference and rehabilitation sites. Response variables were *log* (*x*+1) transformed where necessary to meet assumptions of normality and homogeneity of variances. ANOVAs were performed in R version 3.0.2 (The R Foundation for Statistical Computing 2013).

Macroinvertebrate Community

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

- **Macroinvertebrate abundance** – the average number of individuals collected in the five replicate Surber samples 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 average number of macroinvertebrate taxa recorded from the five Surber samples 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 average number of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) recorded from the five Surber samples 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 average 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 five Surber samples 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 the tolerance scores of Stark and Maxted (2007) for individual macroinvertebrate taxa found in the five Surber samples collected at each site. 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 of the five replicate Surber samples. 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 (1) among sites; and (2) between reference and rehabilitation sites in macroinvertebrate abundance, taxonomic richness, EPT richness, EPT-except Hydroptilidae richness, and MCI and QMCI values. Response variables were *ln* (x+1) transformed to meet assumptions of normality and homogeneity of variances. ANOVAs were performed in R version 3.0.2 (The R Foundation for Statistical Computing 2013).

A non-metric multidimensional scaling (or NMDS) ordination[3], with 1000 random permutations, using abundance data was used to determine if the macroinvertebrate community found was similar among the 8 sites surveyed, and particularly between reference and rehabilitation 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 between reference and rehabilitation sites. It is helpful to view ANOSIM results when interpreting an NMDS ordination.

[3] 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).

An NMDS ordination may show that communities appear to be quite distinct (i.e. when shown graphically, sites could be quite distinct from one another in ordination space), but ANOSIM results show whether these differences are in fact statistically significantly different[4].

If ANOSIM revealed significant differences in macroinvertebrate community composition (i.e. $R \neq 0$ and $P \leq 0.05$) between reference and rehabilitation sites, similarity percentages (SIMPER) were calculated[5] 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).

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 total area fished (i.e. 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.

[4] 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).

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

EXISTING ENVIRONMENT

General Habitat Conditions

Although habitat conditions were generally similar at the eight sites surveyed, there were subtle differences among sites in velocity (ANOVA: $F_{7, 40}$ = 3.99; P = 0.002), the degree to which the substrates were compacted (ANOVA: $F_{7, 40}$ = 17.46; P < 0.001) and embedded (ANOVA: $F_{7, 40}$ = 5.95; P < 0.001), the size of particles that dominated substrates of the stream bed (i.e. Substrate Index) (ANOVA: $F_{7, 40}$ = 8.48; P < 0.001), and the depth of fine sediments on the stream bed (ANOVA: $F_{7, 40}$ = 11.26; P < 0.001) (Table 3). However, these parameters did not differ significantly between the rehabilitation and reference sites: velocity (ANOVA: $F_{1, 46}$ = 0.53; P = 0.469); compactness (ANOVA: $F_{1, 46}$ = 3.03; P = 0.088); Substrate Index (ANOVA: $F_{1, 46}$ = 0.85; P = 0.360); water depth (ANOVA: $F_{1, 46}$ = 0.43; P = 0.513); and sediment depth (ANOVA: $F_{1, 46}$ = 0.53; P = 0.466) (Figures 2 & 3).

Spot water temperature measures at each site ranged from 9.8 – 13.2 °C, with the highest temperature recorded at Avon River near Durham Street (Rehabilitation Site 1) (Table 3). However, there was no significant difference in water temperature between rehabilitation and reference sites (ANOVA: $F_{1, 6}$ = 3.50; P = 0.111) (Figure 3). pH was similar across all sites (Table 3) with no difference in pH between rehabilitation and reference sites (ANOVA: $F_{1, 6}$ = 3.80; P = 0.099) (Figure 3). Specific conductivity, which can be a measure of the amount of pollutants in the water column, was variable among sites (Table 3), but was similar between reference and rehabilitation sites (ANOVA: $F_{1, 6}$ = 1.50; P = 0.267) (Figure 3).

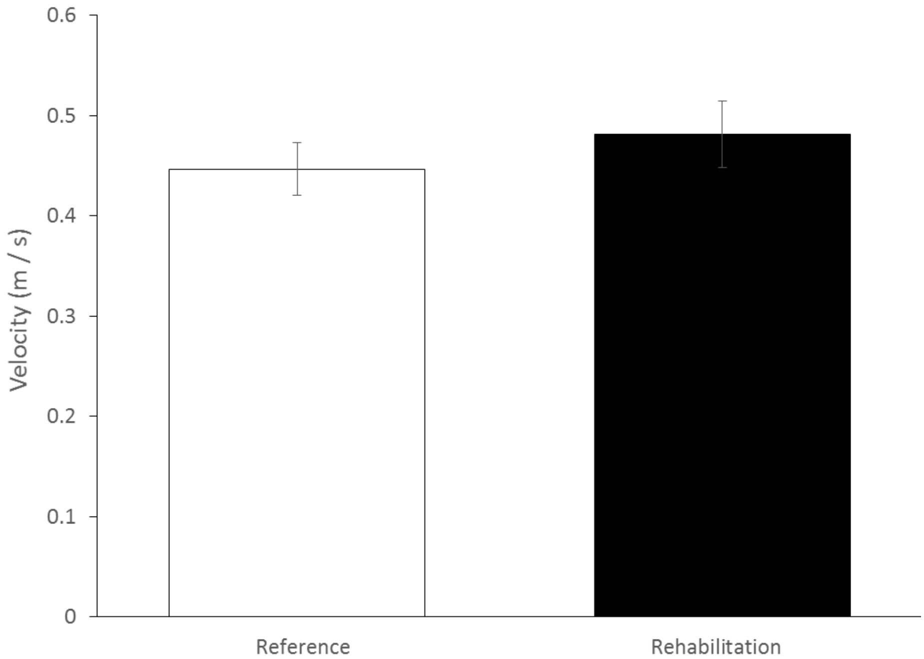

Figure 2. Average velocity (m / s) recorded at the reference and rehabilitation sites along the Avon River. Error bars are 1±SE.

Table 3. Average velocity, Substrate Index, embeddedness, eompactness, fine substrate depth, water temperature, pH, and conductivity at each of the reference and rehabilitation sites. SEs are shown in parentheses. Note, temperature, pH and conductivity were only measured once at each site.

Site		Velocity (m / s)	Substrate Index	Embeddedness	Compactness	Substrate Depth (cm)	Temperature (°C)	pH	Conductivity (µS / cm)
Downstream of Mona Vale weir	Ref1	0.43 (0.02)	2.6 (0.3)	2.3 (0.2)	3.8 (0.2)	2.8 (0.6)	9.8	8.3	189
Carlton Mill Corner	Ref2	0.43 (0.03)	2.5 (0.2)	1.9 (0.1)	3.3 (0.3)	3.4 (1.3)	10.1	8.6	191
In Hagley Park	Ref3	0.48 (0.07)	2.3 (0.5)	2.9 (0.2)	4.0 (0.0)	2.3 (0.6)	10.3	8.3	192
Near Durham Street	Rehab1	0.28 (0.03)	3.0 (0.3)	1.6 (0.1)	1.5 (0.2)	0.8 (0.5)	13.2	8.7	171
Rhododendron Island	Rehab2	0.59 (0.08)	1.5 (0.2)	1.9 (0.2)	4.0 (0.0)	12.7 (2.7)	12.2	8.7	128
Hereford Street (Mill Island)	Rehab3	0.42 (0.06)	3.2 (0.3)	2.5 (0.2)	3.7 (0.3)	1.2 (0.2)	11.0	8.6	174
Victoria Square	Rehab4	0.49 (0.06)	2.8 (0.3)	1.9 (0.1)	3.7 (0.2)	3.5 (2.0)	10.3	8.9	176
Near Kilmore Street	Rehab5	0.63 (0.04)	1.4 (0.2)	1.9 (0.2)	3.5 (0.2)	0.6 (0.2)	10.4	8.4	204

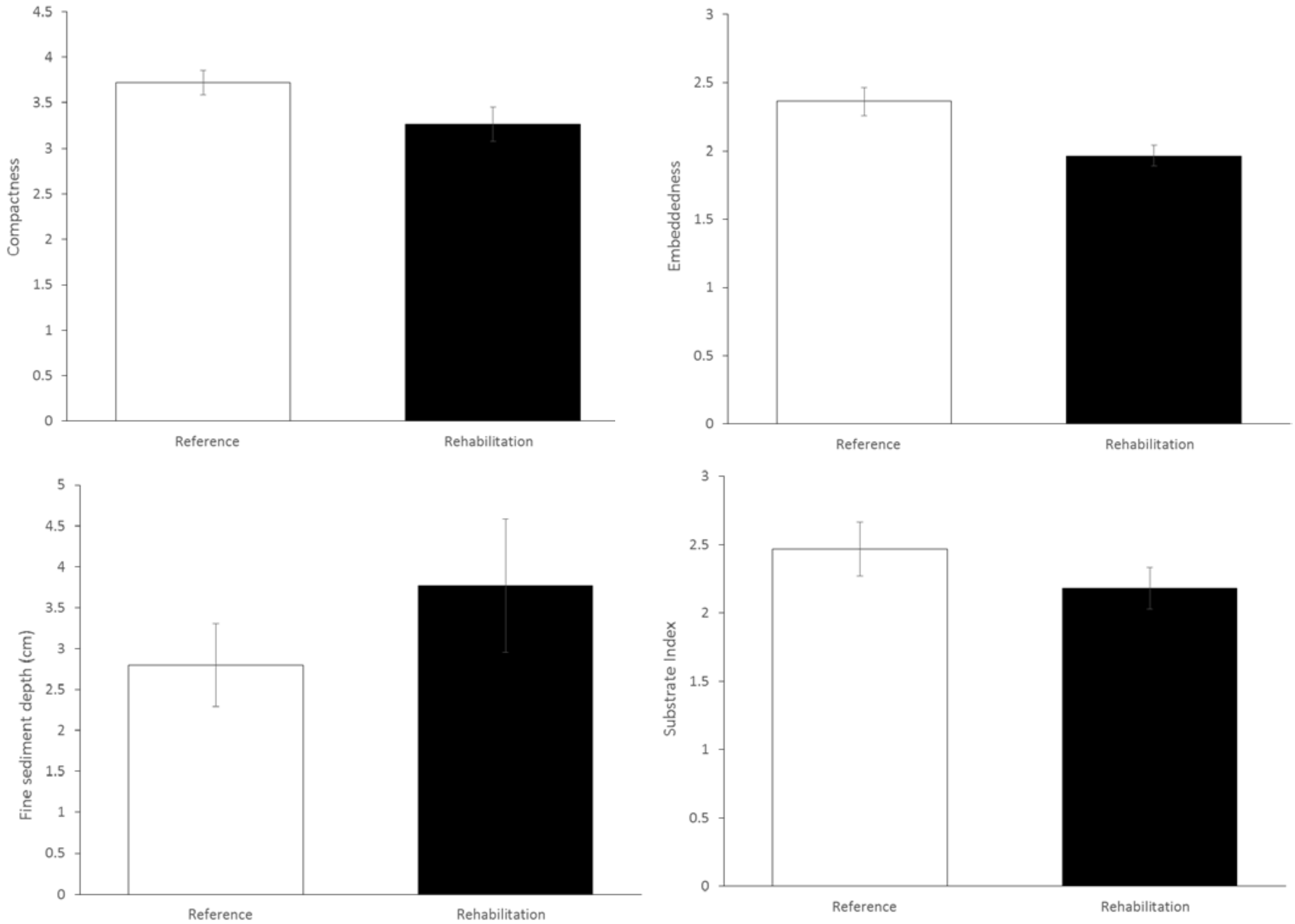

Figure 3. Average compactness (top, opposite page), embeddeness (bottom, opposite page), Substrate Index (top, this page) and fine sediment depth (cm) (bottom, this page) recorded at the reference and rehabilitation sites along the Avon River. Error bars are 1±SE.

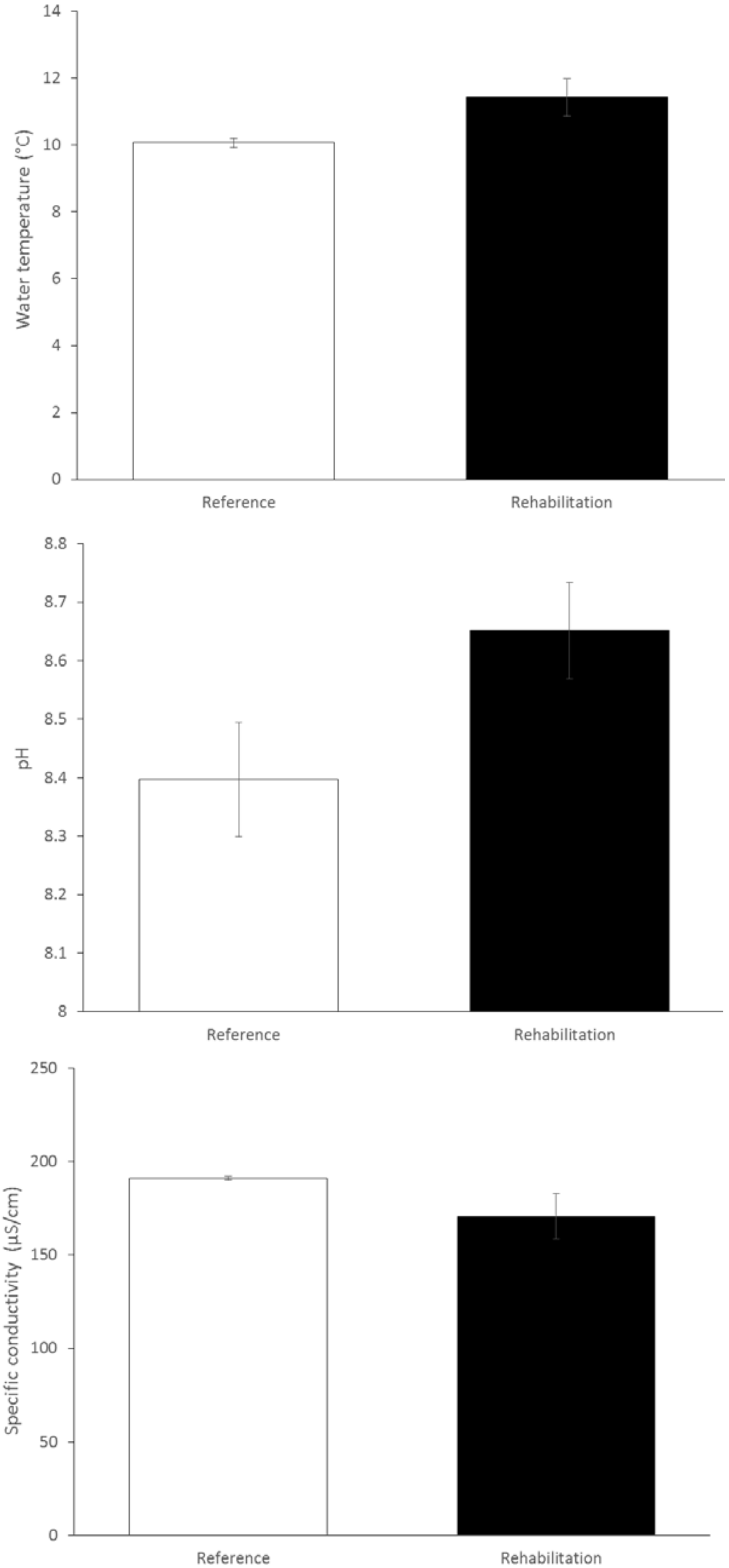

Figure 4. Water temperature, pH and specific conductivity recorded on one occasion at each site along the Avon River.

A brief summary of the general habitat conditions encountered at each site is given below.

Reference Site 1: Avon River downstream of Mona Vale weir

The upper most reference 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 0.43 m / s. The true right (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. The macrophyte *Erythranthe guttata* was abundant, albeit in patches, along the margins of the site. The true left (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. The substrates were slightly embedded (average embeddedness score of 2.3) and moderately-tightly packed (average compactness score of 3.8).

Reference Site 1: Avon River downstream of Mona Vale weir, looking downstream.

Reference Site 2: Avon River at Carlton Mill Corner

The second reference site was in the Avon River at the Carlton Mill Corner. Here the river was approximately 11 m wide with an average water depth of 49 cm and a velocity of 0.43 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. The substrates were slightly embedded (average embeddedness score of 1.9) and moderately packed (average compactness score of 3.3).

Reference Site 2: Avon River at Carlton Mill Corner, looking upstream.

Reference Site 3: Avon River in Hagley Park

The final, downstream most reference site was 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 0.48 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. These substrates were slightly-firmly embedded (average embeddedness score of 2.9) and tightly packed (average compactness score of 4).

Reference Site 3: Avon River in Hagley Park, looking downstream.

Rehabilitation Site 1: Avon River near Durham Street

The upper most rehabilitation site[6] 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 0.28 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. The substrates were generally only slightly embedded (average embeddedness score of 1.6) and mostly loose (average compactness score, 1.5).

Rehabilitation Site 1: Avon River near Durham Street, looking upstream towards the Antigua Boatsheds.

[6] It is important to note that this site had already been rehabilitated prior to this baseline survey, therefore, the data presented in this study should not be treated as 'before' data for the purposes of assessing improvements in ecological condition or rehabilitation success.

Rehabilitation Site 2: Avon River at Rhododendron Island

The second rehabilitation site was located downstream of Montreal Street and approximately 20 m upstream Rhododendron Island. Here the Avon River was approximately 15 m wide and on average 42 cm deep. The velocity on the day of sampling was 0.58 m / s. Both banks had scattered plantings of *Carex secta* and ferns, with relatively long, unmown grass to the water's edge. The banks of the river channel were concrete lined and channelised, limiting the amount of undercut banks in the survey section. The river bed was dominated by smaller substrates of sand and pebbles (Substrate Index of 1.5), but also with areas dominated by cobbles. The substrates were slightly embedded were (average embeddedness score 1.9) and tightly packed (average compactness score 4). Macrophyte beds dominated by *Elodea canadensis* and *Potamogeton crispus* were widespread in parts of the survey reach. Long filamentous green algae also dominated much of the sandy substrates.

Rehabilitation Site 2: Avon River at Rhododendron Island, looking upstream towards the Montreal Street Bridge.

Rehabilitation Site 3: Avon River at Hereford Street

The third rehabilitation site was located in the Avon River at the Hereford Street Bridge crossing. The survey reach extended both upstream of the Hereford Street Bridge and downstream along both sides of 'Mill Island'. Upstream of the bridge the river was approximately 15 m wide, however, the wetted width was around half this width either side of the island. The water depth was on average 36 cm, with a velocity of 0.42 m / s on the day of sampling. Both banks of the river upstream of the bridge were generally grassed with a few scattered *Carex secta*, ferns and large trees overhanging the water. Downstream of the bridge the riparian vegetation of Mill Island added a great deal of shading to the stream. However, the river banks were lined along the entire survey reach, again limiting the amount undercut banks at this site. The substrates varied upstream and downstream of Hereford Street Bridge. Upstream of the bridge the river bed was dominated by finer, sand substrates much of which were covered with long filamentous green algae. Large cobbles and boulders were present downstream at Mill Island, with submerged macrophytes including *Elodea canadensis* and long filamentous green algae. The average Substrate Index for the site was 3.2, indicating coarser substrates dominated the river bed. The substrates were slightly-firmly embedded (average embeddedness score 2.5) and moderately packed (average compactness score 3.7).

Rehabilitation Site 3: Avon River at Hereford Street, looking upstream through the Hereford Street Bridge (top photo) and upstream from Mill Island towards the Hereford Street Bridge (bottom photo).

Rehabilitation Site 4: Avon River at Victoria Square

Rehabilitation Site 4 was in the Avon River at Victoria Square, upstream of the Armagh Street Bridge. Here the river was approximately 12 m wide with an average depth of 38 cm and a velocity of 0.49 m / s on the day of sampling. 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. The substrates were slightly embedded (average embeddedness score 1.8) and moderately packed (average compactness score 3.7).

Rehabilitation Site 4: Avon River at Victoria Square, located upstream of the Armagh Street bridge (facing upstream).

Rehabilitation Site 5: Avon River near Kilmore Street

The final rehabilitation site on the Avon River was located near Kilmore Street; this 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), slightly embedded (average embeddedness score 1.9) and moderately packed (average compactness score 3.5).

Rehabilitation Site 5: Avon River near Kilmore Street, looking downstream

Macroinvertebrate Community

A total of 21,255 macroinvertebrates, belonging to 34 taxonomic groups, was collected from the 3 reference and 5 rehabilitation sites surveyed within the Avon River. The most diverse groups were the caddisflies (Trichoptera; 10 taxa) and the true flies (or two-winged flies; Diptera; 10 taxa). Freshwater snails and bivalves (Mollusca; 5 taxa) were the next most diverse group encountered, followed by crustaceans (Crustacean; 3 taxa), worms and leeches (Annelida; 2 taxa), *Hydra* (Cnidaria; 1 taxon), springtails (Collembola; 1 taxon), a freshwater moth (Lepidoptera; 1 taxon), and flatworms (Platyhelminthes; 1 taxon). No mayfly (Ephemeroptera) or stonefly (Plecoptera) taxa were found in any of the Avon River sites.

Crustaceans and dipterans numerically dominated the macroinvertebrate community, together making up 61% of all the macroinvertebrates collected from the eight sites (i.e. the total macroinvertebrate catch from all samples at all sites), along with molluscs and oligochaete worms. Although caddisflies were one of the most diverse groups, they only made up about 7% of the macroinvertebrate collected across all sites.

Orthocladiinae midges (of the dipteran family Chironomidae) were common at all of the sites, as were oligochaete worms, the ubiquitous native mud snail *Potamopyrgus antipodarium*, and the freshwater amphipod *Paracalliope fluviatilis*.

Macroinvertebrate abundance varied among the sites, ranging from 89 – 1394 individuals collected in the Surber samples. However, there was no difference in the average number of macroinvertebrates per m^2 collected at each site (ANOVA: $F_{7, 32} = 2.28$; $P = 0.052$) (Table 4), nor between reference and rehabilitation sites (ANOVA: $F_{1, 38} = 1.08$; $P = 0.306$) (Figure 5).

Taxonomic richness was less variable among sites, ranging from 7 – 17 taxa, however there was no difference in the number of taxa found among sites (ANOVA: $F_{1, 38} = 1.98$; $P = 0. 089$) (Table 4), nor between reference and rehabilitation sites (ANOVA: $F_{1, 38} = 0.50$; $P = 0.482$) (Figure 5). A few additional taxa were collected in the kick-net samples taken at each site, however, the trend of relatively similar taxon richness among sites remained consistent when total taxonomic richness (i.e. all macroinvertebrate taxa collected in the Surber and kick-net samples at each site) was considered (Figure 6).

Table 4. Average macroinvertebrate abundance, richness, EPT richness, and EPT except Hydroptilidae richness at the reference and rehabilitation sites. SEs are shown in parentheses.

Site		Abundance	Richness	EPT richness	EPT except Hydroptilidae richness
Downstream of Mona Vale weir	Ref1	443 (48)	13 (0.5)	4 (0.3)	4 (0.5)
Carlton Mill Corner	Ref2	163 (30)	10 (0.6)	3 (0.4)	3 (0.3)
In Hagley Park	Ref3	323 (71)	11 (1.3)	3 (0.2)	3 (0.2)
Near Durham Street	Rehab1	331 (75)	11 (1.1)	3 (0.5)	3 (0.5)
Rhododendron Island	Rehab2	607 (220)	14 (0.7)	3 (0.6)	2 (0.5)
Hereford Street	Rehab3	232 (55)	11 (0.5)	2 (0.0)	2 (0.0)
Victoria Square	Rehab4	444 (158)	11 (1.6)	2 (0.4)	2 (0.4)
Near Kilmore Street	Rehab5	422 (76)	14 (1.0)	3 (0.3)	3 (0.3)

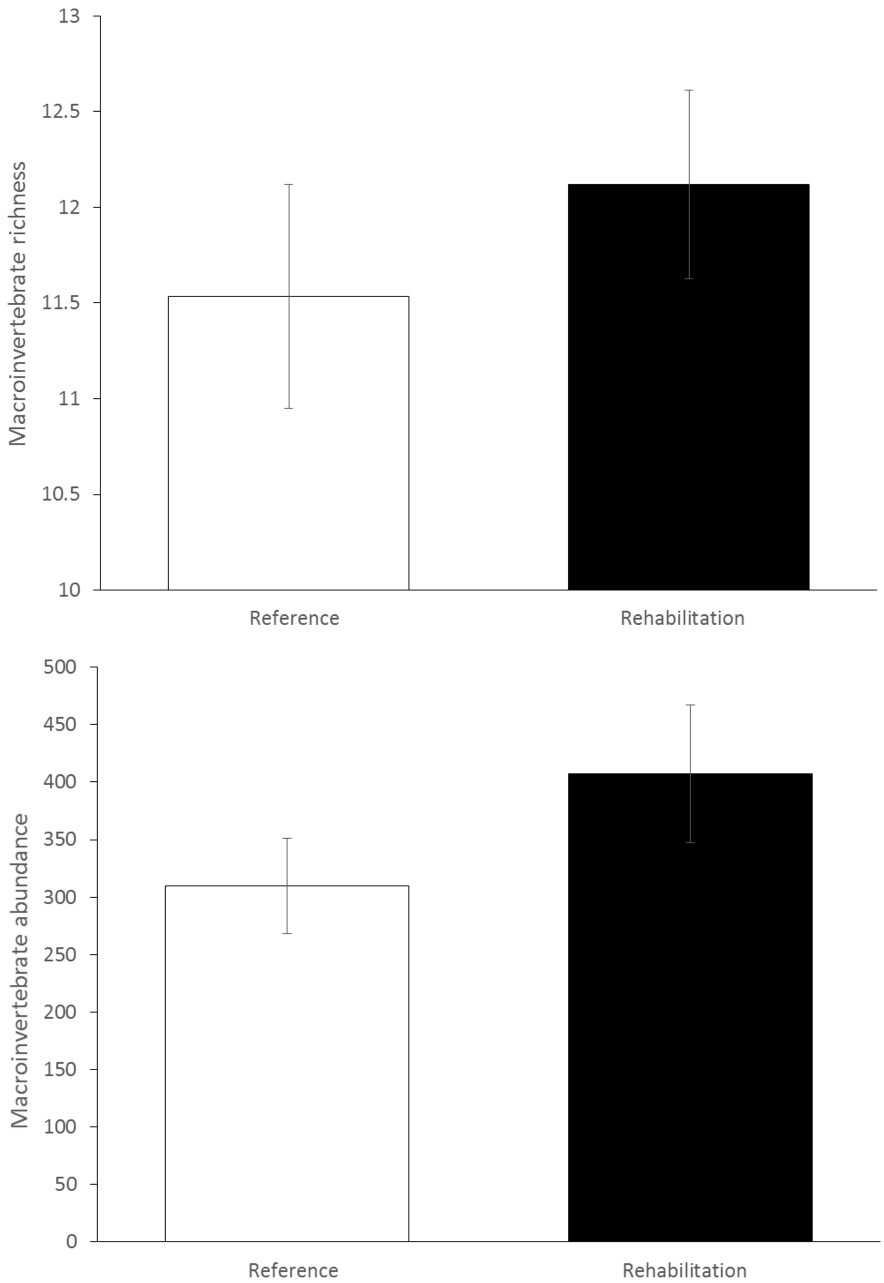

Figure 5. Average macroinvertebrate abundance (individuals / m^2) and average macroinvertebrate taxonomic richness recorded at the reference and rehabilitation sites along the Avon River. Error bars are 1±SE.

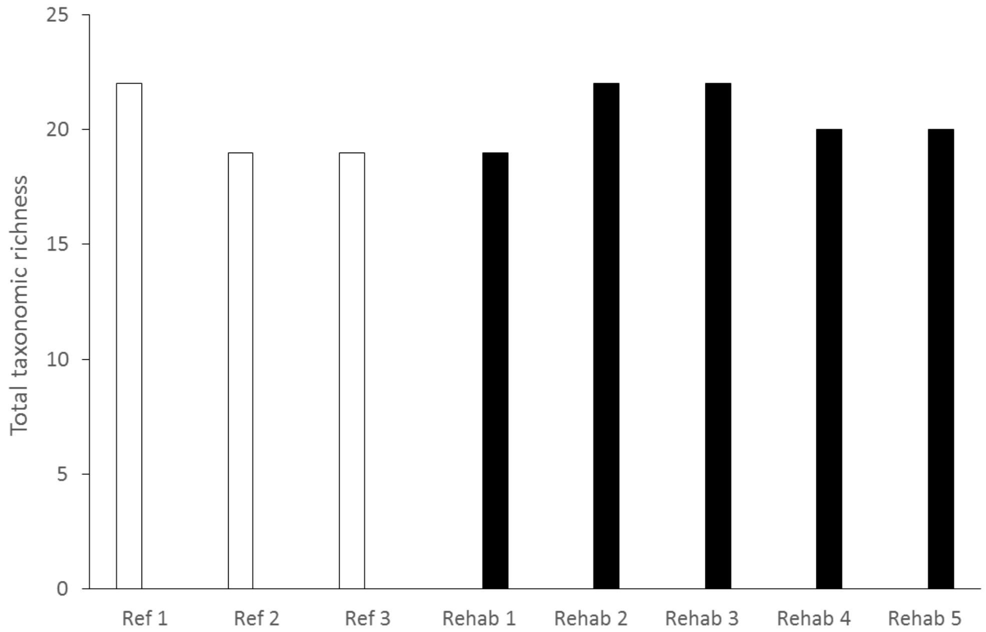

Figure 6. Total taxonomic richness of all macroinvertebrates collected in the Surber and kick-net samples collected at each site along the Avon River.

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. Caddisflies were the only group of the clean-water EPT taxa present in the Avon River and were found at all sites; mayflies and stoneflies were never found at any site. EPT richness (i.e. caddisfly richness) was variable among sites, ranging from 2 to 4 taxa. The greatest number, or diversity, of caddisflies was found in the upper-most reference site (Reference Site 1: Avon River downstream of Mona Vale weir), at two of the rehabilitation sites, (Rehabilitation Site 2: Avon River at Rhododendron Island; and Rehabilitation Site 5: Avon River near Kilmore Street). Although these differences in average EPT richness were statistically significant among sites (ANOVA: $F_{7, 32}$ = 2.73; P = 0.025) the difference was numerically negligible (i.e. a total difference of 2 taxa between the minimum and maximum number of caddisflies found at all sites).

On average, reference sites had slightly more caddisfly taxa (3.5 ± 0.19) than rehabilitation sites (2.6 ± 0.19) (ANOVA: $F_{1, 38}$ = 10.25; P = 0.003). However, again, these differences although statistically significant were likely only minor differences biologically.

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 of significant variation, or differences, in EPT richness among sites was found (ANOVA: $F_{7, 32}$ = 2.726; P = 0.025). However, rehabilitation sites had slightly more caddisfly taxa (excluding hydroptilids) (1.0 ± 0.19), than reference sites (0.8 ± 0.21) (ANOVA: $F_{7, 32}$ = 12.69; P = 0.001) (Figure 7).

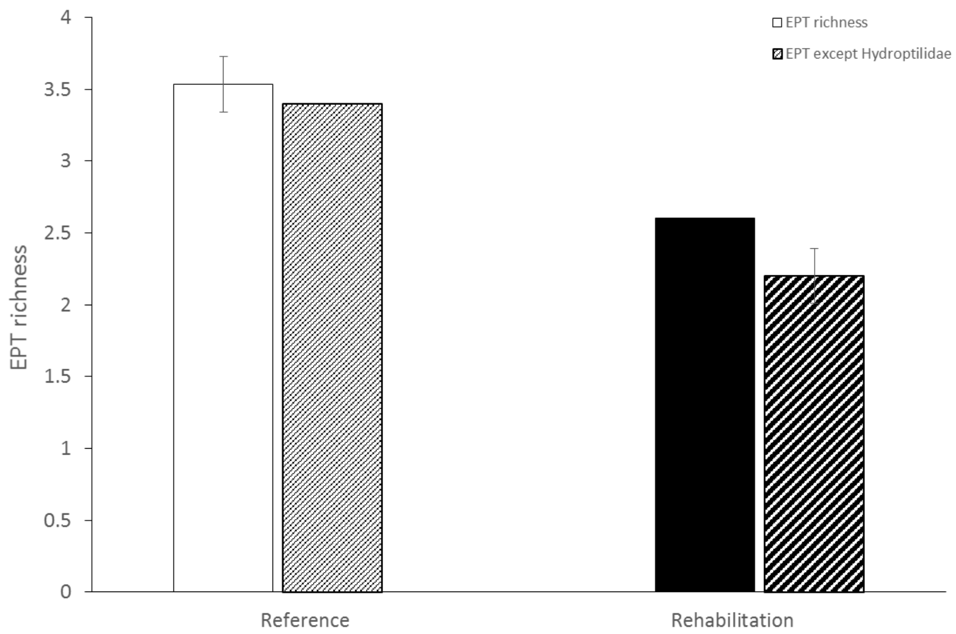

Figure 7. Average EPT richness, and EPT except Hydroptilidae richness collected from the reference and rehabilitation sites along the Avon River. Error bars are 1±SE.

MCI and QMCI scores are a measure of stream or ecological health, with higher scores indicating generally greater water-quality conditions and health. MCI scores were similar among sites (ANOVA: $F_{7, 32} = 1.80$; $P = 0.122$), with the MCI scores of all sites falling below 80 and indicating poor stream health, with probable severe enrichment (based on the water-quality categories of Stark and Maxted 2007) (Figure 8).

There was a subtle, yet significant, difference in the MCI scores calculated for reference and rehabilitation sites. Reference sites had slightly higher MCI scores, on average (77.2 ± 19.9), than rehabilitation sites (71.1 ± 14.2) (ANOVA: $F_{1, 38} = 9.71$; $P = 0.004$).

QMCI scores showed a very similar pattern, with all sites except Avon River downstream of Mona Vale weir (Reference Site 1), falling within the poor stream health, with probable severe enrichnment water-quality categories of Stark and Maxted (2007). QMCI scores varied significantly both among sites (ANOVA: $F_{7, 32} = 8.44$; $P < 0.001$) (Figure 8) and between reference and rehabilitation sites (ANOVA: $F_{1, 38} = 5.72$; $P = 0.022$). Reference sites had slightly greater QMCI values on average (3.6 ± 0.9), than rehabilitation sites (3.1 ± 0.1).

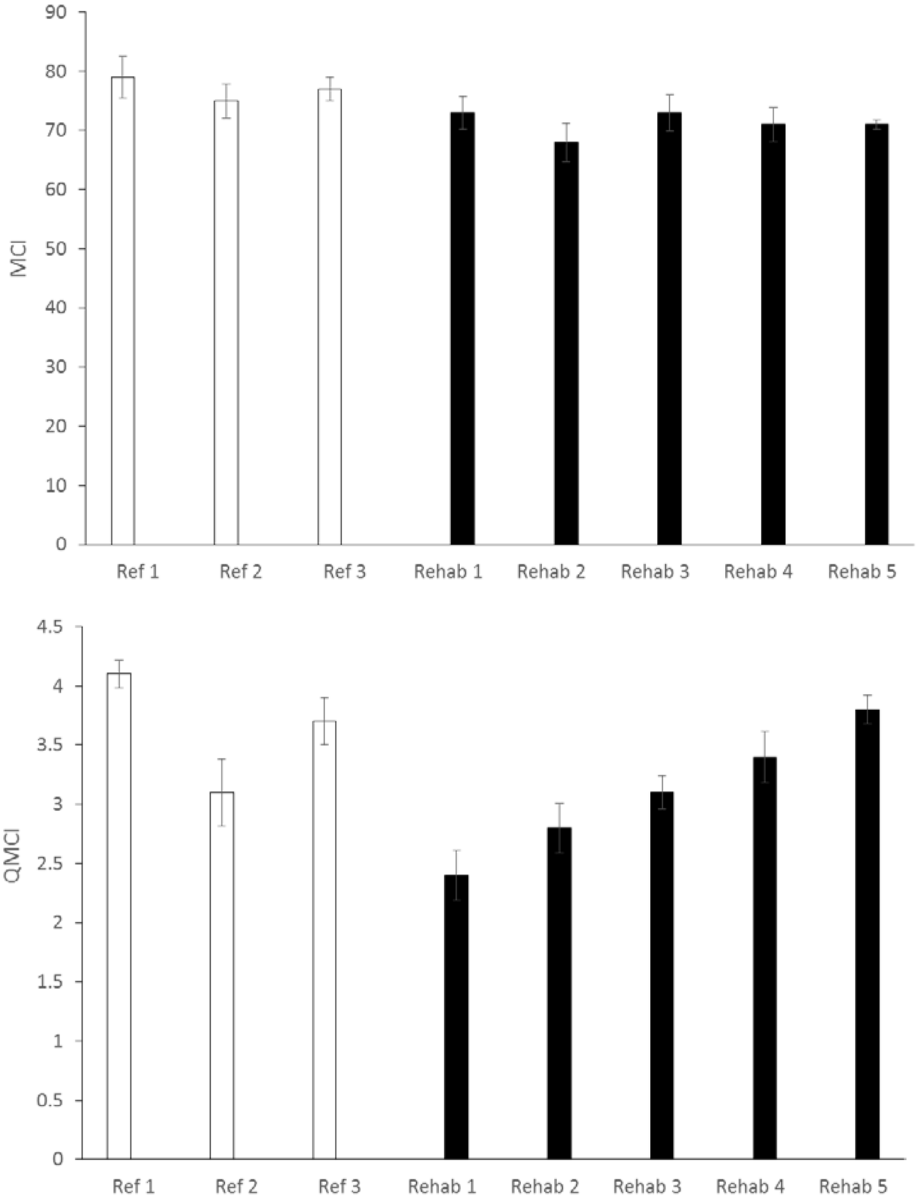

Figure 8. Average MCI and QMCI values for each of the reference and rehabilitation sites surveyed along the Avon River. Error bars are 1±SE.

While all sites were generally dominated by crustaceans (e.g. the freshwater amphipod *Paracalliope*), snails and bivalves (e.g. the ubiquitous mud snail *Potamopyrgus*), and true flies (e.g. orthoclad midge larvae) subtle differences in macroinvertebrate community composition among sites were observed (Figure 9). Caddisflies were present at all sites, but made up only a small proportion at many sites (Figure 9). Overall, macroinvertebrate community composition was similar across sites.

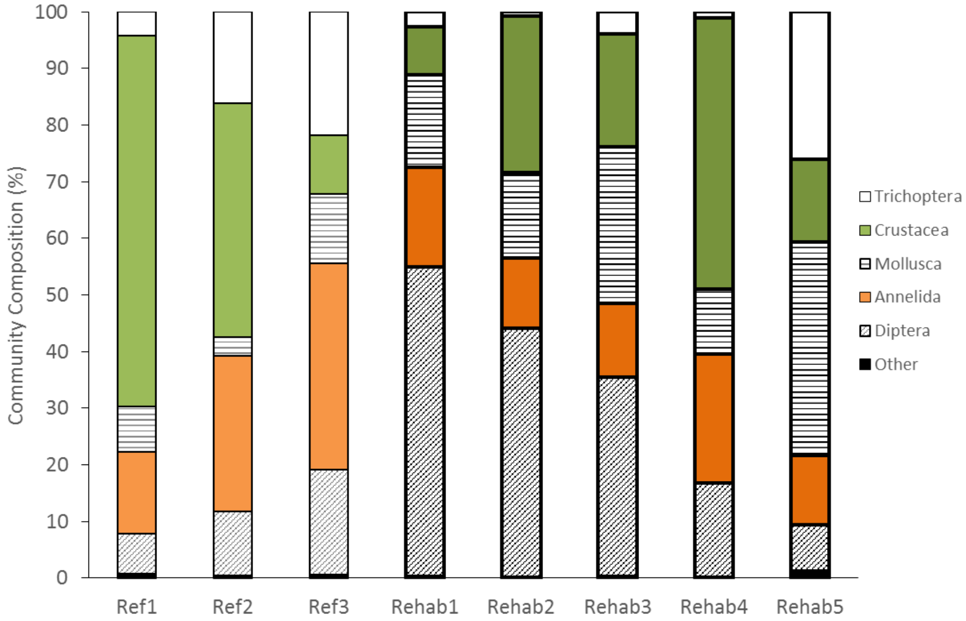

Figure 9. Macroinvertebrate community composition (%) at the reference and rehabilitation sites surveyed along the Avon River. 'Trichoptera' = caddisflies; Crustacea = freshwater crustaceans; Mollusca = snails and bivalves; 'Annelida' = oligochaete worms (Oligochaeta) and freshwater leeches (Hirudinea); Diptera = true flies or two-winged flies; 'Other' = springtails (Collembola), flatworms (Platyhelminthes), *Hydra* (Cnidaria) and the freshwater caterpillar (Lepidoptera) *Hygraula*.

The NMDS ordination further indicated this, where there were only slight differences in macroinvertebrate community composition, and the community within reference and rehabilitation sites was generally similar (Figure 10). The ANOSIM results confirmed this, indicating very weak, yet significant differences in macroinvertebrate community composition between reference and rehabilitation sites (ANOSIM: $R = 0.27$; $P = 0.001$).

SIMPER indicated that these weak, yet significant, differences were almost entirely (i.e. 90%) due to differences in abundances of six macroinvertebrate taxa: the freshwater amphipod *Paracalliope*; orthoclad midge larvae; the mud snail *Potamopyrgus*; oligochaete worms; the stony-cased caddis *Pycnocentrodes*; and seed shrimp ostracods.

See Appendix 3 for full SIMPER results.

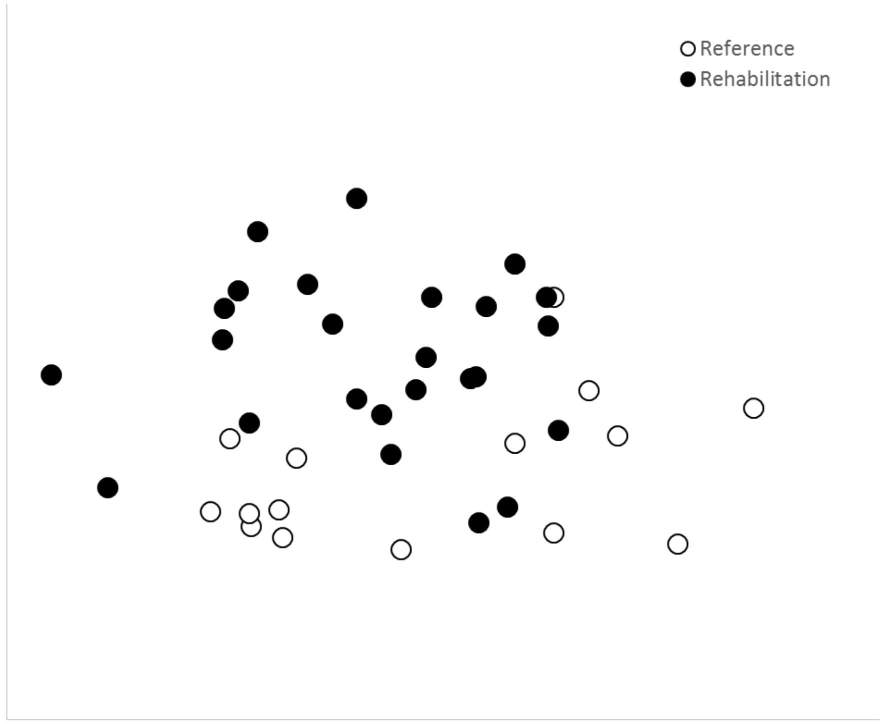

Figure 10. Non-metric multidimensional scaling (NMDS) ordination based on a Bray-Curtis matrix of dissimilarities calculated from macroinvertebrate abundance data collected in five Surber samples at each of 8 sites along the Avon River. The NMDS ordination has been graphically shown where sites are categorised as reference (white circles) or rehabilitation (black circles) sites. Note, the NMDS gave a good representation of the actual community dissimilarities between reference and rehabilitation sites (two-dimensional stress = 0.19). 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 324 fish, belonging to eight species, were captured in the 3 reference and 5 rehabilitation sites along the Avon River. The eight species were, in descending order of total abundance (i.e. across all sites): shortfin eel (*Anguilla australis*), common bully (*Gobiomorphus cotidianus*), bluegill bully (*Go. hubbsi*), longfin eel (*A. dieffenbachii*), brown trout (*Salmo trutta*), upland bully (*Go. breviceps*), inanga (*Galaxias maculatus*), and giant bully (*Go. gobioides*). Longfin eel, bluegill bully, and inanga are all listed as “declining”, while common, upland and giant bullies, and shortfin eels are currently listed as ‘not threatened’ (Allibone et al. 2010). Brown trout is an introduced species.

Species richness was relatively similar, with six fish species found at most sites. However, fewer fish species were found at the Carlton Mill Corner site (Reference Site 2), Hagley Park (Reference Site 3) and Rhododendron Island (Rehabilitation Site 2) (Figure 11).

Shortfin eels were the most commonly encountered species, being found at all of the reference and rehabilitation sites surveyed. Common bullies were found at six of the eight sites, while giant bullies were only found at one site, Hereford Street (Rehabilitation Site 3), amongst overhanging *Carex secta* planted along the true right banks of the Avon River. Threatened species (i.e. longfin eel, bluegill bully, and / or inanga) were found at all sites except at Hagley Park (Reference Site 3). Bluegill bullies were found in four of the Avon River sites, downstream of the Mona Vale weir (Reference Site 1), near Durham Street (Rehabilitation Site 1), at Victoria Square (Rehabilitation Site 4), and near Kilmore Street (Rehabilitation Site 5) (Figure 11).

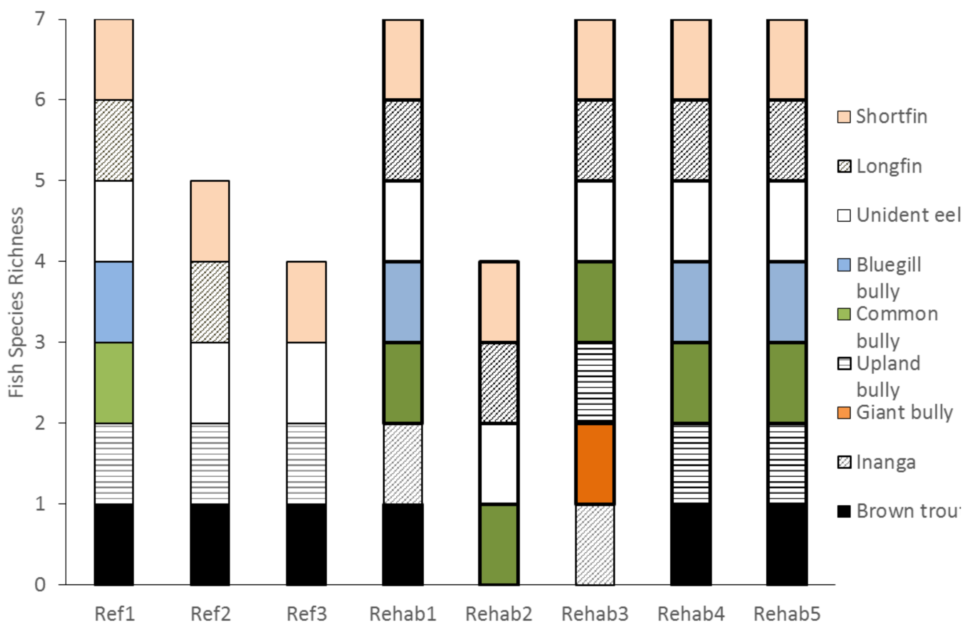

Figure 11. Species richness of fish captured during electro-fishing of reference and rehabilitation sites along the Avon River.

The total number of fish captured (expressed as number per 100 m^2) varied across the sites, ranging from 1.5 – 11.9 fish / 100 m^2. The most fish / 100 m^2 were captured near Kilmore Street (Reference Site 5). Figure 12 shows these fish catches categorised by the different species found at each site.

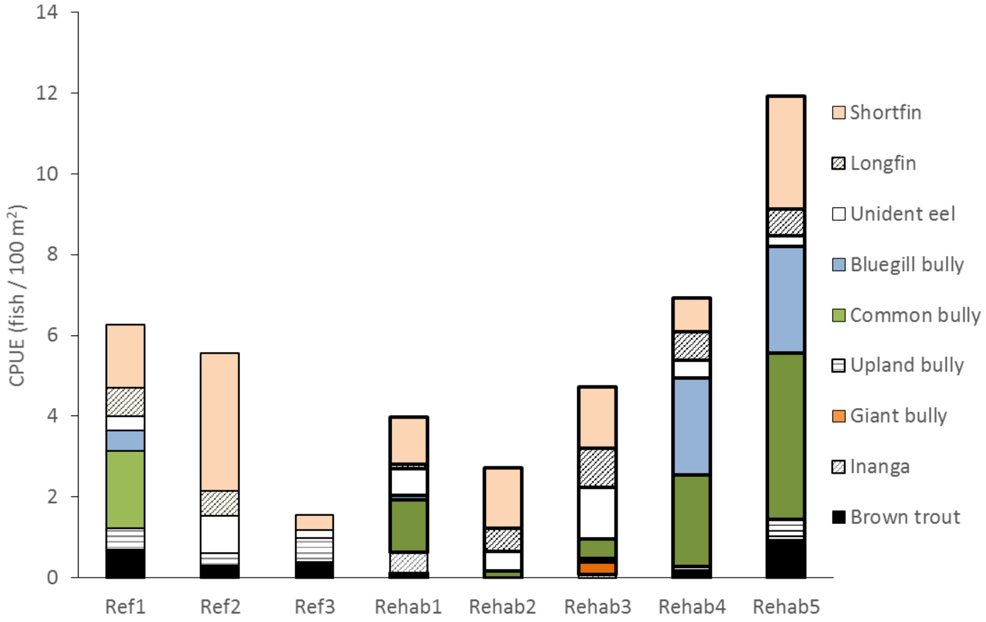

Figure 12. Fish abundance, expressed as number of fish captured per 100 m2 of area fished at each of the reference and rehabilitation sites along the Avon River.

The relative abundances of fish species found was relatively similar across sites, with the community being dominated by shortfin eels and common bullies (Figure 13). Bluegill bullies made up a substantial proportion of the community at the two downstream most rehabilitation sites, Victoria Square (Rehabilitation Site 4, 24%) and Kilmore Street (Rehabilitation Site 5, 34%) (Figure 13).

There appeared to be little difference in fish community composition between reference and rehabilitation sites.

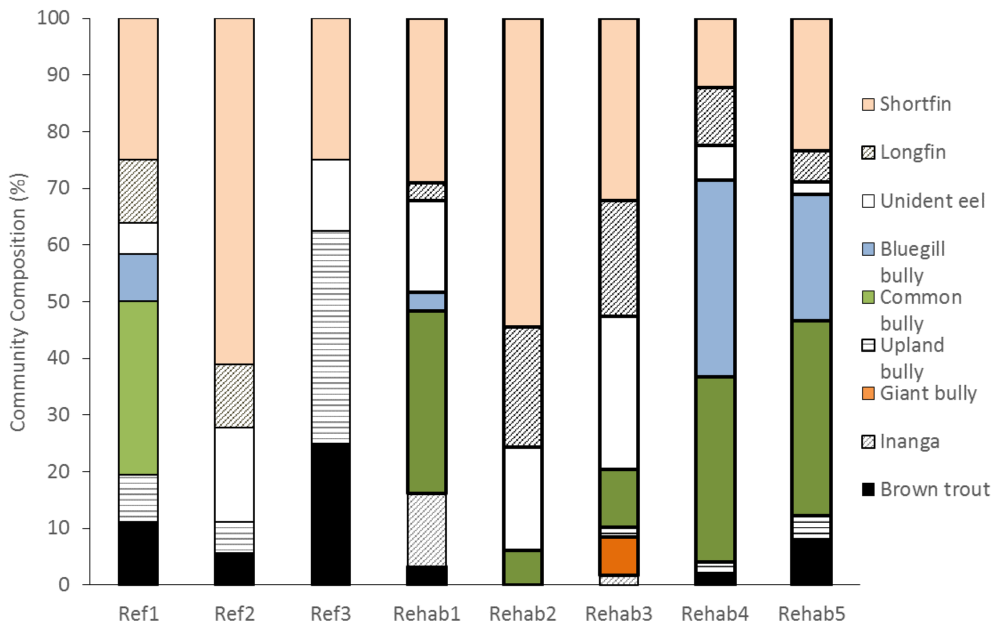

Figure 13. Community composition (%) of fish captured at the reference and rehabilitation sites surveyed using electro-fishing techniques along the Avon River.

SUMMARY

This ecological assessment of the Avon River within and upstream of the Avon River Precinct indicates that the waterway is of low or poor quality ecological health. The in-stream habitat conditions were generally degraded with low Substrate Indexes (i.e. stream bed dominated by finer substrates and generally lacking boulders), modified channels and low habitat diversity. Although there were some subtle differences in habitat conditions among the eight sites surveyed, there were few marked differences in overall habitat conditions between the reference and rehabilitation sites. These generally poor in-stream physical characteristics were also reflected by the macroinvertebrate community and ecological health of the river.

Both the upstream reference sites and the downstream rehabilitation sites (within the Avon River Precinct) were dominated by pollution-tolerant macroinvertebrate taxa, such as crustaceans, dipterans, orthoclad midges, oligochaete worms, the ubiquitous mud snail *Potamopyrgus antipodarium* and the freshwater amphipod *Paracalliope fluviatilis*. Caddisflies, which represent the more pollution-sensitive or clean-water taxa, were present at all sites but only in low numbers. Moreover, the Macroinvertebrate Community Index, which is a biotic index used to measure ecological health or condition based on the macroinvertebrate community present at a site, showed that all of the reference and rehabilitation sites were of poor water-quality and ecological health with probable severe pollution. Overall the macroinvertebrate and fish communities were similar between reference and rehabilitation sites. The only exception of ecological interest was the presence of bluegill bullies at three rehabilitation sites and one reference site.

This ecological assessment provides important information on the baseline conditions of four sites[7] where rehabilitation activities will be conducted along the Avon River as part of the Avon River Precinct project. It also provides information on baseline conditions of reference sites upstream of the Avon River Precinct, which will be used for comparative purposes post-rehabilitation activities.

[7] Note, rehabilitation activities had already been conducted at Watermark – Rehabilitation Site 1: Avon River near Durham Street. The data presented in this report are not representative of baseline conditions (i.e. prior to rehabilitation activities) and should be used with caution in future comparisons of rehabilitation success / improvements in ecological condition.

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Appendix 1: Supplementary Habitat Assessment Methods

Protocol 3 (P3) Quantitative protocol of Harding et al. (2009):

- P3b: Hydrology and morphology procedure, carried out by an Environment Canterbury hydrologist
- P3c: In-stream habitat procedure, conducted by Boffa Miskell ecologists; and
- P3d: Riparian procedure, conducted by Boffa Miskell ecologists;

Sediment Assessment Methods of Clapcott et al. (2011):

- Sediment Assessment Method 2 – in-stream visual estimate of % sediment cover; and
- Sediment Assessment Method 6 – sediment depth.

P3b field form

Site code		Site name	
Assessor		Date	

Reach assessment

Wetted width (m)		
Reach length (m)		
	Easting	Northing
Reach start		
Reach end		

Pool	Maximum depth(m)	Sediment depth (m)	Crest depth (m)
1			
2			
3			
4			
5			
6			

Meso-habitat length (m)					
Rapid	Run	Riffle	Pool	Backwater	Other

Plan diagram of the site (include significant land marks, access points, N direction, direction of stream flow, location of roads, rough scale)

Notes/comments

Cross sections

Run	Location+									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				
Velocity	0	0	0	0	0											0	0	0	0	0

+ 'head', 'middle' or 'tail' of run
LBF = left bank full, LB = left bank (for bank offsets record distance between ground and transect line in depth row), WE = water's edge

Run	Location+									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				
Velocity	0	0	0	0	0											0	0	0	0	0

Run	Location+									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				
Velocity	0	0	0	0	0											0	0	0	0	0

Riffle	Location[+]									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				
[+] 'head', 'middle' or 'tail' of run																				
Riffle	Location[+]									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				
Riffle	Location[+]									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				

Pool	Location$^+$									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				

$^+$ 'head', 'middle' or 'tail' of run
LBF = left bank full, LB = left bank (for bank offsets record distance between ground and transect line in depth row), WE = water's edge

Pool	Location$^+$									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				

Pool	Location$^+$									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				

P3c field form

Site name		Site code	
Assessor		Date	

Riffle 1	Cross-section	Wetted width (m)									
		1	2	3	4	5	6	7	8	9	10
	Substrate size										
	Embeddedness										
	Compactness										
	Depositional & scouring (cm)										
	Macrophytes (cm)										
	Algae (cm)										
	Leaf packs (cm)										
	Woody debris (cm)										
	Large boulders & log jams (count)										
	Bank cover (m)	Left bank					Right bank				

Riffle 2	Cross-section	Wetted width (m)									
		1	2	3	4	5	6	7	8	9	10
	Substrate size										
	Embeddedness										
	Compactness										
	Depositional & scouring (cm)										
	Macrophytes (cm)										
	Algae (cm)										
	Leaf packs (cm)										
	Woody debris (cm)										
	Large boulders & log jams (count)										
	Bank cover (m)	Left bank					Right bank				

Run 1											
	Cross-section	Wetted width (m)									
		1	2	3	4	5	6	7	8	9	10
	Substrate size										
	Embeddedness										
	Compactness										
	Depositional & scouring (cm)										
	Macrophytes (cm)										
	Algae (cm)										
	Leaf packs (cm)										
	Woody debris (cm)										
	Large boulders & log jams (count)										
	Bank cover (m)	Left bank					Right bank				

Run 2											
	Cross-section	Wetted width (m)									
		1	2	3	4	5	6	7	8	9	10
	Substrate size										
	Embeddedness										
	Compactness										
	Depositional & scouring (cm)										
	Macrophytes (cm)										
	Algae (cm)										
	Leaf packs (cm)										
	Woody debris (cm)										
	Large boulders & log jams (count)										
	Bank cover (m)	Left bank					Right bank				

Pool 1	Cross-section	Wetted width (m)									
		1	2	3	4	5	6	7	8	9	10
	Substrate size										
	Embeddedness										
	Compactness										
	Depositional & scouring (cm)										
	Macrophytes (cm)										
	Algae (cm)										
	Leaf packs (cm)										
	Woody debris (cm)										
	Large boulders & log jams (count)										
	Bank cover (m)	Left bank					Right bank				

Pool 2	Cross-section	Wetted width (m)									
		1	2	3	4	5	6	7	8	9	10
	Substrate size										
	Embeddedness										
	Compactness										
	Depositional & scouring (cm)										
	Macrophytes (cm)										
	Algae (cm)										
	Leaf packs (cm)										
	Woody debris (cm)										
	Large boulders & log jams (count)										
	Bank cover (m)	Left bank					Right bank				

P3d field form

Site name		Site code	
Assessor		Date	

	Buffer width (m)		Land slope		Distance to stopbank (m)		Distance to floodplain (m)	
Cross-section	LB	RB	LB	RB	LB	RB	LB	RB
1								
2								
3								
4								
5								

Riparian vegetation	Distance from LB (m)				Distance from RB (m)			
Cross-section 1	0.5	3	7.5	20	0.5	3	7.5	20
Native vegetation	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
Veg tier height								
0 - 0.3 m								
0.3 - 1.9 m								
2.0 - 4.9 m Shrubs								
5 - 12 m Subcanopy								
>12 m Canopy								
Cross-section 2								
Native vegetation	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
Veg tier height								
0 - 0.3 m								
0.3 - 1.9 m								
2.0 - 4.9 m Shrubs								
5 - 12 m Subcanopy								
Cross-section 3								
Native vegetation	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
Veg tier height								
0 - 0.3 m								
0.3 - 1.9 m								
2.0 - 4.9 m Shrubs								
5 - 12 m Subcanopy								
Cross-section 4								
Native vegetation	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
Veg tier height								
0 - 0.3 m								
0.3 - 1.9 m								
2.0 - 4.9 m Shrubs								
5 - 12 m Subcanopy								
Cross-section 5								
Native vegetation	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
Veg tier height								
0 - 0.3 m								
0.3 - 1.9 m								
2.0 - 4.9 m Shrubs								
5 - 12 m Subcanopy								
>12 m Canopy								

	Left bank	Right bank
Gaps in buffer		
Wetland soils		
Stable undercuts		
Livestock access		
Bank slumping		
Raw bank		
Rills/Channels		
Drains (count)		

Shading of water				

Notes

Sediment Assessment Method 2 – In-stream visual estimate of % sediment cover

Rationale	Semi-quantitative assessment of the surface area of the streambed covered by sediment. At least 20 readings are made within a single habitat
Equipment required	• Underwater viewer - *e.g.*, bathyscope (www.absolutemarine.co.nz) or bucket with a Perspex bottom marked with four quadrats • Field sheet
Application	Hard-bottomed streams
Type of assessment	Assessment of effects
Time to complete	30 minutes
Description of variables	
% sediment	A visual estimate of the proportion of the habitat covered by deposited sediment (<2 mm)
Useful hints	Work upstream to avoid disturbing the streambed being assessed. Mark a four-square grid on the viewer to help with estimates – determine the nearest 5% cover for each quadrat. Calculate the average of all quadrats as a continuous variable following data entry. More than five transects may be necessary for narrow streams, to ensure 20 locations are sampled.

Field procedure

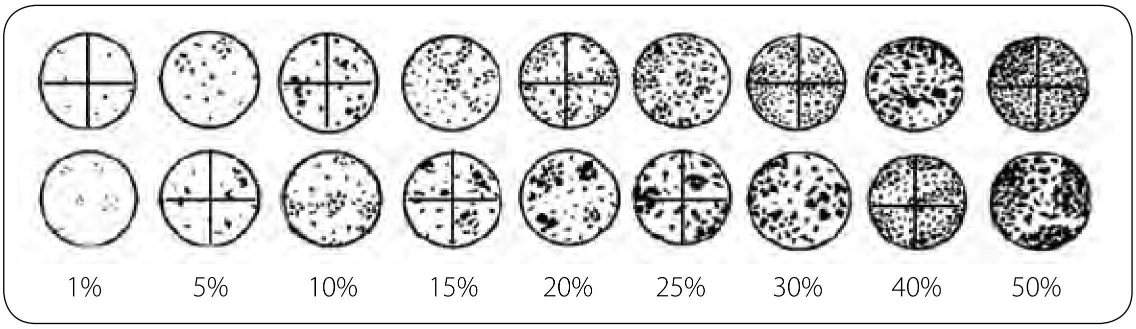
- Locate five random transects along the run.
- View the streambed at four randomly determined locations across each transect, starting at the downstream transect.
- Estimate the fine sediment cover in each quadrat of the underwater viewer in increments (1, 5, 10, 15, 20 …100%).
- Record results in the table below.
- Repeat for four more transects so that 20 locations are sampled in total.

Note: Estimation of cover in each quadrat is important during training but may not be necessary for experienced viewers – instead one measurement per location could be recorded.

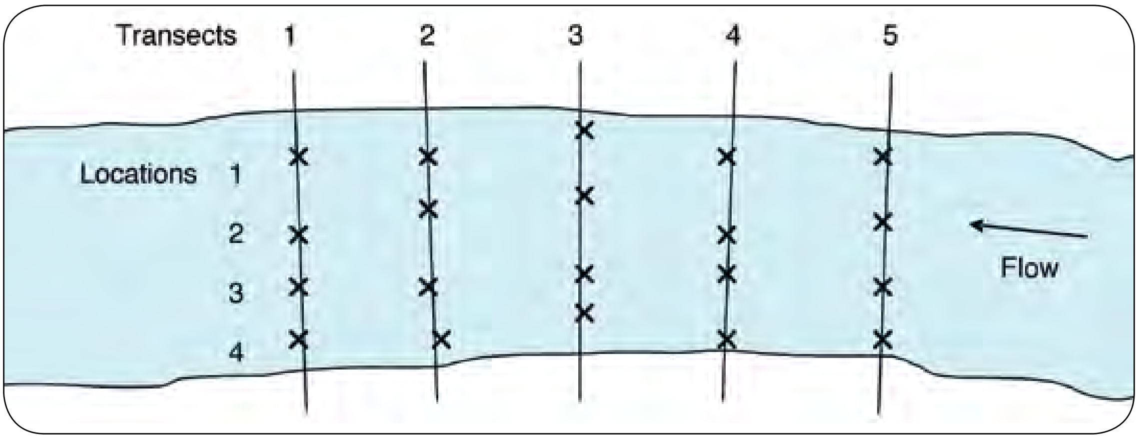
% sediment	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
Location 1	Q1	Q2								
	Q3	Q4								
Location 2										
Location 3										
Location 4										

Useful images

Digital examples of percent cover of sediment on the streambed as seen through an underwater viewer.



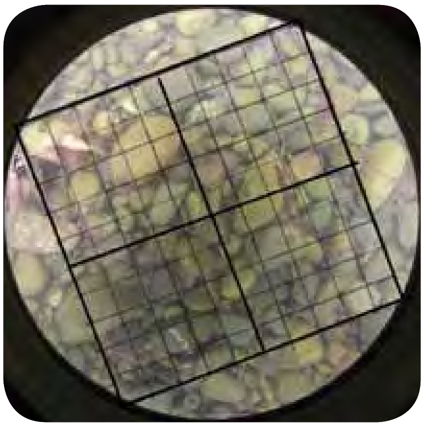
An example of viewer locations (x) for the in-stream visual assessment of sediment.



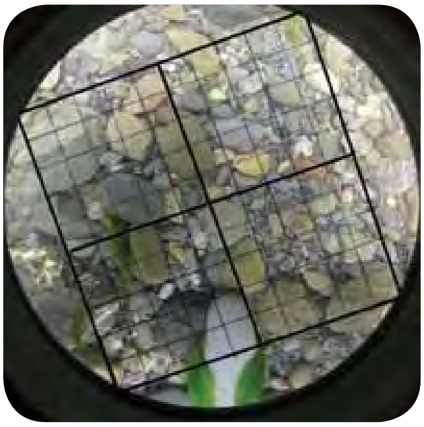
Real examples of percent cover of sediment on the streambed as seen through an underwater viewer.

1%

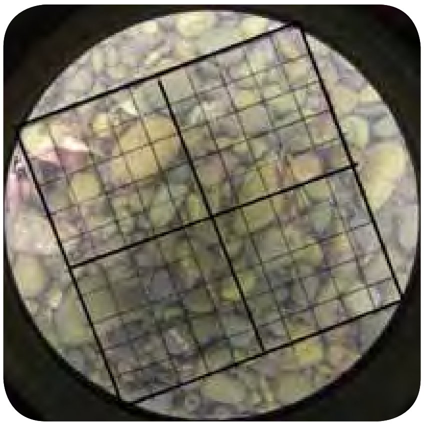
1%



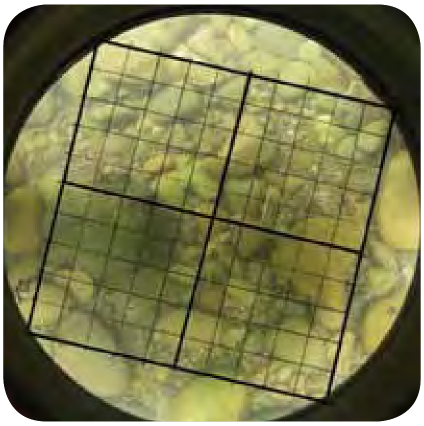
5%



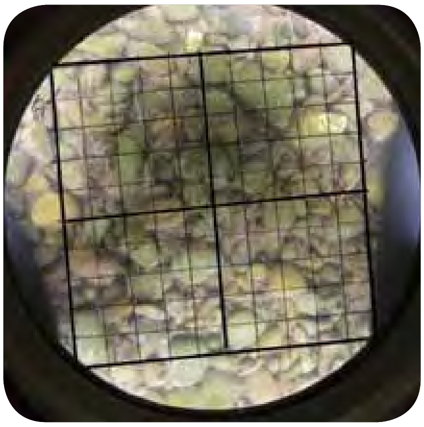
5%



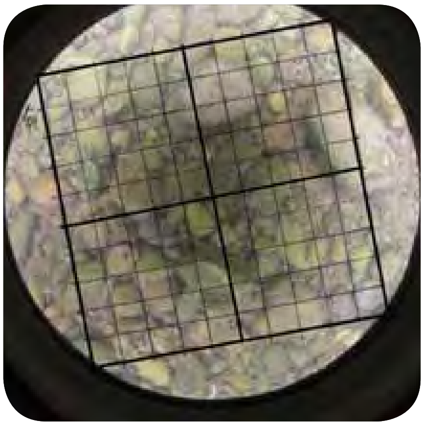
10%



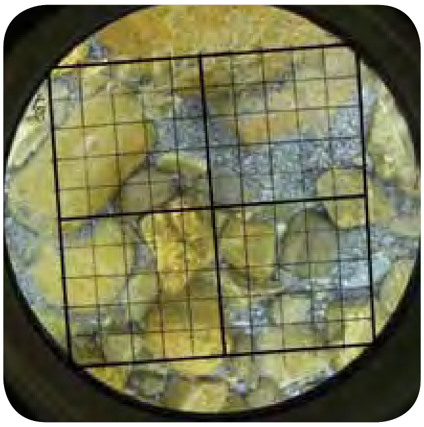
10%



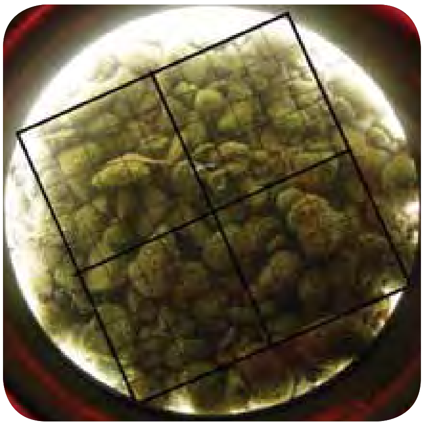
15%



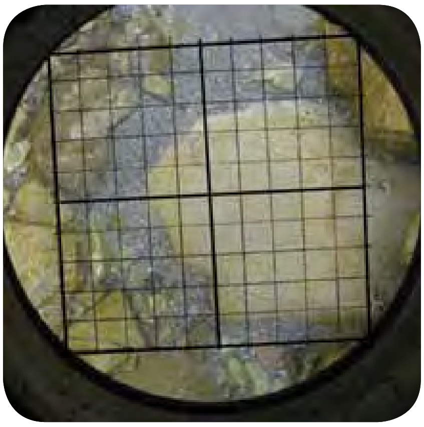
15%



20%

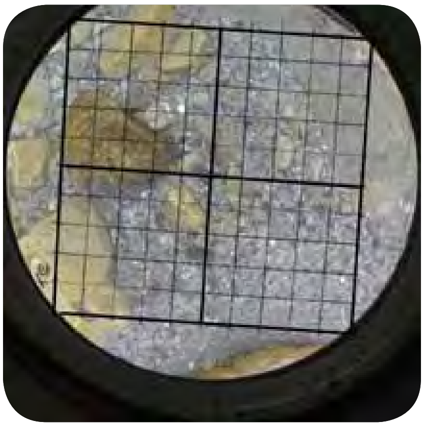


20%

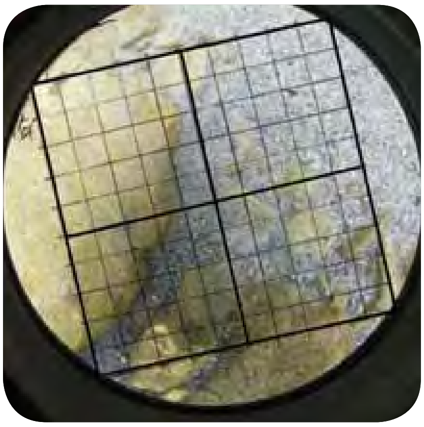


25%

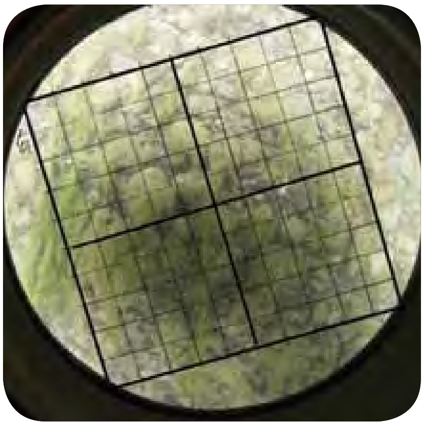
30%



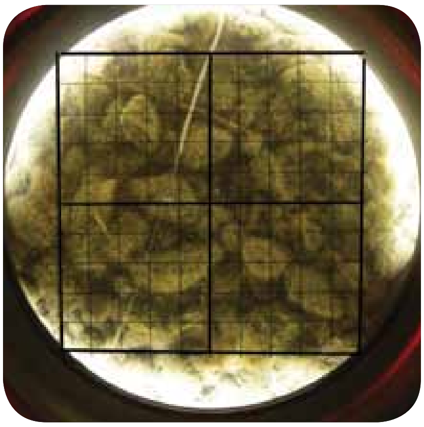
40%



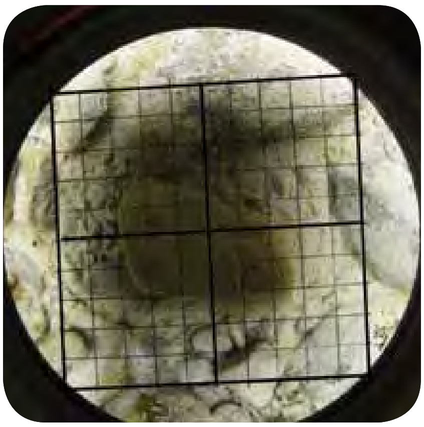
50%



90%



100%



Sediment Assessment Method 6 –Sediment depth

Rationale	Quantitative assessment of the depth of sediment in a run habitat. At least 20 readings are made within a single habitat
Equipment required	• Ruler or ruled rod • Field sheet
Application	Hard-bottomed streams
Type of assessment	Assessment of effects
Time to complete	30 minutes
Description of variables	
Sediment depth (mm)	A measure of the depth of sediment (mm).
Useful hints	Determine the sampling grid first to ensure an even cover of edge and midstream locations. Move upstream to avoid disturbing the streambed being assessed. Calculate the average depth for each site. This method is usually only suitable when fine sediment is visible from the stream bank.

Field procedure

- Start downstream and randomly locate five transects along the run.
- Measure the sediment depth (mm) at four randomly determined locations across each transect and record depth in the table below.

Depth (mm)	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5
Section 1					
Section 2					
Section 3					
Section 4					

Appendix 2: Ryder Consulting – Macroinvertebrate Processing

Boffa Miskell

C13132, November 2013

Summary of Freshwater Macroinvertebrate Sample Processing & Results

Prepared by Katie Blakemore, BSc.(Hons)

Reviewed by Ben Ludgate, MSc.

December 2013

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Dunedin
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Background

Preserved benthic macroinvertebrate samples were provided to Ryder Consulting by Boffa Miskell. Boffa Miskell staff collected these samples in November 2013. Ryder Consulting Ltd was engaged to process the C13132 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.

References

Winterbourn, M.J., Gregson, K.L.D. and Dolphin, C.H. 2006. Guide to the aquatic insects of New Zealand. *Bulletin of the Entomological Society of New Zealand*. **14**.

Appendix 3: SIMPER results

Reference Sites: Average similarity: 47.32

Macroinvertebrate taxon	Average Abundance	Percent Contribution
Paracalliope	141.73	38.33
Oligochaeta	70.60	31.78
Pycnocentrodes	21.80	9.01
Orthocladiinae	27.13	8.39
Potamopyrgus	16.07	4.40

Rehabilitation Sites: Average similarity: 48.26

Macroinvertebrate taxon	Average Abundance	Percent Contribution
Orthocladiinae	119.20	26.92
Potamopyrgus	76.00	23.25
Oligochaeta	63.16	22.92
Paracalliope	92.04	20.26

Reference Sites versus Rehabilitation Sites: Average dissimilarity = 59.72

Macroinvertebrate taxon	Average Abundance		Percent Contribution
	Reference	Rehabilitation	
Paracalliope	141.73	92.04	30.12
Orthocladiinae	27.13	119.20	21.82
Potamopyrgus	16.07	76.00	15.10
Oligochaeta	70.60	63.16	11.79
Pycnocentrodes	21.80	23.60	9.83
Ostracoda	5.13	11.32	1.92