Long-Term Monitoring of Aquatic Invertebrates in Christchurch's Waterways: Otukaikino and Styx River Catchments 2008

Prepared for
Chirstchurch City Council

Prepared by
EOS Ecology

EOS Ecology Report No. 06064-CCC02-01
October 2008

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CONTENTS

EXECUTIVE SUMMARY

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

This report summarises the results of the first year of monitoring, where nine sites each in the Otukaikino and Styx catchments were surveyed during March 2008. Sites along the mainstem rivers as well as tributary waterways were included in the monitoring programme. The sites surveyed had moderate flow and a reasonably coarse substrate of gravel or larger size. The invertebrate community was diverse, with 72 different taxa identified from both catchments; 67 taxa from the Otukaikino catchment and 56 from the Styx. The most diverse group in both catchments were caddisflies (Trichoptera) and two-winged flies (Diptera), with 17 different taxa identified in each of these groups.

In general the aquatic invertebrate communities of both catchments were in relatively good health, with a high abundance of cleanwater EPT taxa at most sites. Both catchments are regarded as the best example of lowland spring-fed stream systems within the Christchurch area, with the City's other main catchments (Avon, Heathcote, and Halswell) now supporting few EPT taxa. However, the more rural Otukaikino catchment supported a healthier invertebrate community than the partially urbanised Styx catchment, and five of the nine sites in the Otukaikino were ranked as the best of the surveyed sites. The Otukaikino catchment had a greater diversity and abundance of EPT taxa (which dominated the invertebrate community at an average of 45% abundance), and this was reflected in higher stream health indices such as MCI/QMCI and UCI/QUCI scores. However, this catchment was not devoid of impacts, with some areas in the upper catchment badly impacted by stock access.

The partial urbanisation of the Styx catchment was most likely responsible for the lower stream health compared to the Otukaikino catchment. In particular, the tributary waterways of this catchment were in the poorest health; possibly a consequence of their smaller size and therefore greater susceptibility to the impacts of urbanisation in their sub-catchments. It was interesting that the best areas in the Styx catchment were within and immediately downstream of the Styx Mill Reserve, which had no stormwater inputs and good riparian vegetation of native and exotic plants.

Current and future land development has the potential to have significant negative impacts on these unique waterways, with the sensitive EPT taxa likely to disappear with increased urbanisation. Given the pressure of urban development and poor rural management in some areas, it would be wise to monitor these two systems more regularly than every five years. In this way any significant decline in the invertebrate communities can used as an early warning system that may allow catchment management changes to be implemented before the decline becomes irreversible.

1 INTRODUCTION

In the Christchurch City Council's (CCC) Long-Term Council Community Plan (LTCCP; Christchurch City Council (2006)) Christchurch residents identified the retention and restoration of biodiversity and protection of the environment as key factors important to their wellbeing. The LTCCP states that the CCC will know it is succeeding in meeting these community desires when 'our lifestyles reflect our commitment to guardianship of the natural environment in and around Christchurch', when 'biodiversity is restored, protected and enhanced', and when 'we manage our city to minimise damage to the environment' (Christchurch City Council, 2006).

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

To be successful in achieving the community's desire for biodiversity and healthy ecosystems in the face of urban expansion and its negative impacts on waterways, first requires a better understanding of the current state of our waterways. In an attempt to achieve this the CCC, in conjunction with Environment Canterbury (ECan) and the Avon-Heathcote Estuary Ihutai Trust (see Batcheler *et al.*, (2006)), has decided to instigate a freshwater monitoring programme that will help to determine the existing state of our waterways and monitor any change in health over time.

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

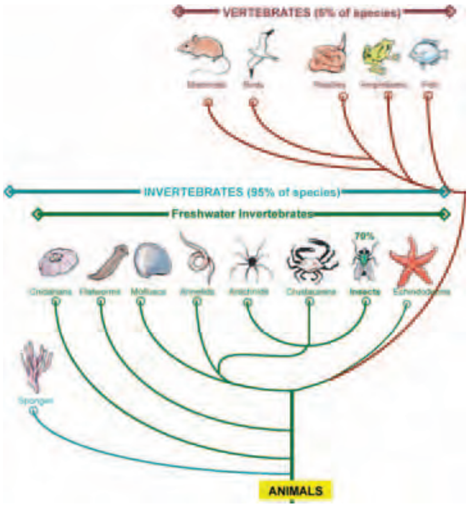
1.1 Why is Monitoring Important?

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

1.2 Why do Aquatic Invertebrates Matter?

Biodiversity

Bugs (invertebrates) make up 95% of the known animals on our planet and are the most diverse animal group. New Zealand's freshwater invertebrates are internationally unique as most are found nowhere else in the world and many are very primitive.



Fishing spider (Dolomedes)

Links to the terrestrial world

Aquatic insects have an adult terrestrial phase (i.e., they live on land), which links the stream and terrestrial food webs. These adult aquatic insects emerge from the water and mate on land before depositing their eggs back into the water. Many terrestrial predators depend on these winged adult insects for a large part of their diet and often congregate around waterways, preying on the emerging insects. Fantails, lizards, and our native fishing spider (*Dolomedes*) are just a few of the animals that love to eat these adult insects.

Resource managers of the freshwater world

Many feed on living and decomposing plant material (e.g., algae and detritus) and form a first link in the food chain. The energy they accumulate from the plants is passed onto higher predators, such as fish and birds, when they eat the invertebrates.

Upland bully (Gobiomorphus breviceps)

The invertebrates inhabiting these streams would be different because of the siltation of the streambed in the bottom picture.

As indicators of stream health

Freshwater invertebrates are good indicators of stream health. They are often relatively long-lived (up to a year or more), are sensitive to physical and chemical changes in their environment, and, unlike fish, have close associations with the streambed habitat. In addition, the assemblage of stream invertebrates in a river at a particular point in time reflects past stream conditions over a moderately long period, unlike water chemistry conditions that can change hourly.

Some invertebrates are more tolerant of organic pollution and siltation than others. Mayflies, stoneflies, and caddisflies (EPT taxa) are particularly sensitive to such pollution. The abundance of particularly pollution sensitive or insensitive taxa in a river can therefore be used to give an indication of its health.

2 METHODS

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

Due to CCC budgetary limitations, it was not possible to sample all five catchments at one time, thus a yearly programme was developed to sample one catchment per year, with a five-year repeat cycle for each catchment. The catchments will be surveyed in the following order: Otukaikino, Styx, Avon, Heathcote, and Halswell. This report represents the first year of the monitoring programme, where two river catchments have been sampled (the Otukaikino and Styx catchments) to make up for the lack of sampling in 2007, when the sampling programme was due to commence.

2.1 Site Selection

Nine sites were selected in the mainstem and key tributaries of both the Styx and Otukaikino rivers (Figure 1). Tributaries were included as their small size makes them more susceptible to changes in environmental conditions, such as water quality changes. Sampling sites were chosen in areas of riffle habitat, or if this did not exist, in runs with coarse substrate. These types of habitats were chosen for monitoring to better enable between-site comparisons and because these areas typically support the most diverse invertebrate communities that are also the most sensitive to change. Sections of waterway that are deeply silted will support an invertebrate community already tolerant of particularly degraded conditions and as such they will be unlikely to respond to small changes in water and habitat quality.

Initial site location was derived using local knowledge and the CCC's Christchurch River Assessment Survey (CREAS) data, with final locations modified to suit the on-site conditions. The most downstream site in each catchment represented the downstream extreme of wadeable water; below this point the rivers became very deep with silted substrates and extensive macrophyte beds.

Figure 1 Location of the nine sites in the Otukaikino River catchment (Sites 1–9) and nine sites in the Styx River catchment (Sites 10–18) surveyed from 12th to 27th March, 2008. Site photographs are provided in Appendix I.

2.2 Sampling

Following fine weather conditions, habitat and aquatic invertebrate communities were assessed between the 12th and 17th March in the Styx catchment, and between the 17th and 27th March in the Otukaikino catchment. At each site three equally-spaced transects were placed across the stream at 10 m intervals (i.e., at 0, 10, and 20 m) and aspects of the instream habitat and aquatic invertebrate community quantified along them. A detailed and quantitative methodology was developed to act as a suitable monitoring protocol that would enable a comparable repeat survey of habitat and invertebrate communities.

Instream habitat variables were quantified at twelve equidistant points across each of the three transects, with the first and last measurements across the transect at the water's edge. Habitat variables measured included substrate composition, presence and type of organic material, depths (water, macrophyte, and sediment), and water velocity. General bank attributes, including lower and upper bank height and angles, lower bank undercut, and lower bank vegetative overhang were measured for each bank at each transect. Bank material and level of stability were also assessed. These bank measurements are similar to those in the CREAS (Christchurch River Environment Assessment Survey) criteria developed for broad scale habitat surveys (McMurtrie & Suren, 2006).

The riparian zone condition was assessed within a 5 m band along the 20 m site on either side of the bank. The cover of 15 different vegetation types were estimated on a ranking scale of present (< 10%), common (10–50%), and abundant (> 50%). The vegetation was assessed three dimensionally so included ground, shrub, and canopy cover levels. The vegetation categories were taken from the CREAS criteria (McMurtrie & Suren, 2006).

Aquatic benthic invertebrates were collected at each transect by disturbing the substrate across an approximate 1.5 m width (e.g., 5 kicknet widths) and within a 0.3 m band immediately upstream of a conventional kicknet (ca. 500 µm mesh size; Figure 2). The full range of habitat types were surveyed across each transect,

Figure 2 Sampling for aquatic invertebrates across a transect at Site 16. Invertebrates collected across each transect (three per site) were pooled from five kicknets, which were collected from all habitat types present across the transect.

Figure 3 Aquatic invertebrates living on macrophytes (top) and the streambed (above) were some of the habitat types sampled across each site transect.

including mid-channel and margin areas, inorganic substrate (e.g., the streambed), and macrophytes (Figure 3). Each invertebrate sample was kept in a separate container, preserved in 60% isopropyl alcohol, and taken to the laboratory for identification. The contents of each sample were passed through a series of nested sieves (2 mm, 1 mm, and 500 µm) and placed in a Bogorov sorting tray (Winterbourn *et al.*, 2000). All invertebrates were counted and identified to the lowest practical level using a binocular microscope and several published keys (Winterbourn, 1973; Chapman & Lewis, 1976; Smith, 2001; Winterbourn *et al.*, 2006). Sub-sampling was utilised for particularly large samples and the unsorted fraction scanned for taxa not already identified. However, the use of sub-sampling was generally limited to the smallest sieve (500 µm), while both larger sieves were sorted in their entirety. Invertebrate counts were converted to percentage abundance values for analysis.

2.3 Data Analysis

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

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

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

Invertebrate data were summarised by taxa richness, total abundance, abundance of common taxa, and Detrended Correspondence Analysis (DCA) axis scores. Biotic indices calculated were the number of Ephemeroptera-Plecoptera-Trichoptera taxa (EPT richness), % EPT, the Macroinvertebrate Community Index (MCI), Urban Community Index (UCI), and their quantitative equivalents (QMCI and QUCI, respectively). The paragraphs below provide clarification on some of these metrics.

- **Taxa richness** is the number of different taxa identified in each sample. 'Taxa' is generally a term for taxonomic groups, and in this case refers to the lowest level of classification that was obtained during the study. Taxa richness can be used as an indication of stream health or habitat type, where sites with greater taxa richness are usually healthier and/or have a more diverse habitat.
- **DCA** is an ordination of data that is often used to examine how communities composed of many different taxa differ between sites. It can graphically describe communities by representing each site as a point (an ordination score) on an x–y plot. The location of each point/site reflects its community composition, as well as its similarity to communities in other sites/points. Thus points situated close together indicate sites with similar invertebrate communities, whereas points with little similarity are situated further away. Habitat variables can also be associated with the different axes, indicating whether the invertebrate communities are responding to habitat differences.
- **EPT** refers to three Orders of invertebrates that are generally regarded as 'cleanwater' taxa. These Orders are Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies); forming the acronym EPT. These taxa are relatively intolerant of organic enrichment or other pollutants and habitat degradation. The exception to the rule are hydroptilid caddisflies (e.g., Trichoptera: Hydroptilidae: *Oxyethira*, *Paraoxyethira*), which are algal piercers and often found in high numbers in nutrient enriched waters and urban streams. EPT richness and % EPT scores can provide a good indication as to the health of a particular site. EPT taxa are generally diverse in non-impacted, non-urbanised stream systems, although there is a small set of EPT taxa that are also found in urbanised waterways (e.g., hydroptilid caddisflies and some leptocerid caddisflies such as *Triplectides* and *Hudsonema*).
- The **MCI/QMCI** score can be used to determine the level of organic enrichment for stony-bottomed waterways in New Zealand (Stark, 1985). It calculates an overall score for each sample, which is based on pollution-tolerance values for each invertebrate taxon that range from 1 (very pollution tolerant) to 10 (pollution-sensitive). MCI is calculated using presence/absence data, whereas the QMCI score incorporates abundance data and so gives a more accurate result by differentiating rare taxa from abundant taxa. MCI scores <80 and QMCI scores <4 indicate poor stream conditions with probable severe organic pollution, whereas MCI scores >120 and QMCI scores >6 indicate excellent conditions and clean water (Boothroyd & Stark, 2000). MCI/QMCI indices are best suited to waterways with shallow depths (0.1–0.4 m), moderate velocities (0.2–1.2 m/s), and a coarse substrate (60–140 mm diameter (Stark, 1993); conditions which all the sites surveyed in this study met.
- The **UCI/QUCI** score can be used to determine the health of urban and peri-urban streams by combining tolerance values for invertebrates with presence/absence or abundance invertebrate data (Suren *et al.*, 1998). Negative scores are indicative of invertebrate communities tolerant of poor conditions and silted habitats, whereas positive scores are indicative of communities found in healthier streams, usually with clean water and coarse substrate (Suren *et al.*, 1998). This biotic index is indicative of habitat relationships, and to some degree incorporates urban impacts.

3 RESULTS

3.1 Habitat

Instream habitat was relatively similar between the Otukaikino and Styx catchments. Most sites in both catchments were between 2–7 m wide, although the two downstream sites on the Otukaikino River (Sites 1 and 2) were between 10–17 m wide (Figure 4). Substrate size was gravel sized or larger at all sites and was similar between sites and streams, apart from the larger small cobble sized substrate at Sites 12 and 17 (Styx catchment, Figure 4). Water velocity varied between sites and rivers, with all sites containing flowing water (Figure 4). The broad water velocity preferences of many of New Zealand's aquatic invertebrates (Jowett *et al.*, 1991) means that most of these sites contain habitat suitable for a wide range of aquatic invertebrates, including cleanwater EPT taxa.

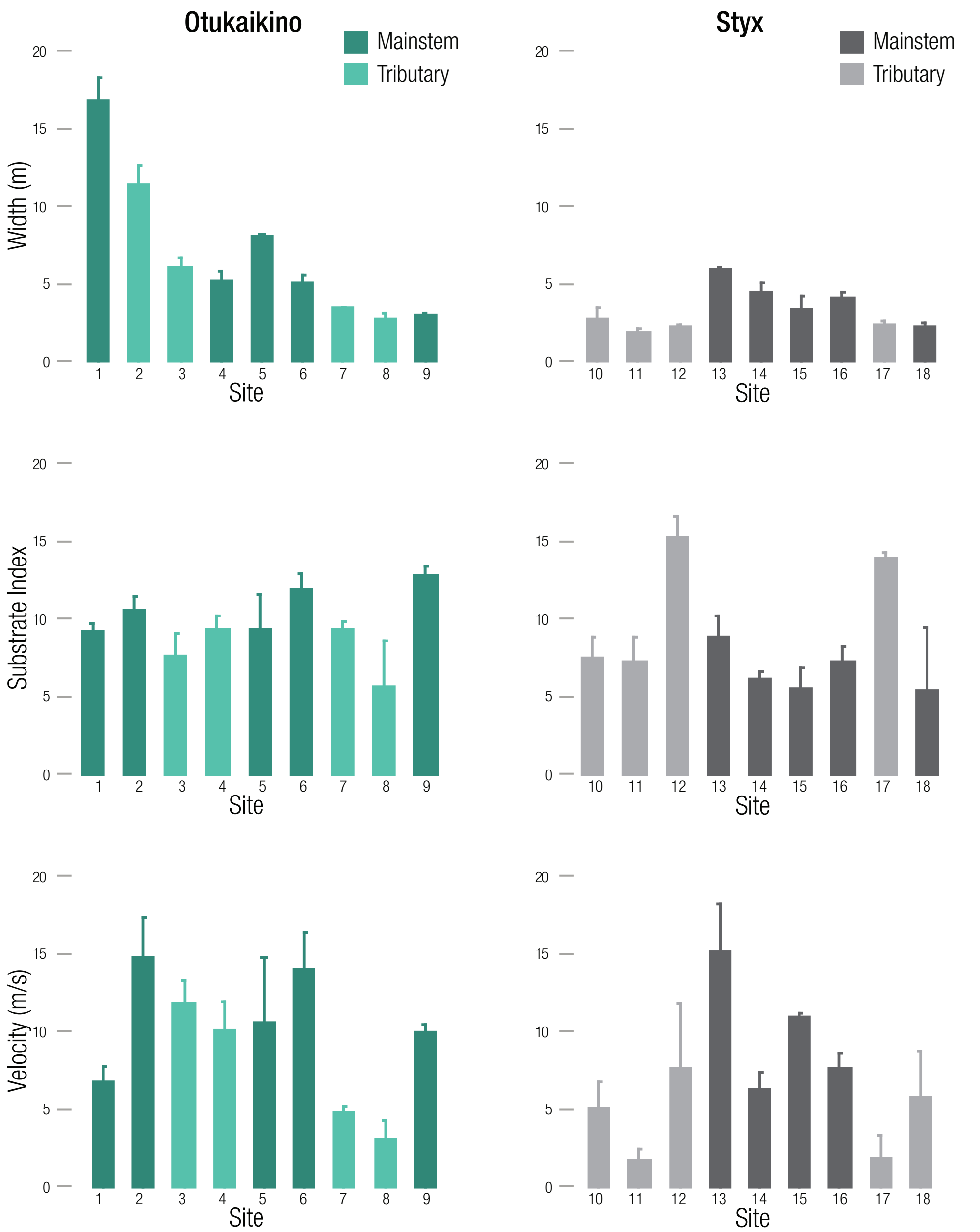


Figure 4 Aquatic habitat conditions at nine sites within each of the Otukaikino and Styx catchments, sampled between 12th and 27th March 2008. Sites 1 and 10 are the most downstream sites in the Otukaikino River and Styx River catchments, respectively. Tributaries are indicated on the graphs. For site locations refer to Figure 1.

3.2 Invertebrates

3.2.1 Overview

A total of 72 invertebrate taxa were recorded from the Otukaikino and Styx catchments, 67 taxa from the Otukaikino and 56 from the Styx. In both the Otukaikino and the Styx catchments the most diverse groups were the caddisflies (Trichoptera) and the two-winged flies (Diptera), with 17 taxa each. In the Otukaikino catchment, these groups were followed by crustaceans (Crustacea; 9 taxa), molluscs (Mollusca; 6 taxa), true bugs (Hemiptera; 4 taxa), mites (Arachnida: Acari; 2 taxa), mayflies (Ephemeroptera; 2 taxa), and damselflies (Zygoptera; 2 taxa). Groups in the Otukaikino catchment represented by one taxon included worms (Nematoda, Oligochaeta, Platyhelminthes), springtails (Hexapoda: Collembola), stoneflies (Plecoptera), leeches (Hirudinea), hydra (Cnidaria: Hydrozoa: Hydridae), and beetles (Coleoptera). In the Styx catchment, caddisflies and two-winged flies were followed in diversity by crustaceans (Crustacea; 6 taxa), molluscs (Mollusca; 5 taxa), mites (Arachnida: Acari; 2 taxa), and damselflies (Zygoptera; 2 taxa). Groups in the Styx catchment represented by one taxon included worms (Nematoda, Oligochaeta, Platyhelminthes), mayflies (Ephemeroptera), springtails (Hexapoda: Collembola), hydra (Cnidaria: Hydrozoa: Hydridae), and beetles (Coleoptera).

The most numerically abundant taxa in the Otukaikino catchment were the freshwater snail *Potamopyrgus antipodarum* (24.8% ± 4.7%), the caddisflies *Pycnocentria* (14.6% ± 3.8%), *Pycnocentrodes* (11.4 % ± 3.9%), and *Aoteapsyche* (6.9% ± 2.2%), the amphipod *Paracalliope fluviatilis* (6.6% ± 3.2%), and the introduced snail *Physella* (5.2% ± 2.0%; Figure 5). In the Styx catchment the most numerically abundant taxa were the amphipod *P. fluviatilis* (32.6% ± 8.0%), the snail *P. antipodarum* (27.6% ± 7.3%), microcrustacean ostracods (8.2% ± 1.9%), orthoclad chironomids (7.1% ± 3.3%), and the caddisfly *Pycnocentrodes* (5.0% ± 2.1%; Figure 5).

In the Otukaikino catchment the most widespread taxa, which occurred in every sample collected, were EPT taxa; the caddisflies *Aoteapsyche, Pycnocentria,* and *Pycnocentrodes* (Figure 5). In the Styx catchment only the caddisfly *Triplectides obsoletus* occurred in every sample (Figure 5). The next most widespread taxa in the Styx catchment (occurred in 26 of the 27 samples) were more pollution tolerant taxa, such as oligochaete worms, microcrustacean ostracods, the amphipod *P. fluviatilis,* and the snail *P. antipodarum* (Figure 5).

In the Otukaikino catchment there were eight rare taxa that occurred in only one collected sample each; microcrustacean cladocerans, the chironomid *Chironomus zelandicus,* the tipulids *Limonia* and *Paralimnophila,* the sciomyzid fly *Neolimnia,* the cased caddisfly *Oeconesus,* the shrimp *Paratya curvirostris,* and the damselfly *Xanthocnemis zealandica.*

In the Styx catchment there were 13 rare taxa, occurring in only one sample each. These were dominated by fly species; ceratopogonid flies, the chironomids *Maoridiamesa* and *Polypedilum,* the tanyderid *Mischoderus,* stratiomyids, and the tipulid *Zelandotipula.* Other rare taxa included cyclopoid copepods, the freshwater limpet *Ferrissia,* the hydrobiosid caddisfly *Hydrobiosis umbrepennis,* the cased caddisfly *Olinga,* and the damselfly *X. zelandica.*

3.2.2 Catchment Comparisons

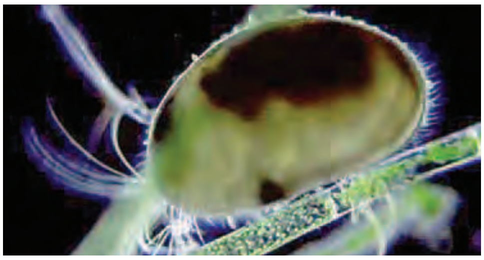
The DCA showed distinctive differences in invertebrate community composition between the two catchments (Figure 6). The Styx catchment sites had higher Axis 1 scores and were more associated with pollution tolerant taxa such as amphipods, ostracods, and chironomids (*Corynoneura* and *Maoridiamesa*), as well as the caddisflies *Oxyethira* and *Triplectides*. In contrast, sites in the Otukaikino catchment

Pollution-Tolerant Taxa

5a: The native snail *Potamopyrgus antipodarum*
Otukaikino: 24.8%; Styx: 27.6%, widespread

5c: The amphipod *Paracalliope fluviatilis*
Otukaikino: 6.6%; Styx: 32.6%, widespread

5e. The introduced snail *Physella*
Otukaikino: 5.2%



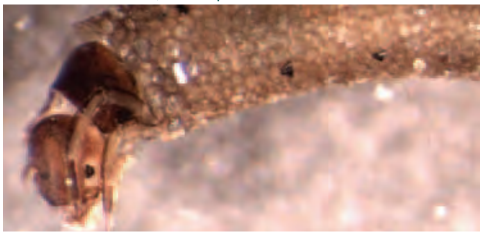
5g. A microcrustacean ostracod
Styx: 8.2%, widespread

5i. An Orthoclad chironomid
Styx: 7.1%

5j. Oligochaete worm
Styx: widespread

Cleanwater Taxa

5b: *Aoteapsyche*
Otukaikino: 6.9%, widespread



5d. *Pycnocentria*
Otukaikino: 14.6%, widespread

5f. *Pycnocentrodes*
Otukaikino: 11.4%, widespread; Styx: 5%

5h. *Triplectides obsoletus*
Styx: <5%, widespread

Figure 5 Photographs of the most abundant (% indicated) and widespread (found in at least 26 of the 27 samples) aquatic invertebrates in the Otukaikino and Styx catchments. Photos © Shelley McMurtrie. except 5j © Stephen Moore, Landcare Research.

had lower Axis 1 scores and were more associated with pollution sensitive EPT taxa such as the caddisflies *Neurochorema*, *Pycnocentria*, *Olinga*, and *Aoteapsyche*, and the mayfly *Coloburiscus*. No habitat variables (water depth, velocity, substrate size, and sediment depth) were significantly correlated with the DCA axes. For the Otukaikino catchment Site 9 (upper Otukaikino River) appeared to be an outlier (e.g., quite different to the rest of the sites), while in the Styx catchment Site 17 (Smacks Creek) was also different.

In general, most sites in the Otukaikino catchment were ranked in better health than the Styx catchment (Table 1). The majority of sites in the Otukaikino catchment had higher MCI, QMCI, and QUCI stream health scores, and contained a much higher abundance (%) and diversity (number) of EPT taxa than the Styx catchment (Figure 7, Table 2). Caddisflies dominated both the number of the EPT taxa and their percentage abundance in the both catchments, and while mayflies were at similar abundances in both catchments they were more widespread in the Otukaikino catchment than in the Styx catchment (Figure 7). Stoneflies were only found in the Otukaikino catchment; at Sites 5 (Otukaikino River), 7 (North Boundary Stream), and 8 (North Boundary Stream; Figure 7).

The majority of Styx catchment sites ranked lower than the Otukaikino sites in terms of overall health, and had the four worst-ranked sites (Site 10, 11, 12, and 17; Table 1). However, four sites within and immediately downstream of the Styx Mill Reserve in the Styx catchment (Site 13, 14, 15, and 16) had similar taxa richness, MCI scores, and abundance of EPT taxa to many of the Otukaikino sites (Figure 7).

Sites 1–5 in the Otukaikino catchment ranked the best out of both catchments, with high values for all of the biotic indices (Table 1). Sites 1, 2, 3, and 4 were categorised as having only "mild" levels of organic pollution based on either the MCI or QMCI scores, while the rest of the Otukaikino catchment sites and all the Styx catchment sites were classified with moderate or severe organic pollution (Figure 7). Site 5 had the greatest number of EPT taxa (14) and the second-highest % EPT and QMCI scores of all the sites. Site 6 and 9 ranked the lowest of the Otukaikino catchment sites, which was reflected in the lower MCI and QMCI scores for this catchment.

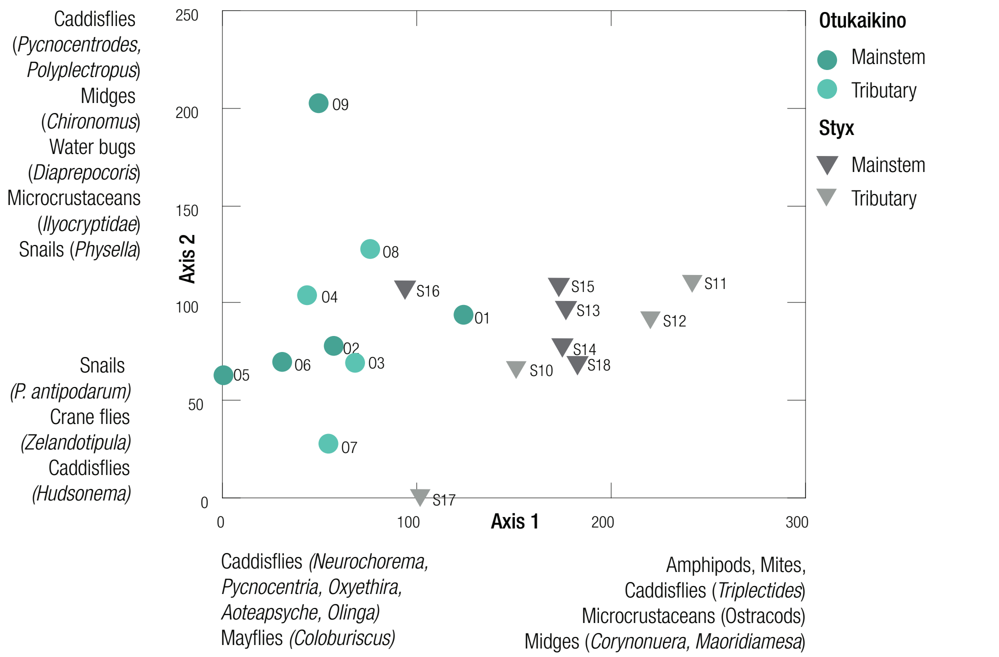


Figure 6 Detrended Correspondence Analysis (DCA) at nine sites within each of the Otukaikino and Styx catchments sampled between the 12th and 27th March 2008. Invertebrate taxa correlated with the axes are shown; no habitat variables were significantly associated with either axis. For site locations see Figure 1.

Table 1 An overall site ranking (1 (best) – 18 (worst)) of each of 18 sites surveyed in the Otukaikino and Styx catchments; site rank is based on the summation of ranks for each biotic index. The possible final ranking score is from 7 (ranking 1 on all variables) to 126 (ranking 18 on all variables). The sites have also been grouped into health categories (best, medium, and worst) according to their final score.

Catchment	Site	Biotic Indices							Sum	Final Rank	Health Grouping
		TAXA	EPT	% EPT	MCI	QMCI	UCI	QUCI			
Otukaikino	4	4	4	3	1	4	3	3	22	1	best
Otukaikino	5	5	1	2	2	9	2	5	26	2	best
Otukaikino	3	13	6	5	3	3	1	2	33	3	best
Otukaikino	2	9	7	4	4	2	5	4	35	4	best
Otukaikino	1	7	5	8	6	1	4	6	37	5	best
Otukaikino	8	3	9	7	9	6	9	8	51	6	med
Otukaikino	7	2	3	11	5	14	6	15	56	7=	med
Styx	16	12	11	6	7	5	8	7	56	7=	med
Otukaikino	6	1	2	9	11	17	7	16	63	9=	med
Styx	15	6	8	10	8	7	13	11	63	9=	med
Otukaikino	9	11	13	1	14	13	12	1	65	11	med
Styx	13	8	12	12	13	8	10	9	72	12	med
Styx	14	10	10	13	12	11	11	13	80	13	med
Styx	18	14	14	14	10	10	14	12	88	14	med
Styx	12	17	17	18	18	15	15	10	110	15	worst
Styx	17	16	15	16	15	16	16	18	112	16	worst
Styx	10	15	16	15	16	18	17	17	114	17=	worst
Styx	11	18	18	17	17	12	18	14	114	17=	worst

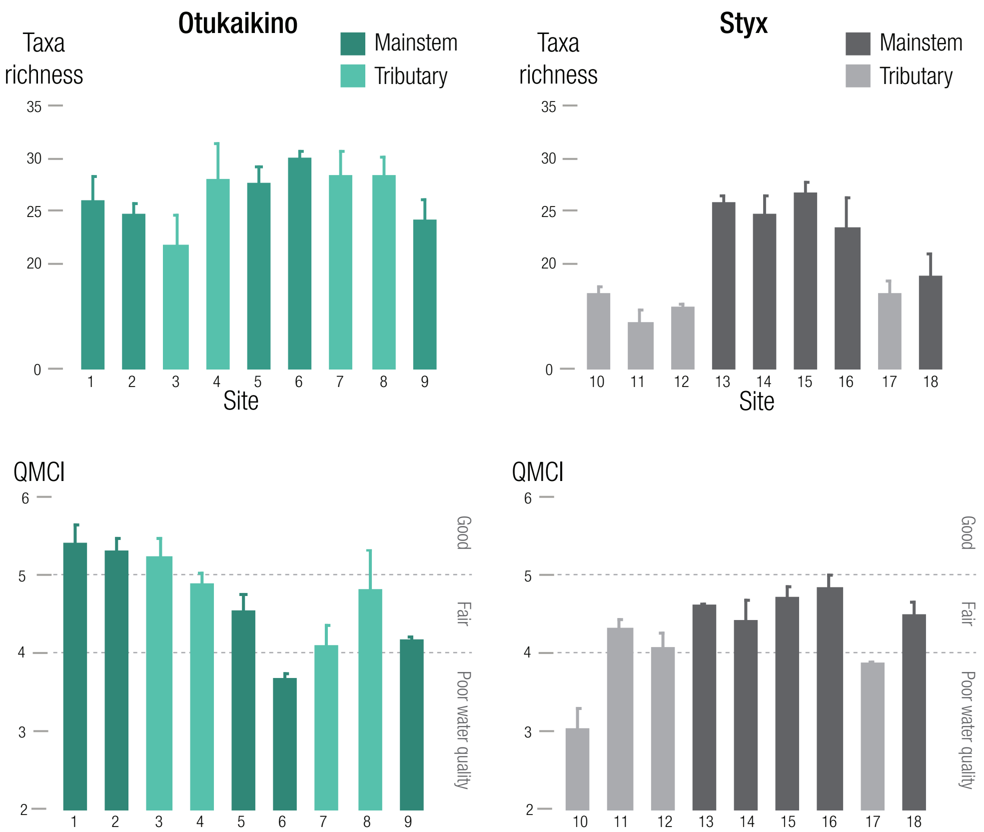
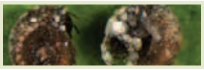
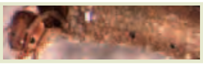
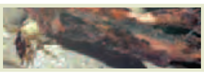


Figure 7 Biotic indices of invertebrate community health at nine sites within each of the Otukaikino and Styx catchments, sampled between the 12th and 27th March 2008. Sites 1 and 10 are the most downstream sites in the Otukaikino and Styx catchments, respectively. The dotted lines on the QMCI and MCI graphs indicate the probable level of organic pollution (Stark, 1985; Stark, 1998). Good water quality conditions (with only possible mild organic pollution) are indicated by MCI and QMCI values from 100–120 and 5–6, respectively. Poor water quality conditions (probable severe organic pollution) are indicated less than 80 for the MCI and less than 4 for the QMCI.

Table 2 The presence of EPT taxa in the Otukaikino and Styx catchments, as indicated by an X. The MCI values indicate the tolerance of the taxa to organic pollution (10 = highly pollution sensitive, 1 = pollution tolerant; (Stark, 1985). A stream with good water quality has a more pollution-sensitive taxa, i.e., those with high MCI scores. MCI values are from Boothroyd & Stark (2000).

	EPT taxa	Sensitivity Value (MCI)	Otukaikino	Styx
	Mayflies (Ephemeroptera)			
	*Coloburiscus*	9	X	
	*Deleatidium*	8	X	X
	Caddisflies (Trichoptera)			
	*Aoteapsyche*	4	X	X
	*Helicopsyche*	10	X	
	*Hudsonema amabile*	6	X	X
	H. alienum	6	X	X
	*Hydrobiosis sp.*	5	X	X
	H. parumbripennis	5	X	X
	H. umbripennis	5	X	X
 ‡	*Neurochorema*	6	X	X
 ‡	*Oecetis*	6	X	X
	Oeconesus	9	X	X
	*Olinga*	9	X	X
	*Oxyethira*	2	X	X
	*Paraoxyethira*	2		X
	*Polyplectropus*	8	X	X
	*Psilochorema*	8	X	X
	*Pycnocentria*	7	X	X
	*Pycnocentrodes*	5	X	X
	*Triplectides obsoletus*	5	X	X
	Stoneflies (Plecoptera)			
	*Zelandobius*	5	X	
	Total EPT taxa		**20**	**18**

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Those sites regarded as the worst in both catchments were the tributary waterways of the Styx catchment; Site 10 and 11 (Kaputone Creek), Site 12 (Horner's Drain), and Site 17 (Smacks Creek). All four sites were classified as having severe organic pollution according to the MCI score and also had the lowest QMCI scores (Figure 7). In particular, Site 10 and 11 (Kaputone Stream) scored in the lowest three for all biotic indices and consequently ranked lowest equal of the 18 surveyed sites (Table 1). Site 11 also had the highest Axis 1 scores in the DCA analysis and was associated with pollution tolerant taxa such as amphipods, ostracods, and *Corynoneura* chironomid midges (Figure 6). Site 12 (Horner's Drain) had the lowest MCI score (68.9) and abundance of EPT taxa (1.1%) of all 18 sites, while Site 17 (Smacks Creek) had the lowest QUCI score (0.04; Table 1, Figure 7).

DISCUSSION

The aquatic invertebrate communities of both the Otukaikino and Styx catchments were typical of moderately enriched, lowland spring-fed rivers. Although, both catchments contained taxa tolerant of moderate levels of organic enrichment and common to urban streams, such as the snails *Physella* and *P. antipodarum*, microcrustacean ostracods, and amphipods, they also both contained a high abundance and diversity of EPT taxa, most of which are sensitive to organic pollution and urbanisation. In comparison to most other lowland waterways in Christchurch, the Otukaikino and Styx catchments support particularly diverse and healthy invertebrate communities, with many of the EPT taxa otherwise absent or rare in the City's other river catchments (e.g., Avon, Heathcote, and Halswell rivers). For example, in an analysis of invertebrate data collected between 2001 and 2007, McMurtrie & Suren (in press) found that urban and semi-urban areas such as the Avon River and Heathcote River catchments only supported up to three EPT taxa, and had average MCI scores below 80 (i.e., indicating severe pollution). This is in stark contrast to the 18 and 20 EPT taxa found in this survey of the Styx and Otukaikino catchments (respectively), and MCI scores that were generally above 80 (with the exception of Sites 10, 11, 12, 17 in the Styx catchment) or above 100 (Site 4 in the

Otukaikino catchment), indicating only moderate or mild organic enrichment.

There were some distinct differences in the invertebrate communities of the two catchments, and these could not be explained by habitat conditions. Thus while the aquatic habitat (i.e., water depth, velocity, substrate size, and sediment depth) in the two catchments was relatively similar and all sites contained areas suitable for EPT taxa (i.e., relatively coarse substrate and flowing water), there were some other unmeasured variables driving the differences in community composition at the sites.

In general, the predominantly rural Otukaikino catchment supported a particularly healthy and diverse aquatic invertebrate community. The top five ranked sites were all from the Otukaikino catchment, incorporating both mainstem and tributary waterways (Figure 8). The MCI scores of >90 for eight of the nine sites in the Otukaikino catchment indicated fair water quality, and for one site (Site 4; >100) good water quality, which is regarded as being particularly good for a lowland spring-fed rural catchment. The widespread distribution of EPT taxa throughout the Otukaikino catchment and presence of one stonefly taxa (*Zelandobius,* found at Sites 5, 7, and 8) are further indications of the good health of this system.

Site 4 (ranked 1st), North Boundary Stream, looking upstream

Site 5 (ranked 2nd), Otukaikino River, looking upstream

Site 3 (ranked 3rd), Kaikanui Stream, looking downstream

Site 2 (ranked 4th), Otukaikino River, looking upstream

Site 1 (ranked 5th), Otukaikino River, looking upstream

Figure 8 The five sites from the Otukaikino River catchment that supported the healthiest invertebrate communities of both the Otukaikino River and Styx River catchments.

The better stream health of the Otukaikino catchment compared to the Styx catchment is not surprising given the rural nature of the area. While rural land use, in particular cattle farming, is known to badly affect stream systems (Parkyn & Wilcock, 2004), the impacts are generally not as significant as those associated with urban areas. Rural land use can affect stream communities, particularly if stock have access to the waterway, via increased nutrient run-off, stock effluent additions, a reduction in riparian vegetation, and eroded stream banks; the latter of which contributes fine sediment to the stream (Parkyn & Wilcock, 2004). The access of stock to the streams in the Otukaikino catchment was variable, with the lower reaches (e.g., downstream of The Groynes area) generally fenced off from stock, the middle reaches protected from stock due to The Groynes park area and the Clearwater Golf Course development, and the upper reaches mostly unfenced and providing access for both sheep and cattle. The localised effect of stock access was observed during this survey, with the upper-most sites (Sites 7, 8, and 9) characterised by very little riparian vegetation and eroded banks (Figure 9). However, the negative effect of bank destabilisation and silt ingress was not evident in the invertebrate community at these sites, which still supported high numbers of cleanwater EPT taxa. This was most likely due to the fast flowing water helping to wash any input sediment further downstream to areas of slower flowing water (McMurtrie *et al.*, 2003). Certainly an initial site visit did indicate that many slower flowing areas and smaller headwater channels that were known to support healthy invertebrate communities and trout rearing habitat five years ago, could now be severely degraded due to a combination of stock damage, siltation, and water loss (Figure 10).

In contrast to the Otukaikino catchment, the Styx catchment contained a lower diversity (3–12) and abundance (between 5–50%) of EPT taxa, and most sites were dominated by more pollution tolerant taxa, such as amphipods, P. antipodarum, microcrustacean ostracods, and orthoclad chironomids. This type of invertebrate community composition indicated lower stream health than that of the Otukaikino catchment, and reflects an intermediate state of decline most likely brought about by the higher proportion of urban development. The pattern of degradation of waterways as a result of urbanisation is so similar worldwide that it is referred to by ecologists as the 'urban stream syndrome' (Figure 11). This syndrome describes the gradual decline in EPT taxa, which are typically intolerant of habitat degradation and poor water quality, and a subsequent increase in more pollution tolerant taxa such as snails (*P. antipodarum, Physella*), chironomids, worms, and some micro-crustaceans (ostracods). The urban stream syndrome is brought about by a combination of factors that pervade an urban catchment, including increased catchment imperviousness, altered hydrologic regimes (lower but flashier flow regimes), increased water-borne contaminants from stormwater inputs (e.g., heavy metals and

Site 7, North Boundary Stream, looking downstream

Site 9, Otukaikino River, looking downstream

Figure 9 Stock damage to banks (either past or current damage) was evident at some sites in the Otukaikino catchment, such as Site 7 and 9 pictured above. However, there was not a significant negative impact on the instream invertebrates, presumably because the faster flow washed the sediment downstream to slower flowing areas.

Figure 10 Bank damage and siltation caused by stock entering the stream, such as in the upper reaches of the Otukaikino catchment, will badly impact on the fish and invertebrates living within the stream. The photographs show a similar location approximately five years apart. In 2003 this area supported the best invertebrate community in the upper catchment (McMurtrie *et al.,* 2003), but in 2008 would be unable to support any cleanwater EPT taxa or fish.

polycyclic aromatic hydrocarbons), and a significant input of fine sediment during the initial catchment development phase (Paul & Meyer, 2001). The stream systems also become more fragmented due to buildings, bridges, and culverts, which interrupt the dispersal of winged adult aquatic insects (Blakely *et al.*, 2006).

According to Suren *et al.*, (manuscript), the human population in the Styx catchment has increased in 40 years, from 41 people per km in 1961 to 233 in 2001. This increase in human habitation would be associated with an increase in housing and roads (e.g., impervious areas), and the addition of stormwater to the catchment's waterways. While this density of habitation is still low compared to fully urbanised areas (e.g., the Avon catchment had 528 people per km in 2001), many studies have shown that even a small level of catchment urbanisation can lead to a decline in stream health (Paul & Meyer, 2001).

Because urbanisation of the Styx catchment is still relatively recent and currently represents a small portion of the overall catchment, the catchment's rivers still support EPT taxa and invertebrate communities of moderate health. Interestingly, the sites with the greatest proportion of EPT taxa appear to be concentrated within and immediately downstream of the Styx Mill Reserve (e.g., Sites 13–16; Figure 12). Within

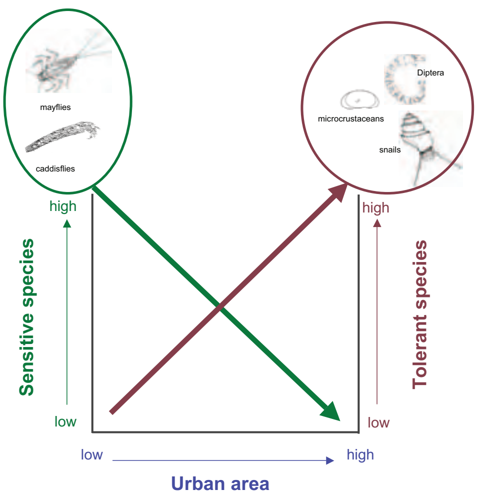

Figure 11 The Urban Stream Syndrome describes the decline in cleanwater EPT taxa (mayflies, stoneflies, and caddisflies) and increase in pollution-tolerant taxa (flies, snails, and worms) with an increase in urban area and catchment imperviousness.

this reserve the Styx River has large riparian vegetation zones and there are limited stormwater inputs. The abundance of riparian vegetation provides shade and cover, as well as a source of energy (leaves and branches) to the river (Suren, 2000). The river within this reserve has also been allowed to maintain a natural meandering path with no fragmentation (e.g., few culverts and lights to disturb the winged passage of adult insects).

The sites with the poorest invertebrate community health were all from tributary waterways in the Styx catchment (Sites 10, 11, 12, and 17; Figure 13). The poorer state of these streams may be related to their smaller size and the modified nature of some of these waterways. For example, Horner's Drain (Site 12) is a deep box drain with high wooden walls and little riparian vegetation. The straight and boxed nature of box drains eliminates structural variability such as pool-riffle complexes and debris dams. This means that few areas of low flow are present during floods and invertebrates are often washed away in high flow events (Suren, 2000).

While having a natural meander and a coarse substrate, the small size of Smacks Creek (Site 17) may make it more vulnerable to stormwater inputs than larger rivers, which can partially dilute contaminants and buffer any temperature fluctuations due to a higher volume of water. This small waterway has an upper urbanised catchment, recent riparian vegetation removal associated with a native planting programme, and a timber yard approximately 200 m upstream of our sampling point. The small size of the stream means that it would be more significantly affected by untreated stormwater inputs. In addition, the timber yard upstream of Gardiners Road is a source of large amounts of wood chips that in some areas have smothered the stream bed. Taylor & McMurtrie (2003) thought that bacterial breakdown of

Site 16 (ranked 7th equal), Styx Mill Reserve, looking downstream

Site 15 (ranked 9th equal), Styx Mill Reserve, looking downstream

Site 13 (ranked 12th), downstream of the Styx Mill Reserve, looking upstream

Site 14 (ranked 13th), Styx Mill Reserve, looking downstream

Figure 12 Four sites along the Styx River that supported the best invertebrate communities for the Styx catchment (ranked as medium overall). These sites all occur within the Styx Mill Reserve, a recreational area that provides an abundance of riparian vegetation and has no stock access or stormwater inputs.

these wood chips would cause localised oxygen depletion and contribute to reduced abundance of EPT taxa that typically require high oxygen levels. There are plans to remove the wood chips and prevent more from entering the stream, but this has not yet been fully investigated. The reduction in riparian vegetation as a consequence of willow tree removal immediately upstream of the survey site would decrease the amount of shade the stream receives and in such a small waterway could conceivably increase water temperature and lead to filamentous algal growths (Reeves *et al.*, 2004). Many EPT taxa, especially stoneflies and mayflies, are sensitive to increases in stream temperature and filamentous algal growths can smother the more palatable algal species that these invertebrates like to eat.

Kaputone Creek has had high levels of urban development in the upstream catchment, has diminishing flows, and is heavily silted throughout much of its length. The sites at which we sampled (Sites 10 and 11) were therefore likely to be the only two reaches that contain habitat suitable for cleanwater EPT taxa. As populations of EPT taxa would be limited to these small sections of stream with a coarse substrate, they would be isolated populations with slim potential for re-colonisation from other areas following a disturbance. Thus it is not surprising that these sites, despite good instream habitat, still supported the worst invertebrate communities with few EPT taxa (< 5 EPT taxa and < 10% abundance) compared to the other surveyed sites. However, despite their lowest ranking in the current survey, these two sites represent the best areas for Kaputone Creek, with EPT taxa having not been identified from anywhere else (Taylor & McMurtrie, 2004).

Site 12 (ranked 15th equal), Horner's Drain, looking upstream

Site 17 (ranked 16th equal), Smacks Creek, looking downstream

Site 10 (ranked 17th equal; last), Kaputone Creek, looking downstream

Site 11 (ranked 17th equal; last), Kaputone Creek, looking downstream

Figure 13 Four tributary waterway sites in the Styx catchment supported the poorest invertebrate communities for the Styx and Otukaikino catchments combined. These smaller water-ways are likely to be more susceptible to impacts such as urbanised catchments, stormwater inputs or stock access than larger waterways which, due to a higher volume of water, may be able to dilute some of the pollutants or sediment input

4.1 Summary

The invertebrate communities of the Styx and Otukaikino catchments are typical of moderately enriched lowland spring-fed waterways. In general the stream invertebrate communities in both catchments were in relatively good health with abundant cleanwater EPT taxa. Certainly both these systems are the best example of lowland stream systems within the Christchurch area. However, increased urban development in the Styx catchment may explain the poorer health of some sites, particularly the smaller tributaries, when compared to the rural Otukaikino catchment.

Specific sites within both these catchments are impacted by either rural or urban land use effects such as stock access, stormwater inputs, sedimentation, and channel modification. Because of the high abundance of EPT taxa that are sensitive to the negative effects of rural and urban land use, poor rural management and further urban development has the potential to have significant negative impacts on these unique waterways. As Suren *et al.* (manuscript) points out, if urban development in rural areas such as the Styx and Otukaikino catchments expand without consideration for how we manage stormwater runoff, then the fauna of these still relatively healthy rivers will degrade as our urban areas expand. Given the pressure on the Styx catchment for development, and the continued access of stock into the upper Otukaikino catchment, it may therefore be necessary to monitor these two systems more regularly than every five years. In this way, any significant decline in the invertebrate communities can be used as an early warning system that may allow changes to be implemented before the decline becomes irreversible.

5 ACKNOWLEDGEMENTS

We thank the landowners for granting us access across their land. Thank you also to EOS Ecology staff that assisted with the field work and laboratory processing.

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7 APPENDICES

7.1 Appendix I: Site Photographs

Site 1: Otukaikino River (looking upstream from middle of site)

Site 2: Otukaikino River (looking upstream from bottom of site)

Site 3: Kaikanui Stream (looking downstream from middle of site)

Site 4: North Boundary Stream (looking upstream from bottom of site)

Site 5: Otukaikino River (looking upstream from bottom of site)

Site 6: Otukaikino River (looking upstream from bottom of site)

Site 7: North Boundary Stream (looking upstream from bottom of site)

Site 8: North Boundary Stream (looking upstream from bottom of site)

Site 9: Otukaikino River (looking downstream from top of site)

Styx River Catchment

Site 10: Kaputone Stream (looking upstream from bottom of site)

Site 11: Kaputone Stream (looking downstream from middle of site)

Site 12: Horner's Drain (looking downstream from top of site)

Site 13: Styx River (looking upstream from bottom of site)

Site 14: Styx River (looking downstream from middle of site)

Site 15: Styx River (looking downstream from middle of site)

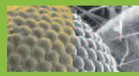
Site 16: Styx River (looking upstream from middle of site)

Site 17: Smacks Creek (looking downstream from top of site)

Site 18: Styx River (looking upstream from bottom of site)

ASSESSMENT AND MONITORING 

RESTORATION DESIGN 

LABORATORY SERVICES 

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