The invertebrate communities of the Styx River: summary of monitoring programme 2006-2011, and recommendations for future work

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Contents

Summary

1. The Styx Living Laboratory Trust (SLLT) has established a volunteer monitoring programme throughout the Styx catchment involving collection of habitat and biological data at 8 sites twice a year. The monitoring program commenced in 2005, with samples being collected each spring and autumn. It is hoped to detect changes in habitat condition or invertebrate communities over time, and to improve the current understanding of the state of stream health in the catchment. The volunteers attend a number of training courses for sampling and identification procedures. Given the importance of accurate data to detect changes in invertebrate community compositions, the SLLT also arrange for independent Quality Control/Quality Assurance (QA/QC) tests on the volunteer data.
2. To date, little of the data collected by the volunteers has been loaded into digital form, or even analysed. Much of the work done by the volunteers has thus produced little in the way of tangible outputs. The aim of this report was to: 1) analyse and comment on differences between invertebrate data collected from volunteers and the QA/QC tests; 2) analyse all invertebrate data to detect differences in community compositions between sites and streams; 3) examine relationships between invertebrate data and habitat data; 4), make recommendations on field and laboratory protocols to help fulfil goals of the SLLT.
3. No differences existed in the relative abundance of any of the main invertebrate groups when identified by either the volunteer group, or the QA/QC. Lack of such differences suggests that the data obtained by the volunteer group was robust, and comparable to the data are obtained by more experienced ecologists. However, analysis of habitat data showed considerable variability among volunteers for some of the habitat parameters - even when such variability was considered unlikely. It is thus recommended that some form of QA/QC checking be done on habitat data as well as invertebrate data.
4. A total of 33 volunteers have assisted with collection and processing of invertebrate data since 2005. However, there was a large turnover of volunteers, with most undertaking only one round of invertebrate monitoring. The obvious implication here is the need to increase longevity and interest of many of the volunteers. Some form of formal induction protocol could be investigated, as well as some form of "exit interview" so that the SLLT board members could better understand what motivates volunteers, and what makes them

leave. This information would hopefully be useful for implementing measures to improve the volunteering experience.

5. A total of 23 invertebrate groups were identified by the volunteers. The fauna was dominated by cased caddisflies, spired snails, amphipods, micro-crustaceans, and worm/nematodes. The invertebrate community composition differed between the four waterways: the fauna at Kaputone Creek was characterised by micro-crustaceans and pea clams, while communities in the Styx River, Smacks Creek, and the Otukaikino was dominated by amphipods, cased or free-living caddisflies and mayflies. Examination of temporal data showed few consistent patterns with regards to annual or seasonal variation.
6. A wide range of habitat data was also collected. The four waterways differed in water, macrophyte and sediment depths, and width. No differences were observed in the cover of organic material in each of the four waterways. Kaputone Creek had the finest substrate, whereas the Otukaikino and Smacks Creek had the most coarse substrate. Water velocity was highest in the Otukaikino and the Styx River, and lowest in Kaputone Creek. Other habitat variables did not differ between the waterways, or displayed a high degree of variability suggesting operator variability. Invertebrate communities were affected by variables such as the depth of soft substrate, substrate size, water velocity, and water depth. It is recommended that the habitat collection protocol be reviewed, and altered where necessary to ensure that only useful data with minimal potential for operator variability is collected. It is also suggested that at least some water quality monitoring be done at the same sites that invertebrates are collected.
7. It was not surprising that no significant shifts in invertebrate community composition over time were detected. Invertebrates respond to a number of environmental parameters, but many of these did not change during the study, suggesting that catchment conditions were relatively constant. The stability of the invertebrate communities in the Styx River highlights a potential dilemma for the volunteer monitoring programme. If land-use activities around the four waterways are not changing dramatically, then there is no reason why the invertebrate communities in these waterways would change. Moreover, the current monitoring programme has a fairly low resolution to detect more subtle changes in invertebrate composition that may be occurring. It may be some time (10+

years) before any changes are detected, and this represents a long term commitment of the SLLT and its volunteers. However, given that there is further urbanisation planned for the Styx catchment it seems that ongoing monitoring effort is warranted.

8. A balance needs to be found between a monitoring frequency sufficient to maintain the interest of the volunteers, and to maximise the return of their effort in gathering useful information assessing potentially adverse effects of landuse changes occurring in the catchment. The current twice yearly approach may be too frequent to detect relatively long-term changes to waterway health. However, monitoring at a less frequent interval may reduce the volunteers' morale, motivation and expertise. Monitoring of streams such as Kaputone Creek, where instream habitat conditions are already degraded, is questioned, as the remaining fauna there is not expected to change – unless restoration activities are planned in this catchment.
9. Recommendations are made to increase the number of sites sampled and reduce the sampling frequency to once per year for each site, while maintaining the twice yearly volunteer effort. This could be achieved by splitting sites into two groups with one group sampled in autumn and the other in spring, or by focussing on different activities in each season, such as long-term monitoring in autumn and short-term monitoring of restoration sites in spring. The fact that the Styx River represents one of the healthiest waterways in Christchurch is a strong argument to continuing monitoring its invertebrate communities, and those of its tributaries.
10. The recent 2011-2012 Christchurch earthquakes have resulted in the fast-tracking of land development in currently rural areas of the lower Styx catchment. These areas are presently not monitored due to the absence of safe and easy methods for volunteers. Given the documented effects of urban development on stream health, it is important that some form of monitoring is conducted in the lower Styx River – providing that suitable method can be developed. In order to keep consistent to The Styx Vision, the SLLT should investigate whether such a monitoring programme could be developed for the lower reaches of the river.

1.0 Introduction

1.1 Background to the Styx Living Laboratory

The City of Christchurch is the largest urban area in New Zealand's South Island (population ca. 400,000). With Christchurch flow two rivers, the Avon and Heathcote[1.] The headwaters of the Avon arise from a number of small springs in the west that coalesce and flow east through the suburbs and city centre into the northern apex of the Avon-Heathcote Estuary. This river is an integral part of Christchurch, and provides considerable visual amenity and open space through the built-up Central Business District (CBD). It drains largely residential areas in its headwaters, and flows through the commercial heart of Christchurch before meandering through more residential areas to the estuary. The second river, the Heathcote, arises in the south-west of Christchurch and is fed from numerous springs near Templetons Road, as well as receiving wet weather flows from as far west as Pound Road. It meanders around the base of the Port Hills from west to south-east, through a mix of residential, commercial and industrial areas. The Heathcote River has generally been regarded as less attractive than the Avon River, due in part to the historical legacy of discharging industrial waste into its lower reaches for many years fouling the water, the banks and bed. Both rivers flow into the aptly named Avon-Heathcote estuary, which has a high degree of ecological, recreational, social and cultural values.

Christchurch also has a third, but much lesser known river, The Styx[2]. This river is located in the north of Christchurch city, where it drains a combination of residential, horticultural, agricultural and lifestyle developments, and more recently, a number of conservation reserves. As with the Avon and Heathcote rivers, the pre-European landscape of the Styx was largely raupo and flax dominated swamp and grassland, but most of this has since disappeared. A small

[1] The Maori names for these waterways are as follows: Avon/Ōtākaro, Heathcote/Ōpāwaho, Avon-Heathcote Estuary/Ihutai. For the sake of brevity this report uses only the English names of these waterways, although it is acknowledged that the Maori names have equal validity to be used.

[2] The Maori name for The Styx is Pūrākaunui. Again, rather than use the combined terms Styx/ Pūrākaunui for brevity only the English names have been used.

town (Belfast) was established in the mid reaches of the Styx catchment in the 1900s, and this development would have impacted on the waterways, however the upstream reaches would have remained in a relatively un-impacted condition. Urban expansion in the upper catchment has increased dramatically since the 1990s with residential and commercial areas rapidly expanding in the upper part of the catchment, all of which may lead to a deterioration in stream health.

Management of waterways and wetlands in Christchurch is vested mainly to Christchurch City Council, through the Resource Management Act 1991, objectives and policies of the City Plan, and the Local Government Act. The latter in particular requires the council to produce a Long Term Plan (LTP), which among other things requires plans for the management of waterways, wetlands and surface water within its locality. To address these requirements, the former Water Services Unit of the Christchurch City Council developed a Waterways and Wetlands Natural Asset Management Strategy. Extensive public consultation and research in the later part of the 1990's highlighted concerns of increased urban expansion and development activities within the Styx catchment, and the potentially adverse effects that these activities could have on the ecosystem of the Styx River. Based on these concerns, and on community consultation, a long-term visionary document was developed for the Styx River and its catchment. This plan, known as The Styx Vision 2000 - 2040, seeks to protect and build on the values associated with the Styx River catchment. This long term vision was adopted by the Christchurch City Council at its Council meeting on the 11 July 2001.

The Styx Vision is made up of 5 core elements:

- **Vision 1** To achieve a **"Viable Springfed River Ecosystem"** to complement the other representative protected ecosystems of Christchurch such as the Port Hills, Travis Wetlands and the Coastline.
- **Vision 2** To create a **"Source to Sea Experience"** through the development of an Urban National Reserve.
- **Vision 3** To develop a **"Living Laboratory"** that focuses on both learning and research as practised by Dr Leonard Cockayne (1885).
- **Vision 4** To establish **"The Styx"** as a place to be through maintaining and enhancing the special character and identity of the area.

- **Vision 5** To foster **"Partnerships"** through raising the quality of relationships as we move forward together.

These Visions provide key directions, along with actions for their implementation. Since the 'Styx Vision 2000 - 2040' was adopted by the Christchurch City Council, the Council has acquired large areas of land alongside waterways in the Styx catchment that will eventually form part of the green corridor network, including the Styx Mill Conservation Reserve (57 hectares) that extends along the Styx River for nearly 1.6km. The reserve forms part of the natural river corridor associated with the Styx River and provides a diversity of site conditions and opportunities for restoration. The Styx Living Laboratory Trust (SLLT) has also been established to oversee one of the cornerstones of the Styx Vision 2000 – 2040, that of developing a Styx Living Laboratory (Vision 3). This is intended to raise awareness of the Styx River and its environs, along with maximising opportunities for research and learning. This educational focus is based on work commenced by one of Christchurch's early leading botanists - Dr Leonard Cockayne (1855 - 1934), who purchased property on Highsted Road, to the south of the Styx River, where he cultivated and described many native plants. The Trust has established a number of activities that progress learning and research in the Styx catchment, including a community monitoring programme of water quality and invertebrates. The invertebrate monitoring programme involves collection of habitat data and sampling of invertebrate communities at 8 sites twice a year; once in spring and once in autumn.

1.2 Freshwater Invertebrates

Freshwater invertebrates play a vital role in transferring plant based material into animal biomass, which is available to higher predators such as fish and birds. They also have biodiversity and ecological values, and almost all freshwater invertebrates found in New Zealand waterways are native to New Zealand and found nowhere else in the world. There are four major groups of freshwater invertebrates:

1. aquatic insects such as mayflies, caddisflies, stoneflies, dragonflies and true flies (*e.g.*chironomid midges, blackflies)
2. snails and filter-feeding bivalves such as freshwater mussel
3. crustaceans such as freshwater shrimps and amphipods

4. worms, flatworms and leeches

These animals are influenced by environmental variables such as water velocity, depth, substrate size and the presence of silt, as well as water quality. They are relatively long lived, with life-spans from months – weeks, and, because of their small size, they generally do not move particularly far within a stream. They are relatively easily collected and identified, and a lot is known of their tolerances to environmental factors. Because of these reasons, they are used to indicate stream health, as their presence in a particular stream reflects the overall habitat and water chemistry conditions in that stream. For example, mayflies, stoneflies, and caddisflies (called Ephemeroptera, Plecoptera and Trichoptera: EPT) are relatively intolerant to stream degradation, and are often scarce or absent in rivers flowing through highly modified catchments as a result of organic enrichment, sediment inputs, and high temperatures resulting from the loss of shading streamside vegetation. Their presence within a river thus indicates streams of high "ecological health".

Urban development has dramatic effects on stream health, reflecting changes to stream flow, loss of terrestrial and bankside vegetation, and reduction in water quality. Such changes result in streams with low biodiversity values. Although we do not know what the habitat conditions of the Styx River were like prior to European settlement, we can fairly confidently state that it would have been a relatively fast-flowing spring-fed river that flowed over a coarse streambed of cobbles and gravels - similar to what the nearby Otukaikino Stream is currently like. Water quality would have been high. The streamside vegetation would have been a mixture of flaxes, tussocks, native shrubs and trees that would have shaded the river in places. Urban development has resulted in a loss of the native vegetation, and a replacement with non-native grasses, shrubs and deciduous trees. This would have altered the timing and quantities of organic inputs into the river. Stream flows are also likely to have been reduced as a result of drainage, and the increased quantities of impervious surfaces within the catchment that would have lowered the amount of water entering the ground. Sedimentation in the river has increased considerably, and this has been exacerbated by large areas of introduced macrophytes such as curly pondweed (*Potamogeton crispus)* and Canadian oxygen weed *Elodea canadensis* that trap fine sediments. Water quality, although still good at base flow, undoubtedly declines when it rains as a result of stormwater entering the river, flushing with it a large amount of different contaminants from the surrounding urban areas.

These changes have occurred to a great extent in the Avon and Heathcote rivers, as Christchurch has been urbanized for well over 120 years. However, urban growth in the Styx has been only a relatively recent phenomenon, so adverse effects of urban activities have not affected this river as much. There have been dramatic changes to the invertebrate fauna of the Avon and Heathcote rivers. In particular there has been a loss of mayfly and stonefly taxa, and a shift in community composition to one dominated by tolerant animals such as worms, snails (*Potamopyrgus*, Sphaerium and *Physa*), the amphipod *Paracalliope*, and a variety of midges. This fauna is indicative of relatively degraded conditions when compared to non-urban streams. In contrast, the invertebrate fauna of the Styx River is more diverse, with more of the sensitive EPT animals being found there. Indeed, a total of 13 EPT taxa have been found in the Styx – 12 caddisfly and the common mayfly *Deleatidium*. This latter animal used to be found in the Avon, but has disappeared since the 1990's, so the importance of the Styx River in representing a healthy ecosystem close to Christchurch cannot be over-emphasised. The only other stream within the greater Christchurch area to support as many EPT taxa is the Otukaikino, which flows through a rural catchment. Despite its high ecological values, there is concern that sensitive taxa such as the mayfly *Deleatidium* may be disappearing from the Styx catchment. The ecological health of this river may thus be regarded as being in a transitional state between a healthy rural stream, and a less healthy urban stream.

1.3 Invertebrate Monitoring

Because of the potential adverse effects of urban development on the health of the Styx River, the SLLT commenced an invertebrate monitoring program using community-based volunteers to monitor both invertebrate communities, habitat conditions, and water quality. Monitoring invertebrate communities in the Styx would enable the SLLT to:

- ascertain if there are any trends between changes in habitat condition and changes to invertebrate communities over time.
- compare invertebrate communities in the Styx with invertebrate communities in other catchments within the region.

- improve understanding of the current state of the in-stream habitat and invertebrate communities.

The monitoring program commenced in 2005, and samples were collected each spring and autumn.

Invertebrate samples had been collected from eight sites in four waterways the area (Figure 1):

1. Styx River: three sites (Headwaters, Styx Mill Conservation Reserve, Main North Road)
2. Smacks Creek: one site (Gardiners Road)
3. Kaputone Creek three sites (Belfast Rd, Blakes Rd, Ouruhia Domain)
4. Otukaikino Creek: one site (control).

Figure 1. Map of the Styx Living Laboratory invertebrate monitoring sites where volunteer monitoring is conducted (Source http://www.thestyx.co.nz/new-zealand/monitoring/)

Annual monitoring has been done by volunteers, who when joining the volunteer group have attended training courses organized by the SLLT to show them techniques associated with invertebrate sampling procedures, and with laboratory techniques to correctly identify and count the different animals found in each sample. To ensure consistency and validity of data, specific field and laboratory methodologies were developed that were based on rigorous, well documented protocols (EOS Ecology 2005). The field protocols involved collection of information at each site on nine instream habitat parameters known to influence invertebrate communities:

1. Water Velocity
2. Stream Profile
3. Streambed Substrate
4. Aquatic Plants
5. Riparian Vegetation

Four semi-quantitative replicate invertebrate samples are collected from each site using methods described in EOS Ecology (2005). Briefly, this involves collecting 2 replicate kick samples from the centre of the stream at 2 transects at each site, with one sample being collected at the top of the stream reach and the other being collected at the bottom of the reach. The invertebrate samples are either preserved on site with isopropyl alcohol, or returned to the SLLT laboratory where they are processed live. Processing techniques are described in full by EOS Ecology (2005), but are based on a 200 fixed count methodology modified from Stark et al (2001). A number of field guides exist to help identify aquatic invertebrates (e.g., Winterbourn and Gregson, Winterbourn, Moore), but many of these require a relatively high degree of formal training to properly use. Moreover, these allow the identification of insects or snails down to relatively low taxonomic levels such as family, genera or even species. Such a high level of taxonomic resolution is considered outside the scope of what can be achieved by volunteer community monitoring. As such, a pictorial invertebrate identification chart was prepared by EOS Ecology (2005) where different invertebrates were grouped into larger groups whose identification was thought to be within the realms of what could be achieved by a community volunteer group. A total of 12 main invertebrate groups were recognised, with 29 subgroups (Table 1).

Table 1. List of invertebrate taxa as originally identified to in 2005, and changes made to some of the invertebrate types to minimize confusion and uncertainty

Main Group	Invertebrate type 2005	Invertebrate type 2006	Invertebrate type 2007	Invertebrate type 2010
Molluscs	Snails (flat spiral)	Snails (flat spiral)	Snails (spiral)	Snails (flat spiral)
	Snails (Pointed)	Snails (spired)	Snails (spired)	Snails (spired)
	Snails (Rounded)	Snails (spired)	Snails (spired)	Snails (spired)
	Pea clam	Pea clam	Pea clam	Pea clam
Crustaceans	Shrimp	Shrimp	Shrimp	
	Amphipod	Amphipod	Amphipod	Amphipod
	Ostracods	Ostracods	Microcrustaceans	Microcrustaceans
	Water flea	Water flea	Microcrustaceans	Microcrustaceans
	Copepod	Copepod	Microcrustaceans	Microcrustaceans
			Crayfish	Crayfish
Worms	worm	Worm or nematode	Worm or nematode	Worm or nematode
	Leech	Leech	Leech	Leech
	Flatworm	Flatworm	Flatworm	Flatworm
	Nematode	Worm or nematode	Worm or nematode	Worm or nematode
Fly larvae	Mosquito larvae	Mosquito larvae	Mosquito larvae	Fly larvae
	Midge larvae	Fly larvae	Fly larvae	Fly larvae
	Blackfly larvae	Blackfly larvae	Blackfly larvae	Fly larvae
	Fly larvae	Fly larvae	Fly larvae	Fly larvae
Bugs	Back swimmer	Back swimmer	Back swimmer	
	Water boatmen	Water boatmen	Water boatmen	Water boatmen
	Pond skater	Pond skater	Pond skater	Pond skater
Beetles	Beetle	Beetle	Beetle	Beetle
	Riffle beetle larvae	Riffle beetle larvae	Riffle beetle larvae	Riffle beetle larvae
Spiders	Mite	Mite	Mite	Mite
Odenata	damselfly larvae	damselfly larvae	damselfly larvae	damselfly larvae
	Dragonfly larvae	Dragonfly larvae	Dragonfly larvae	Dragonfly larvae
Caddis	Purse caddis	Purse caddis	Purse caddis	Purse caddis
	Stony case caddis	Stony case caddis	Cased caddis	Cased caddis
	Twig case caddis	Twig case caddis	Cased caddis	Cased caddis
	Cased caddis (out of case)	Cased caddis (out of case)	Cased caddis (out of case)	Cased caddis
	Smooth case caddis	Smooth case caddis	Cased caddis	Cased caddis
	Spiral case caddis	Spiral case caddis	Cased caddis	Cased caddis
Free living caddis	Free living caddis	Free living caddis	Free living caddis	Free living caddis
Mayflies	Mayfly	Mayfly	Mayfly	Mayfly
Stoneflies	Stone fly	Stone fly	Stone fly	Stone fly

1.4 QA/QC Audits

Given the importance of accurate data in being able to detect changes to invertebrate community composition in rivers that may be arising as a result of land use change, or other activities, the SLLT arranged for independent Quality Control/Quality Assurance tests on the invertebrate data collected by the volunteers to be undertaken each year. In each case, the volunteer groups provided a subset of all samples collected to either EOS Ecology (2006, 2007), or Environment Canterbury (2007 to 2011) where more experienced laboratory technicians were able to check and validate both the identification and counting skills of the volunteers. Note that this QA/QC check only compared the consistency and accuracy of the volunteers in processing individual samples: it did not compare differences between the way that the samples were collected. In this way, the QA/QC protocol assumed that the samples collected by the volunteers did indeed reflect the types of invertebrate found in each waterway.

A number of recommendations were highlighted in reports by these organisations with the aim of improving the quality of data collected by SLL volunteers. These QA/QC reports highlighted concerns such as:

- the need to ensure samples are properly labeled;
- the need to ensure proper sample preservation with isopropyl alcohol
- difficulties of some volunteers to identify some taxa

The first two concerns were adequately addressed by emphasising the need for proper sample labeling and sample preservation, while the third concern reflected more of a training issue. For example, McMurtrie (2006) found that the volunteers had difficulties identifying between pointed and rounded snails, and inaccurately misidentified mayflies for stoneflies and damselflies, midge larvae for free-living caddisflies, and leeches for worms. Based on these inaccurate identifications, McMurtrie (2006) suggested a number of changes to the level of identification. For example, pointed and rounded snails were grouped into spired snails, fly larvae were combined with midge larvae, and nematodes grouped with worms (Table 1).

The following year, McMurtrie (2007) performed a second QA/QC, based on samples collected in 2006, and found that the community volunteers were still incorrectly identifying a number of invertebrate taxa. Based on this second QA/QC report, McMurtrie recommended further grouping to help reduce potential errors. This included combining four different caddis fly types (recognised by their spiral, stony, smooth or twig constructed cases) into a single class (cased caddis), and combining ostracods, copepods, and water fleas into a single microcrustacea category (Table 1). They also identified large discrepancies in the total counts between volunteers and quality control, and attributed this to volunteers counting empty caddis fly and snail cases, and only counting heads of animals which have fragmented.

Environment Canterbury also conducted annual QA/QC audits on volunteer collected data in 2007, 2009, 2010 and 2011. In their 2007 report, Vessy (2007) noted that the decision to regroup taxa had resulted in the elimination of a number of previous errors. However, they also noted differences in the counting of invertebrates, particularly for worms (which often break up during sample processing and storage), snails and pea claims. Beech (2009 and 2010) also noted a marked improvement in the accuracy of identification, but still commented on problems with the accuracy of counting, and the preservation of samples. Inconsistent results between community volunteers and QA/QC audits were also highlighted by Lees (2011), particularly with regard to the accuracy of counting.

Although a considerable amount of work has been done to ensure the accuracy of volunteer data, none of this data has yet been analysed. Furthermore, much of habitat data is yet to be even loaded into Excel spreadsheets. As such, the work done by the volunteers in collecting all biological and habitat data has produced little in the way of tangible outputs. This has led to discussions between SLLT Board of Management and the volunteers, who have highlighted concerns about a reduction in morale, especially when considering the amount of work already gone into the monitoring. The aim of this report is thus fourfold:

1. to analyse and comment on differences between invertebrate data obtained from the volunteers and the QA/QC protocols
2. to collate all invertebrate data since 2005, and analyse it to detect any inherent differences in community compositions between sample sites, streams or over time
3. where possible, examine relationships between invertebrate data and physical and/or water quality data collected from the same sites.

4. Where necessary, make recommendations on field and laboratory protocols, or other ways to modify the valuable work undertaken by the community volunteers in order to help continue to fulfil goals of the Styx living laboratory.

2.0 Methods

2.1 Data storage and management

As of the time that this report was written (June 2012), there were no established databases or structures for both biological or habitat data to be entered. Consequently, a large proportion of time was spent in entering data (especially the habitat data) into appropriate Excell sreadsheets, as well has combining the different datasets from the volunteers and QA/QC analyses over time. Much of the invertebrate data was also entered in a relatively inefficient way in Excel, in a typical "full matrix" format, with sites as columns, and species as rows. A recurring problem with the data was that different levels of identification were used over time, as QA/QC recommendations were to group taxa that were confused by the volunteers. This complicated the analysis of all data over time, as the original taxa were no longer identified in the latter surveys.

None of the habitat data had been entered onto Excell, so a number of individual worksheets were made for each of the many habitat parameters, and all data presently collected were entered. There now exists 2 separate datasets: invertebrate and habitat. These data are now discoverable, and recoverable - two highly desirable characteristics of data, especially when considering the time commitments that the volunteers put into its collection. It is hoped that future surveys will simply add to these existing datasets over time.

2.2 Comparisons of volunteer and QA/QC data

All invertebrate data was obtained from the six QA/QC reports that compared the volunteer monitoring results with that of professional labs. This data had been collected in three autumns

(2006, 2009 and 2010) and three springs (2007, 2008, and 2011), with the total number of 51 samples (Table 2). Given the commonly observed differences in densities between the volunteer and QA/QC data, all data was first converted into percentages. This is commonly done with the vast majority of invertebrate monitoring programmes, as the added expense of obtaining true density values is not in proportion to the extra information obtained. Furthermore, invertebrate densities often fluctuate as a result of changes in flow regime, or season, and are not necessarily caused by changes in land use or other human activities. However, changes in the composition of the invertebrate community are often related to the effects of human activities, and these changes can be detected simply by analyzing either presence-absence data, or percentage composition data. Secondly, because of the noted difficulties in the earlier QA/QC reports about identification of certain invertebrate groups, the taxonomic resolution of all data from each year was assigned to the consistent level as recommended by McMurtrie (2007), with further groupings of mosquito and blackfly larvae to fly larvae, and combining “Cased caddis” and “Cased Caddis (out of case)” (Table 1). The latter was done as these two “groups” in fact represented the same organisms – the fact that some were found out of their cases is immaterial. Once these changes were made, a comparative dataset of sites sampled by the community volunteers and rechecked by the QA/QC protocols over a six-year period was obtained. This corrected and combined dataset was analysed to determine whether there were any consistent differences between the community group and the QA/QC data.

Table 2. Total number of samples processed for QA/QC analysis in each year, showing the season that the data came from.

Year	Season	Total
2006	Autumn	6
2007	Spring	5
2008	Spring	14
2009	Autumn	11
2010	Autumn	6
2011	Spring	9
TOTAL		**51**

All data was first analysed to see whether differences occurred in the percentage abundance of the different invertebrate groups when processed either by the volunteers, or the QA/QC audits. For information on this analysis, see Appendix 1. Secondly, we analysed the entire community composition data to determine whether there were differences in the ability of the volunteer data or the QA/QC data to detect differences between the different streams. (See Appendix 1 for further details about these analyses).

2.3 Trends in invertebrate data

Unlike the QA/QC analysis which used only a subset of all possible data collected by the volunteers, this analysis was based on the entire dataset collected from all four waterways since 2005, during spring and autumn (wherever possible). The sampling procedure resulted in a total of 148 samples being collected (Table 3). As with the QA/QC data, all invertebrate data was converted to percentages, and grouped to a consistent level of taxonomic resolution (see Table 1). The names of the volunteers who collected and processed the samples were also recorded. This information was used to obtain information on the total numbers of volunteers who had participated in the surveys, and on how long different volunteers had remained active for.

Table 3. Total number of samples collected by the SLLT volunteers each year, showing the season that the data came from.

Year	Season	Total
2005	Spring	13
2006	Spring	15
2007	Spring	17
	Autumn	16
2008	Spring	16
	Autumn	16
2009	Autumn	14
2010	Spring	9
	Autumn	16
2011	Spring	16
TOTAL		148

All invertebrate data was analysed to see whether differences occurred in the percentage abundance of the different invertebrate groups between the different waterways. Community composition in each site at each waterway was then analysed using ordination techniques over time to determine whether any trends were apparent over the six-year period (See Appendix 1 for further details)

2.4. Trends in habitat data

Four types of habitat data have been collected, providing information on

1. stream width, open water depth, macrophyte depth, and sediment depth, and velocity;
2. substrate composition and cover of organic vegetation;
3. bank material, stability and land use;
4. riparian vegetation

Much of this data was collected from three separate transects placed across a selected reach within each stream. Stream width was measured at each transect, while depths were recorded at three locations within each transects (near the left and right banks, and in the middle.) The average depth at each transect was calculated, as we were not interested in the small-scale variability within each transect. This gave us three observations of stream width and the different depths at each stream on every sampling occasion. Information on bank material, bank stability, surrounding land use and riparian vegetation were assessed on each bank. For assessments of riparian vegetation, the stream banks were divided into lower and upper banks, whereby the lower banks were defined as the area from the water's edge to where a significant change in bank angle occurs (ie., the flood channel), and the upper bank defined as an area extending 5m in from the upper end of the lower bank. Both the true left and true right banks are assessed separately. The cover of 15 classes of riparian vegetation on the banks was assessed, according to three cover classes: 1 (<10% cover); 2 (10 – 50% cover), 3 (> 50% cover). Because these were categorical variables, we could not calculate their averages, and so analysis of these habitat variables was based on the true left and true right banks collected at each stream of every sampling occasion. Variables such as velocity, substrate composition, and cover of organic vegetation within each stream were assessed at the scale of the reach. This meant that there was no within-stream replication on each sampling trip for these variables.

The community groups collected information on substrate composition by recording the percentage of five substrate classes: bedrock, boulder, large cobbles, small cobbles, gravels, sand, and mud/silt. To simplify the analysis, all substrate information was converted to a single index such that:

substrate index = [0.8 ×bedrock, + 0.7 × boulder + 0.6 × large cobbles + 0.5 × small cobbles + 0.4 × gravels + 0.3 × sand + 0.2 × mud/silt]

Thus, streams dominated by large boulders and cobbles would have a large substrate index score (e.g. 0.8), while a stream that is dominated by fine substrate such as mud would have a low substrate index score (e.g. 0.2).

Variables such as water depth, macrophyte cover, and stream width, which were measured at the three individual transects within a site, allow us to analyse the data to see how this varied over time within a particular site. Other variables, such as water velocity and measurements of the substrate index, were measured without replication within a site. This meant that we could only analyse for differences between sites over time, and not differences within sites over time due to the lack of replication within each site.

2.5 Interactions between invertebrates and habitat

The effects of the measured habitat parameters on the invertebrate communities in the four waterways was examined. Before this analysis could be done, we had to ensure consistency between the number of invertebrate samples collected and the number of records describing habitat variables. Most of the habitat information was either collected or analysed at the level of sites within waterways, and over time. This differs to the biological data, where two replicate samples were collected at each site. The average percentage abundance of invertebrate data at each site was thus calculated, and compared this to site-specific habitat information. Only the quantitative habitat parameters were used in this analysis for three reasons:

1. the difficulty in examining relationships between invertebrate communities and categorical parameters
2. the fact that many of the categorical variables such as vegetation cover appeared highly variable between sites, suggesting a high degree of inter-operator variability
3. the fact that other variables such as bank stability, or land use within the stream changed little within a site.

Examination of the biological data matrix and the habitat data matrix showed an inconsistency in the number of samples collected for each matrix. A total of 83 invertebrate samples had been collected from the four waterways over a period of 14 sampling trips. In contrast, 82 records were available describing habitat variables from the four waterways over a similar period. Examination of the combined data showed that no habitat data had been collected from the Kaputone Site 1 on trip 8 (Spring 2009) and Kaputone Site 3 on trips 2, 3 and 8 (Spring 2006 , Autumn 2007 and Spring 2009) and from the Styx Site 1 on Trip 11 (Spring 2011). No biological data had been collected from Kaputone Site 1 and the Styx Site 2 on trip 11 (Spring 2011) and from Kaputone site 3 on trip 7 (Autumn 2009). These missing samples were consequently deleted from the combined dataset.

We used ordination techniques to determine which environmental variables were influencing the observed invertebrate communities in each of the four waterways. This involved a mixture of ordination analysis (see Appendix 1) and regression of the ordination scores against the measured environmental parameters.

3.0 Results

3.1 Comparisons of volunteer and QA/QC data

All data was first analysed to see whether differences occurred in the percentage abundance of the different invertebrate groups when processed either by the volunteers, or the QA/QC audits.

No differences existed in the relative abundance of any of the main invertebrate groups when analysed by either the volunteer groups, or the QA/QC. Furthermore, no differences were found in the number of invertebrate groups identified on each sampling occasion and at each site between the two data sources. Significant differences were seen in the relative abundance of some invertebrate groups between the four waterways, but these differences were consistent between the volunteer and QA/QC data (Figure 2). Thus, cased caddis flies were more common in Smacks Creek, the Otukaikino, and the Styx River, and were less common in Kaputone Creek. Free-living caddis and mayflies were most common in the Otukaikino, and least common, or absent in the Kaputone Creek (Figure 2). Amphipods were most common in the Styx River, and least common in the Otukaikino and Smacks Creek.

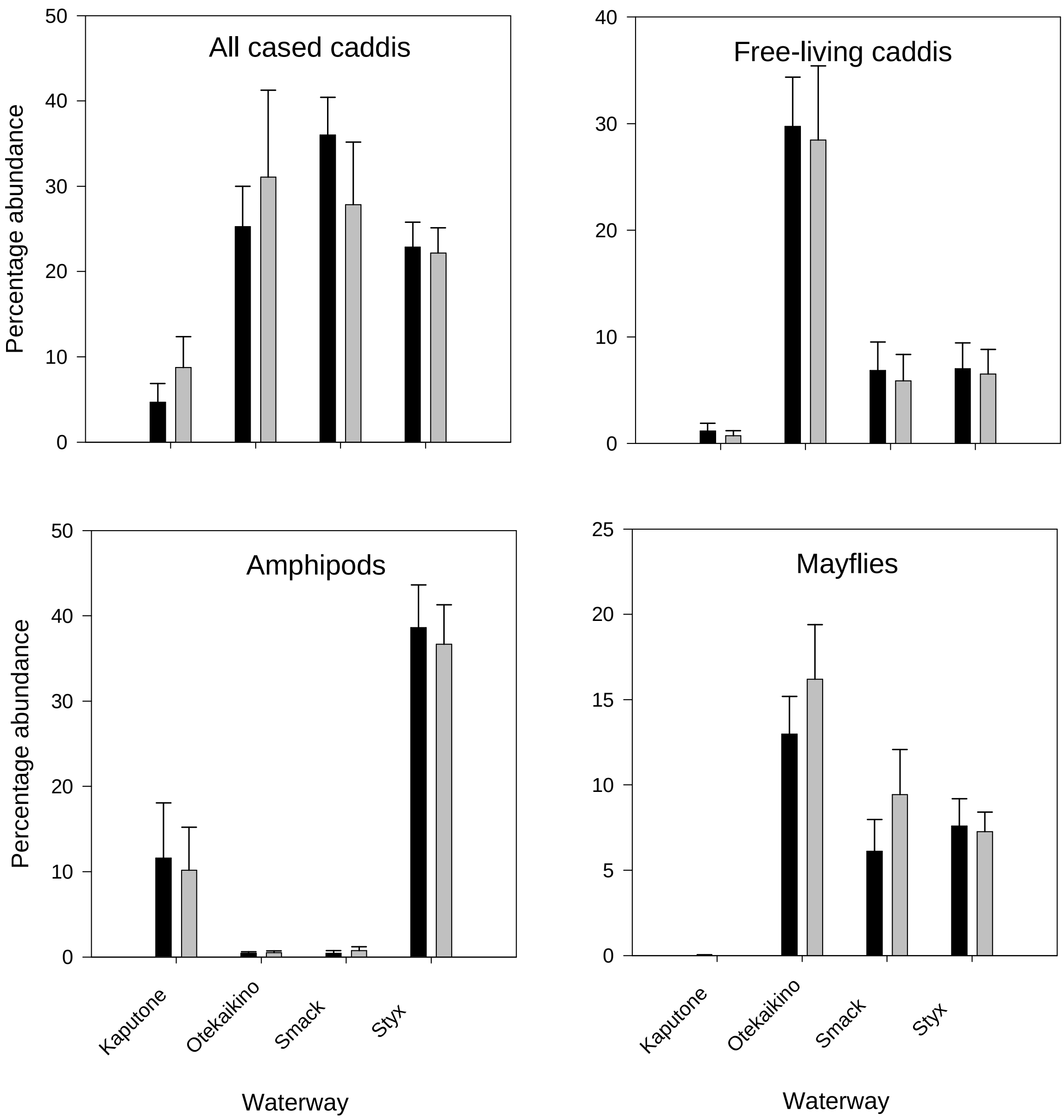

Figure 2. Percentage abundance of four of the most common invertebrate groups found in the four waterways sampled from 2006 to 2011, showing differences in volunteer data (black bars) and QA/QC data (grey bars).

Significant differences over time were observed for many of the invertebrate groups in the four waterways. For example, the percentage of amphipods peaked in Kaputone Stream in 2009, while in the Styx River, the percentage of these animals was low in both 2006 and 2011, but high in the intervening years (Figure 3). The percentage abundance of most taxa also differed over time in the four waterways. For example, the percentage of cased caddisflies peaked in 2009 at Kaputone Creek, declined over time in Smacks Creek, and decreased in 2007 in the Styx River before increasing to a more or less constant level (ca. 35%). The percentage of these animals varied without pattern in Otukaikino stream (Figure 4). Samples processed by the volunteers or the QA/QC showed very similar patterns in temporal variability for most of the other invertebrate groups at most streams (see Figure 5 and 6 for micro-crustaceans and spired snails). This would explain the lack of any significant effect of processing type on differences between sites, or over time. Lack of such differences suggests that the data obtained by the volunteer group was robust, and comparable to the data obtained by more experienced ecologists when samples were identified to a similar level.

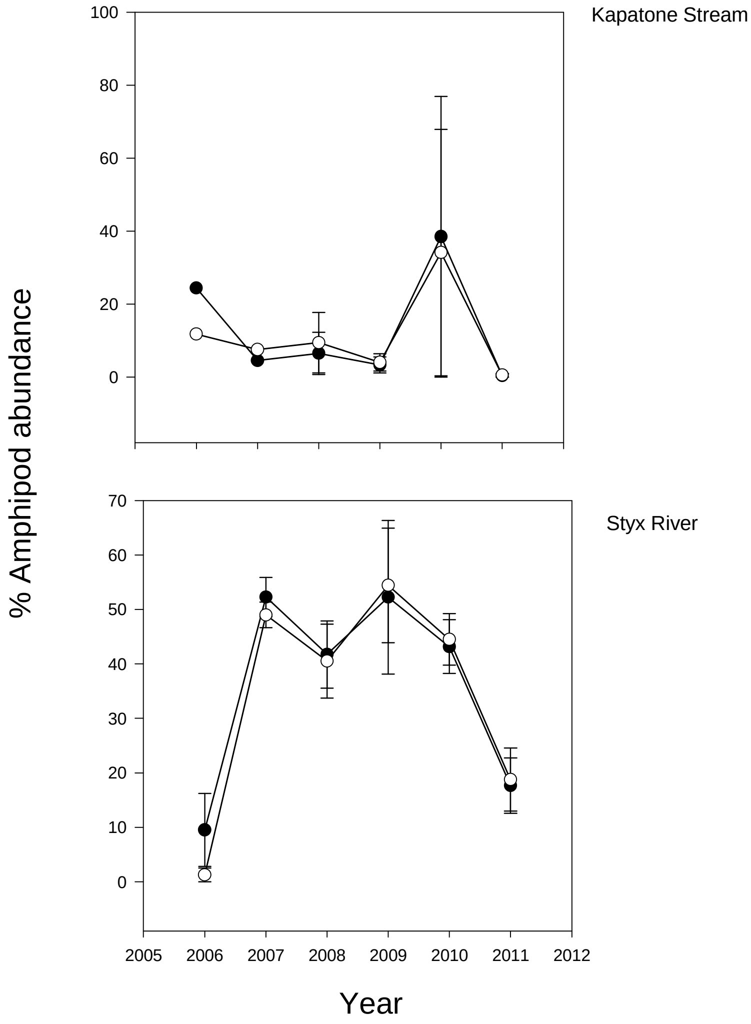

Figure 3. Percentage abundance of amphipods in Kaputone stream and the Styx River between 2006 and 2011 as obtained from volunteer data (black symbols) and QA/QC data (open symbols).

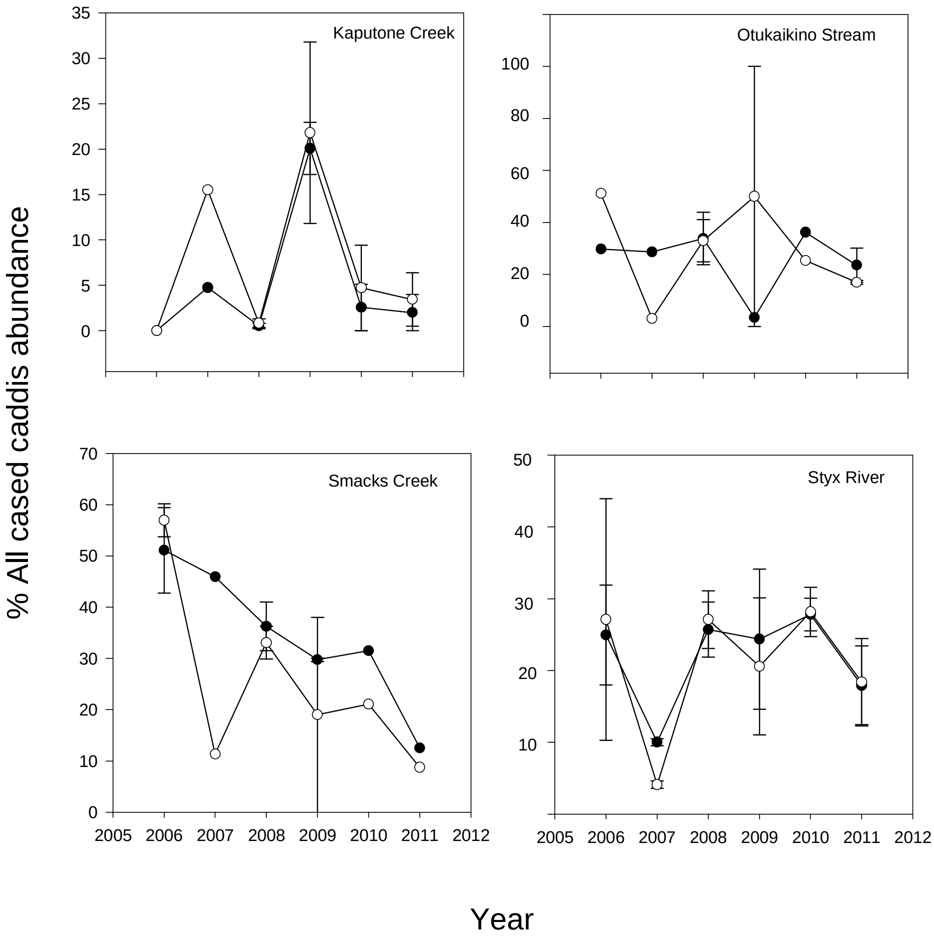

Figure 4. Percentage abundance of cased caddis flies in the four waterways between 2006 and 2011 as obtained from volunteer data (black symbols) and QA/QC data (open symbols).

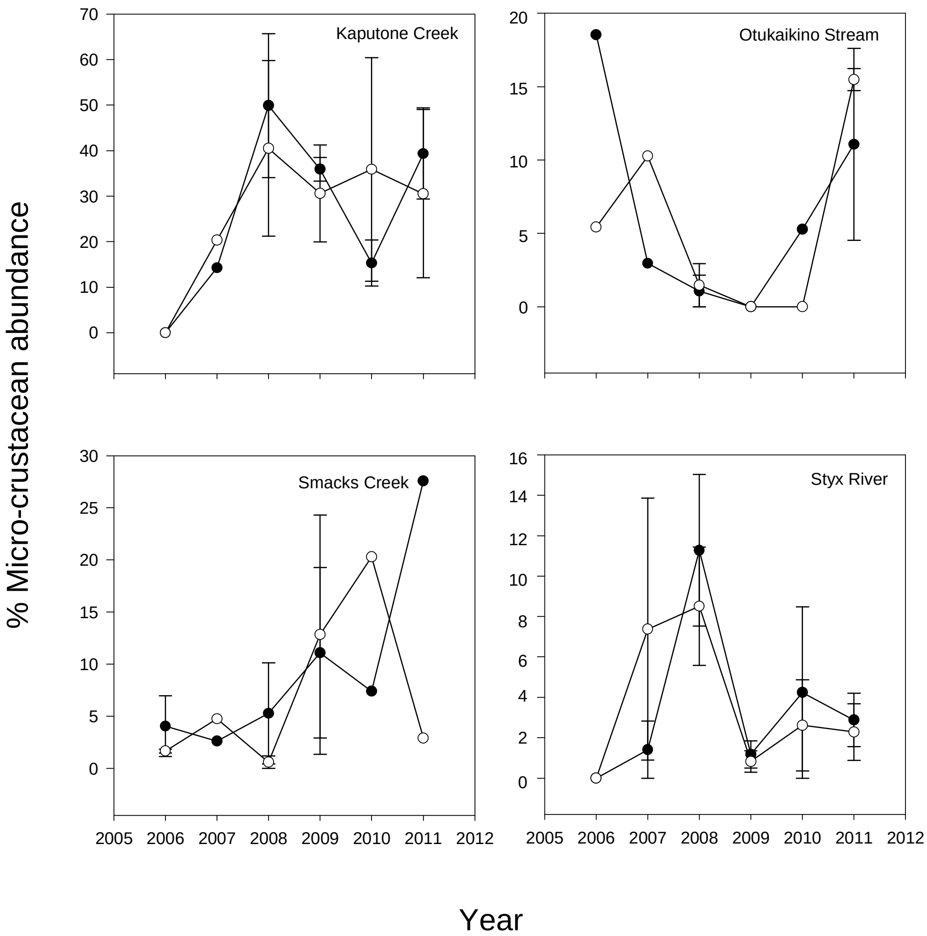

Figure 5. Percentage abundance of micro-crustaceans in the four waterways between 2006 and 2011 as obtained from volunteer data (black symbols) and QA/QC data (open symbols).

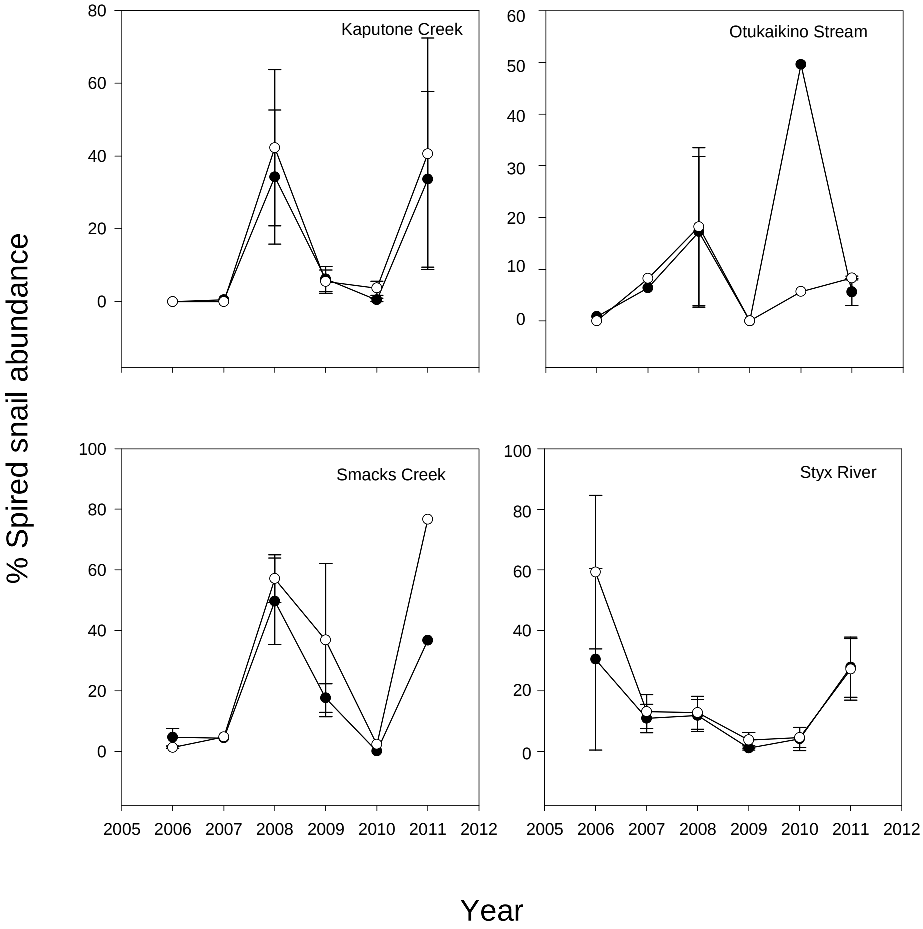

Figure 6. Percentage abundance of spired snails in the four waterways between 2006 and 2011 as obtained from volunteer data (black symbols) and QA/ QC data (open symbols).

All data obtained from the QA/QC audits were combined with that from the volunteer data to see whether there were differences in the ability of two data sets to detect differences between the four waterways, using ordination techniques. Examination of the combined data showed clear differences in invertebrate community composition between the waterways (Figure 7). Communities from Kaputone Creek appeared more different to those from the other three waterways, while communities from the Otukaikino and Smacks Creek appeared more similar. Little difference existed in the data collected between community groups and QA/QC (Figure 7). This gave us confidence in using the combined volunteer dataset from all sites for further analyses.

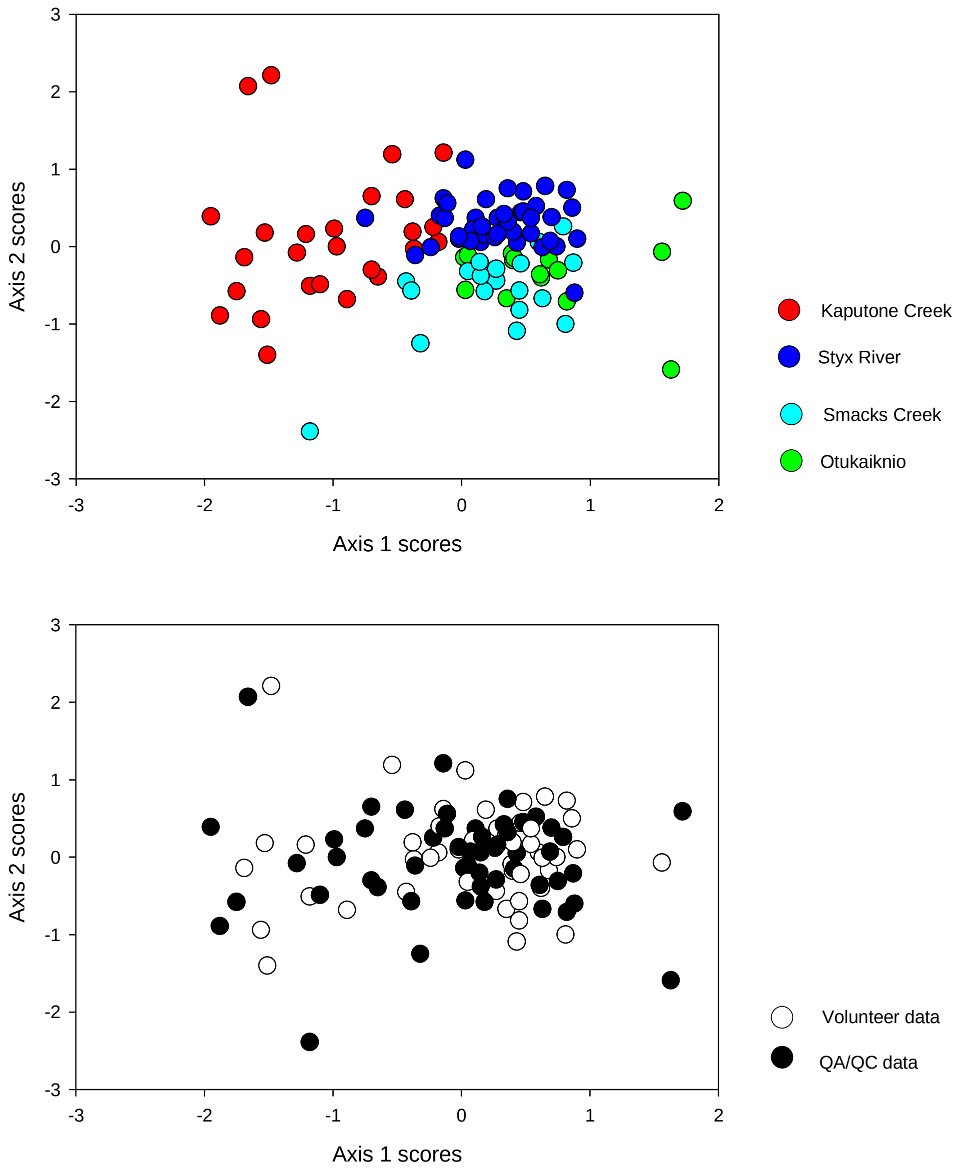

Figure 7. Results of an ordination analysis showing the combined volunteer and QA/QC data when coded by site (upper panel) or data source (lower panel). Note the clear differences between sites, but no apparent differences based on data source.

3.2 Trends in invertebrate data

3.2.1 Volunteer information

A total of 33 volunteers had assisted with the collection and processing of invertebrate data since 2005. Almost 40% of volunteers (13/33) had undertaken only one round of invertebrate monitoring. In contrast, only two volunteers have been involved with sampling since 2005 (Figure 8). Ten volunteers had been involved with at least 20% of sampling occasions, and could be considered as representing a relatively experienced volunteer base. The obvious implication here is how to increase longevity and interest of many of the volunteers who had partaken in only one sampling round.

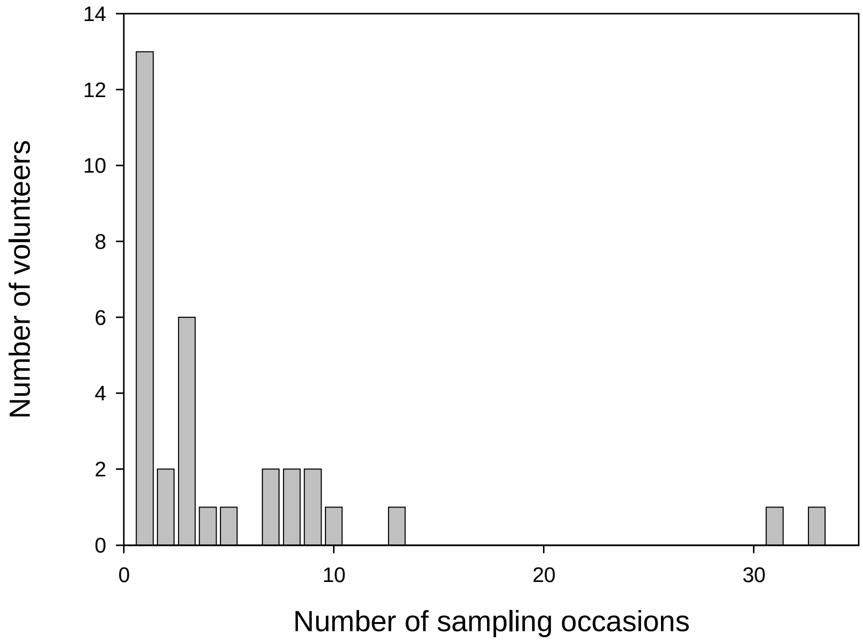

Figure 8. The number of individual volunteers who have undertaken sampling occasions associated with the SLLT monitoring programme.

3.2.2 Invertebrate data – between waterways differences

A total of 23 invertebrate groups have been identified by the volunteers in all the streams since 2005. The fauna in the four waterways was dominated by cased caddis flies (23.5%), spired snails (14%), amphipods, micro-crustaceans, and worm/nematodes (11%). The next most commonly encountered groups were mayflies (8%), free-living caddis, and fly larvae (7%). Other relatively common groups include pea clams (2%), and riffle beetles (1%). All other taxa were found with relative abundances of less than 1%.

Analysis of the invertebrate data showed that relative abundances of the seven most common taxa differed significantly between the four waterways. For example, relative abundance of free-living caddis flies and mayflies were highest in the Otukaikino, moderate in the Styx River and Smacks Creek, and least in Kaputone (Figures 9 and 10). In contrast, relative abundance of micro-crustaceans and pea clams were highest in Kaputone, and lowest in the other three waterways. Relative abundance of amphipods was equally high in the Styx and Kaputone, and low in Smacks Creek and the Otukaikino (Figure 9 and 10).

Relative densities of only three taxa (fly larvae, micro-crustaceans, and spiral snails) differed over time between the 11 sampling trips. Closer examination of the temporal data showed few consistent patterns with regards to annual or seasonal variation. Thus, the observed temporal differences were thought to reflect random differences between sampling periods, and not pronounced seasonal or annual differences.

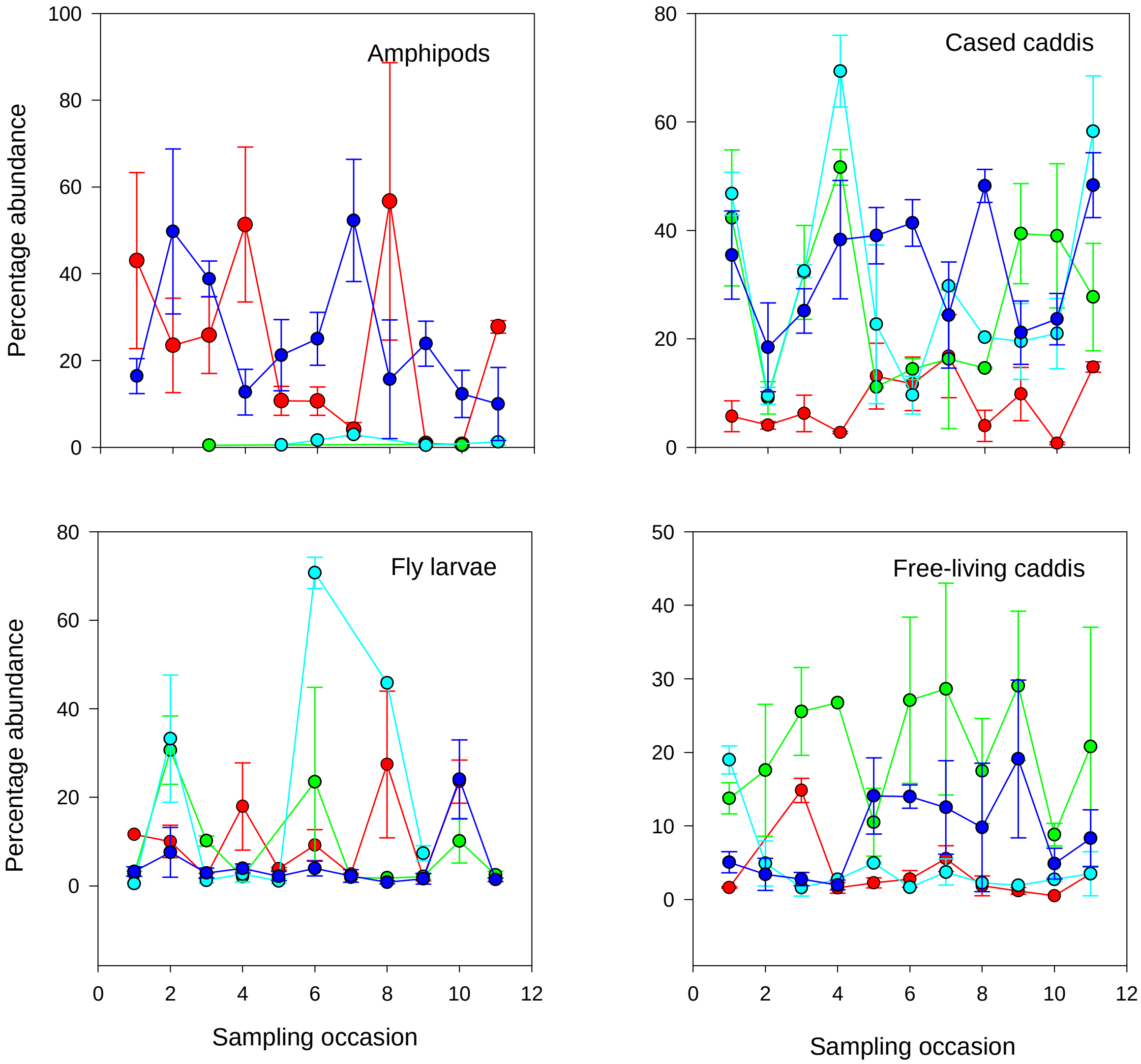

Figure 9. Average percentage abundance of common taxa found in four waterways over the 11 sampling occasions from Spring 2005 until Spring 2011. Otukaikino = green symbols; Styx River = dark blue symbols; Smacks Creek= light blue symbols; Kaputone Creek = red symbols

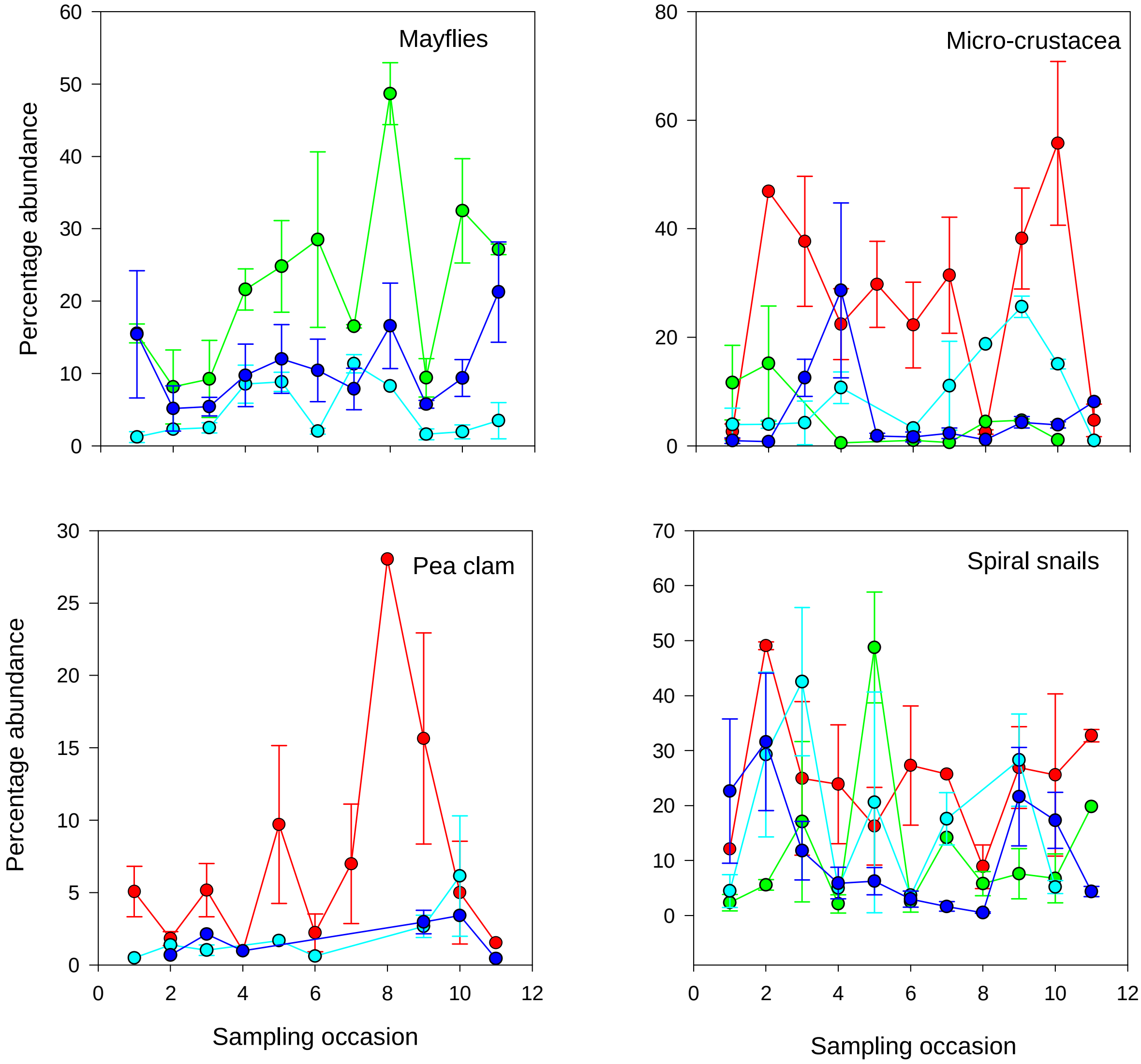

Figure 10. Average percentage abundance of common taxa found in four waterways over the 11 sampling occasions from Spring 2005 until Spring 2011. Conventions as per Figure 9.

Differences in invertebrate community composition between the four waterways were also examined. This analysis showed clear differences in the overall community composition between the four waterways (Figure 11). The invertebrate communities found in Kaputone Creek were very different to those of the other three waterways, and were characterised by taxa such as micro-crustaceans and pea clams. In contrast, the communities in the Styx River, Smacks Creek, and the Otukaikino were dominated by amphipods, cased or free-living caddis flies and mayflies. Communities in these three latter waterways also differed from each other, with communities in the Styx River being distinctive to those from the Otukaikino and Smacks Creek. Community composition was more variable in Kaputone Creek than the other waterways, as indicated by the wider separation of sample points on the ordination graph. In contrast, community composition appeared least variable in the Otukaikino. One reason for this difference is that the Otukaikino is represented by just one site in this dataset while there are three sites on the Kaputone.

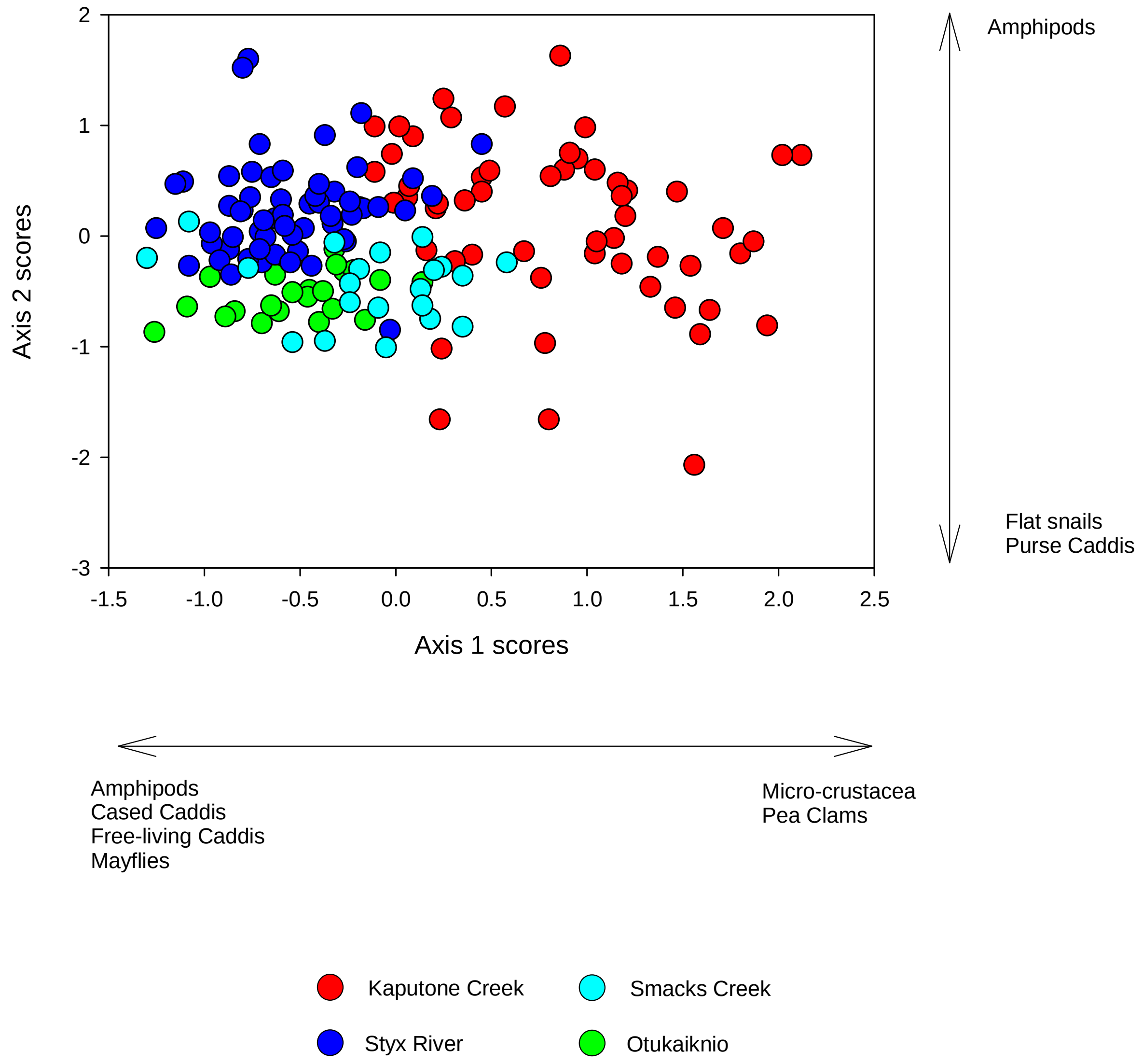

Figure 11. Results of an ordination analysis showing differences in the invertebrate community composition between the four waterways examined in the study.

3.2.3 Invertebrate data – within waterway differences

Samples had been collected from three different sites both within the Styx River and Kaputone Creek. This gave us the opportunity to determine whether invertebrate communities differed significantly between different sampling locations within each of these two waterways. Examination of the percentage abundance data show that relative abundance of only spired snails differed in Kaputone Creek. Here, relative abundance was higher at K3 (Blakes Rd) than at the other two sites (Figure 12). There were no other differences in relative abundance of taxa at the Kaputone sites, nor were there any significant differences in relative abundance of any taxa over time.

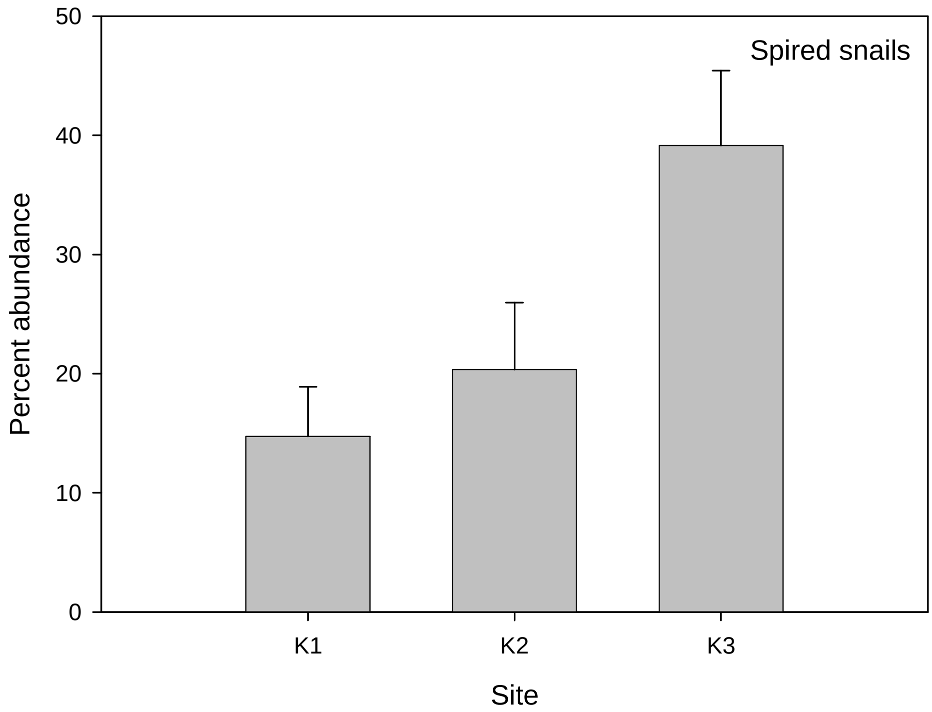

Figure 12. Percentage abundance of spired snails collected from the three sampling sites in the Kaputone Creek.

Despite the lack of difference in the relative abundance of most invertebrates between the three different sites in Kaputone Creek, examination of the overall community composition showed that this was significantly different between the three sites (Figure 13). Site three in particular appeared to be more distinctive than sites one or two.

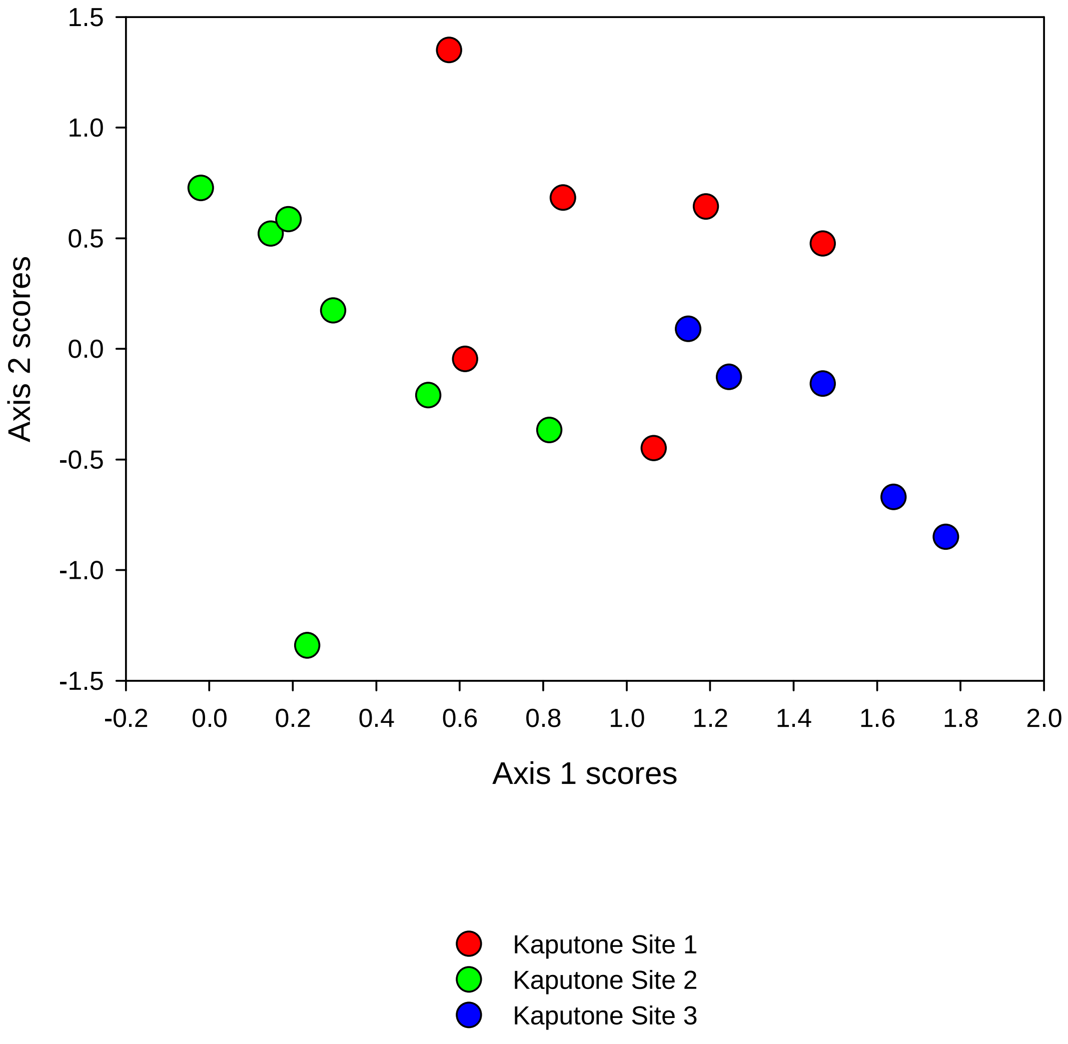

Figure 13. Results of an ordination analysis showing differences in the invertebrate community composition between the three sampling sites in the Kaputone Creek over time.

Within the Styx River, relative abundances of amphipods, cased caddis flies, mayflies and spiral snails differed between the three sites. Percent abundance of amphipods, cased caddis, and spiral snails were highest at S1 (Headwaters), while the percentage abundance of mayflies was highest at S2 (Styx Mill Conservation Reserve) (Figure 14). Relative abundances of mayflies differed between sampling trips, although no seasonal patterns were evident. No other temporal differences were observed in the major invertebrate groups over time at any of the three sites on the Styx River.

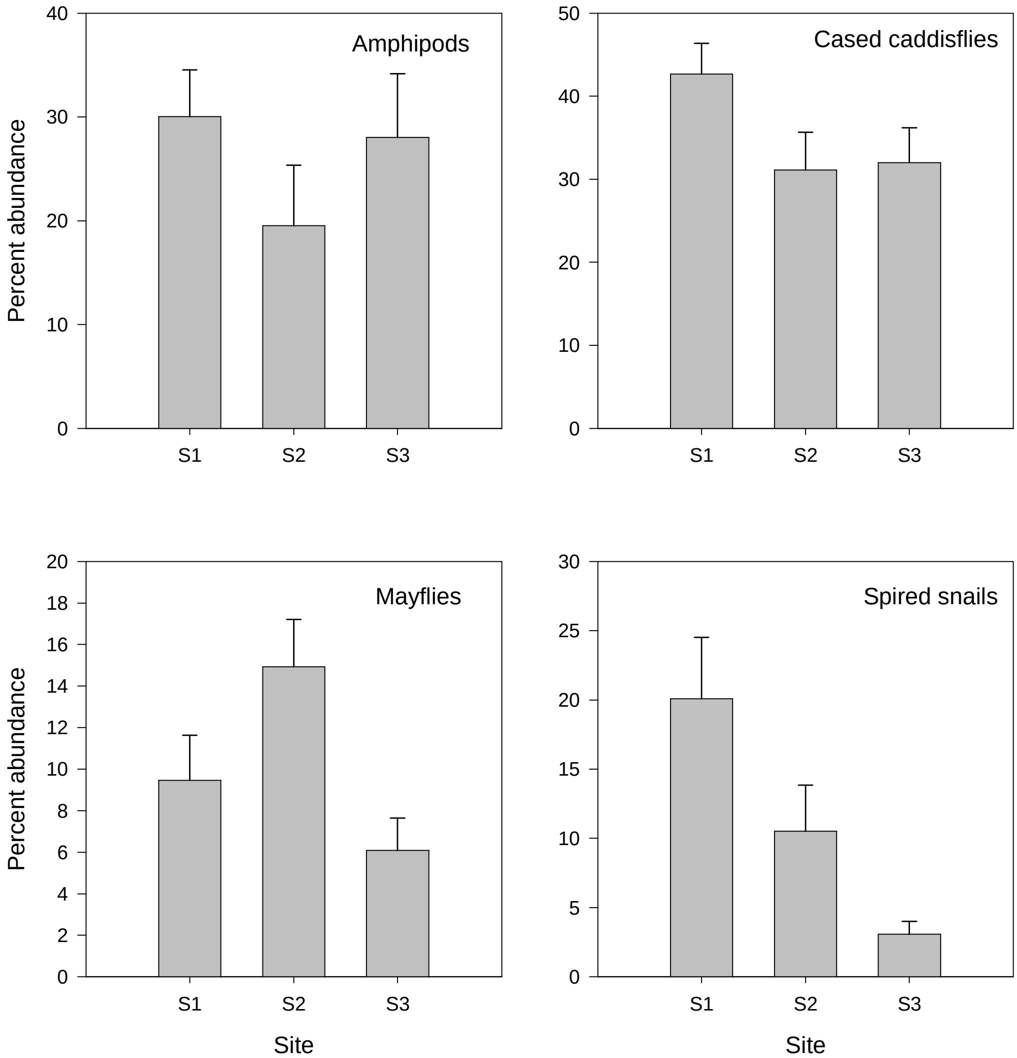

Figure 14. Relative abundances of amphipods, cased caddis flies, mayflies and spiral snails in the three sites in the Styx River.

Despite relatively large differences in percentage abundance of some common taxa between the sampling sites in the Styx River, analysis of all community composition data showed little evidence of consistent differences between the three sampling sites (Figure 15).

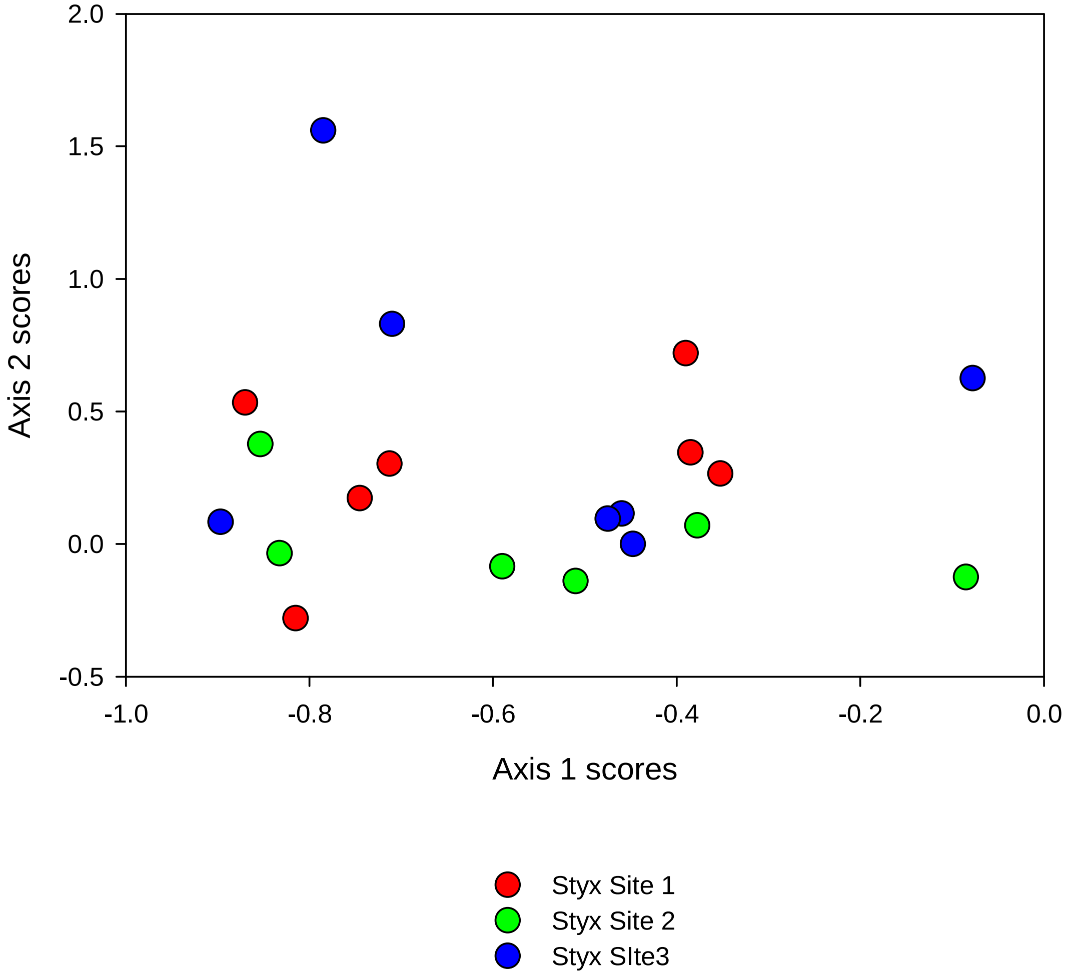

Figure 15. Results of an ordination analysis showing differences in the invertebrate community composition between the three sampling sites in the Styx River over time.

3.3 Trends in habitat data

3.3.1 Habitat data – between waterway differences

Habitat data was first analysed to determine whether significant differences existed between the four waterways, and over time. The average of water, macrophyte and sediment depth were calculated for each transect, and these used to obtain averages for each waterway over time. Analysis of this data showed significant differences in water, macrophyte and sediment depth, and stream width between the four waterways. Thus, the Styx River was usually the deepest, while Smacks Creek was the shallowest. Kaputone Creek and the Otukaikino had intermediate water depths (Figure 16). Macrophyte depth was highly variable, and generally highest in the Styx, and Smacks Creek. The depth of fine sediments was consistently highest in Kaputone Creek, and low in the other three sites (Figure 16). Stream width was greatest in the Otukaikino (where it varied considerably), and was narrowest in Smacks Creek. The extreme width recorded in the Otukaikino on the 9th sampling occasion could have been due to 2 reasons. Firsty, the field notes stated that the stream here was flooded as a result of heavy rain. As a consequence, the river may have overtopped its banks and the width measurements may have indeed reflected this. However, an alternative and much more plausible explanation is that a transcription error was made when writing the width down, so that instead of writing down a value of “1067cm” wide, the volunteer recorded instead “9067 cm” wide. This is the likely scenario, as stream widths at transects 2 and 3 on this occasion had the widths recorded as 1100 cm and 1020 cm respectively. This highlights the fact that habitat data is presently not subject to any form of QA/QC and thus potentially subject to many errors. Furthermore, stream width at the Otukaikino on trips 5 and 7 were very narrow (ca 100 cm), compared to the long term average of 1110 cm. Again, this is most likely to reflect simple transcription errors. Thus, the values of stream width on trip 5 was recorded as being 103, 103 and 100 cm, whereas this most probably should have been recorded as 1003 (twice) and 1000 cm. Similarly, on trip 7, the width was recorded as 104, 97 and 94 cm for transects 1 to 3 respectively, whereas this most probably should have been 1040, 970 and 940cm. These examples of simple transcription errors in the habitat data sheets highlight the need for some form of QA/QC analysis on this data, similar to that presently done for the invertebrate data. Water and sediment depth, and stream width varied inconsistently between the four waterways over time, without obvious pattern.

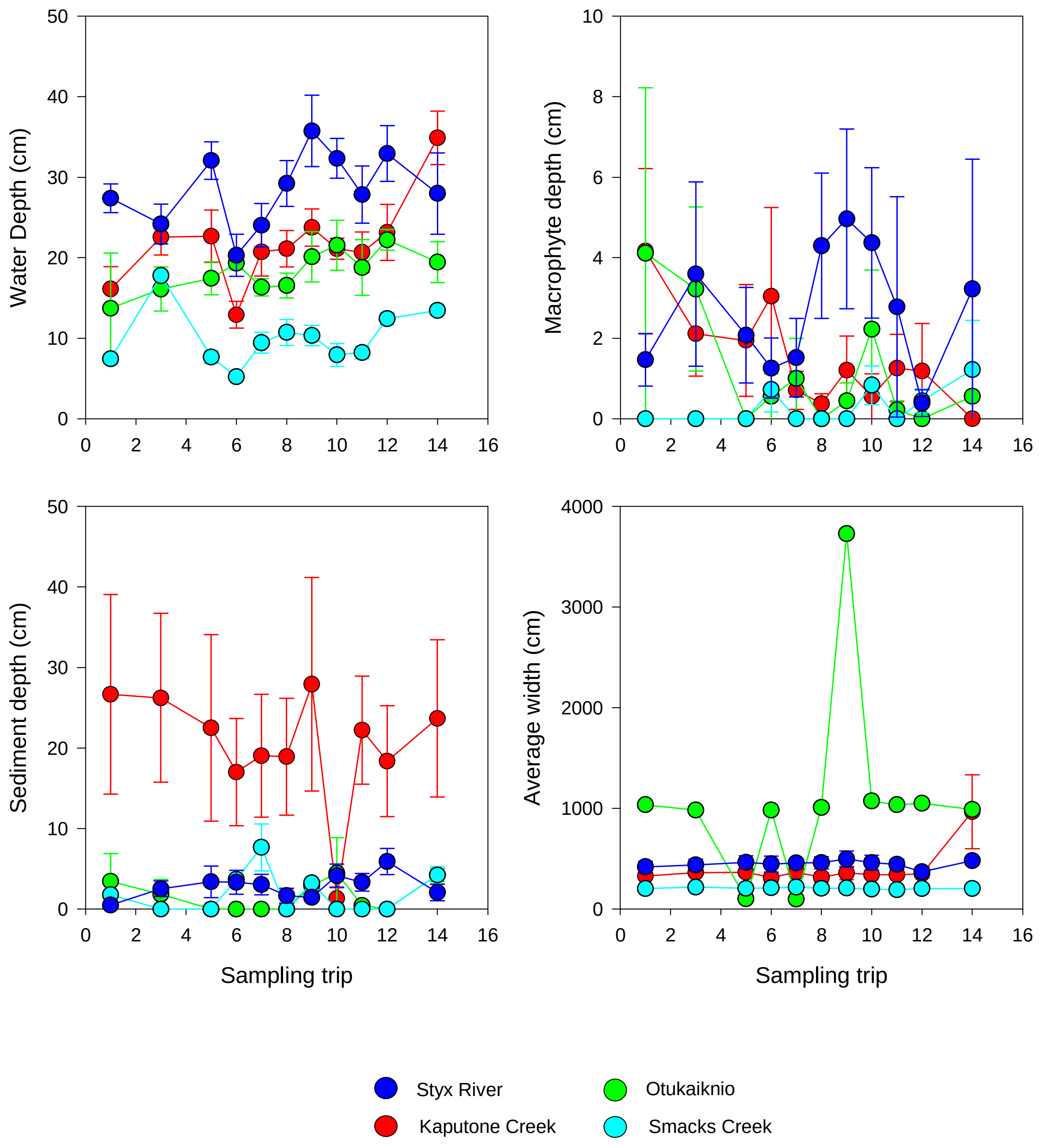

Figure 16. Water depths, macrophyte depth, sediment depth and average stream width in the four waterways during the monitoring period.

Examination of the cover of organic material showed a degree of variability both within sites, and over time (Figure 17). Significant differences only existed in the cover of aquatic mosses and liverworts, which were highest in Smacks Creek, moderately high in Styx River, and either low or absent in the Otukaikino and Kaputone. Cover of these plants varied greatly over time in Smacks Creek, reaching a high of 60% cover on one sampling occasion. Cover of these plants immediately before and after that sampling occasion were less than 5%. Given the fact that these plants are generally long lived in streams, are not washed away due to flood events, and do not grow quickly, this extreme fluctuation may instead be due to misidentification by some of the volunteers. The only other instream vegetation to differ significantly between sites was the submerged macrophytes (Figure 17). Here, cover was significantly higher in the Styx River, followed by Smacks Creek and Kaputone Creek, and was lowest in the Otukaikino. Macrophyte cover was generally above 20% in the Styx River until the 11th sampling occasion (Autumn 2010) when cover decreased markedly to less than 5%. Given the fact that these plants are so easily recognised, this may have been a real phenomenon, caused either by a large flood event that scoured plants from the stream, `or more likely by the City Council stream maintenance team as part of their regular stream maintenance activities with instream weed clearing. Analysis of the composition of organic material in each of the four waterways over time showed that there were no significant differences in the type of organic material.

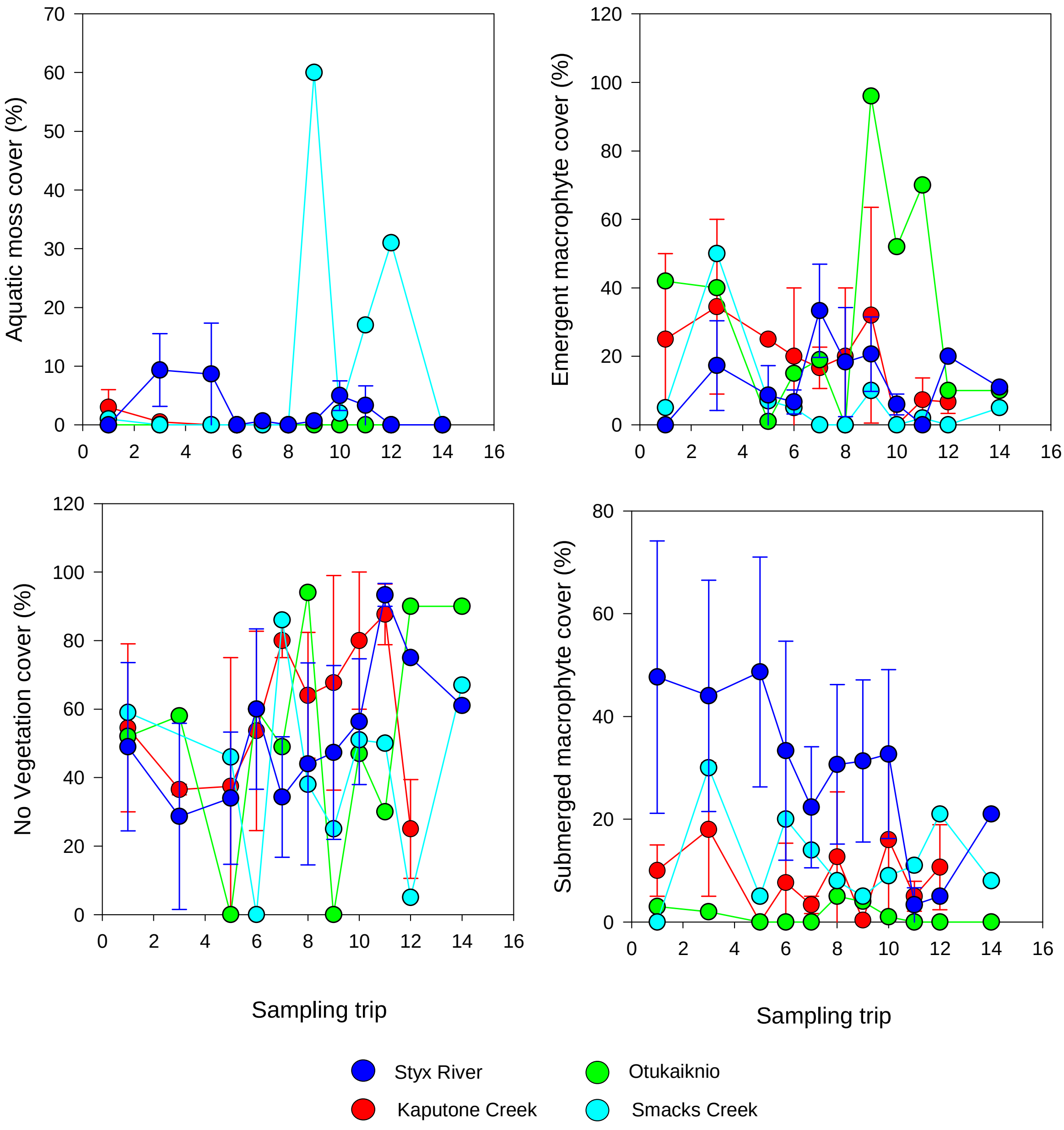

Figure 17. Percent cover of the four dominant vegetation types in the four waterways during the monitoring period. Only the cover of aquatic mosses and submerged macrophytes differed between the waterways. Note also the high variability of cover within each river over time.

Analysis of the substrate data showed clearly that Kaputone Creek had the finest substrate size, whereas the Otukaikino and Smacks Creek had the largest substrate size. Substrate size in the Styx River was intermediate (Figure 18). There was a high degree of within river variability in Kaputone Creek, likely reflecting the large differences between K1, K2 and K3.

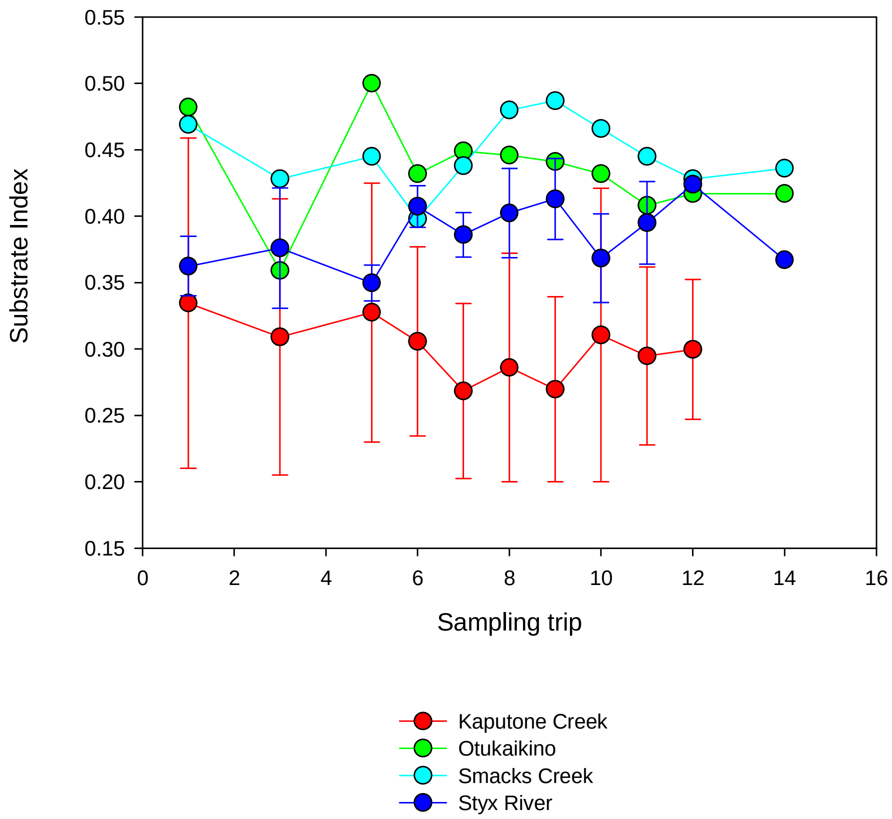

Figure 18. Calculated substrate index in the four waterways during the monitoring period. Note the high degree of variability in Kaputone Creek as indicated by the wide error bars.

Significant differences existed in the average velocity in each of the four waterways in the study. Velocities were highest in the Otukaikino and the Styx River, and lowest in Kaputone Creek (Figure 19). Although there was considerable variability over time, no detectable trends were evident. Velocities were measured by timing the movement of either a tennis ball or an orange down a 10 m section of a waterway, and we found no difference in measured velocities between these two methods.

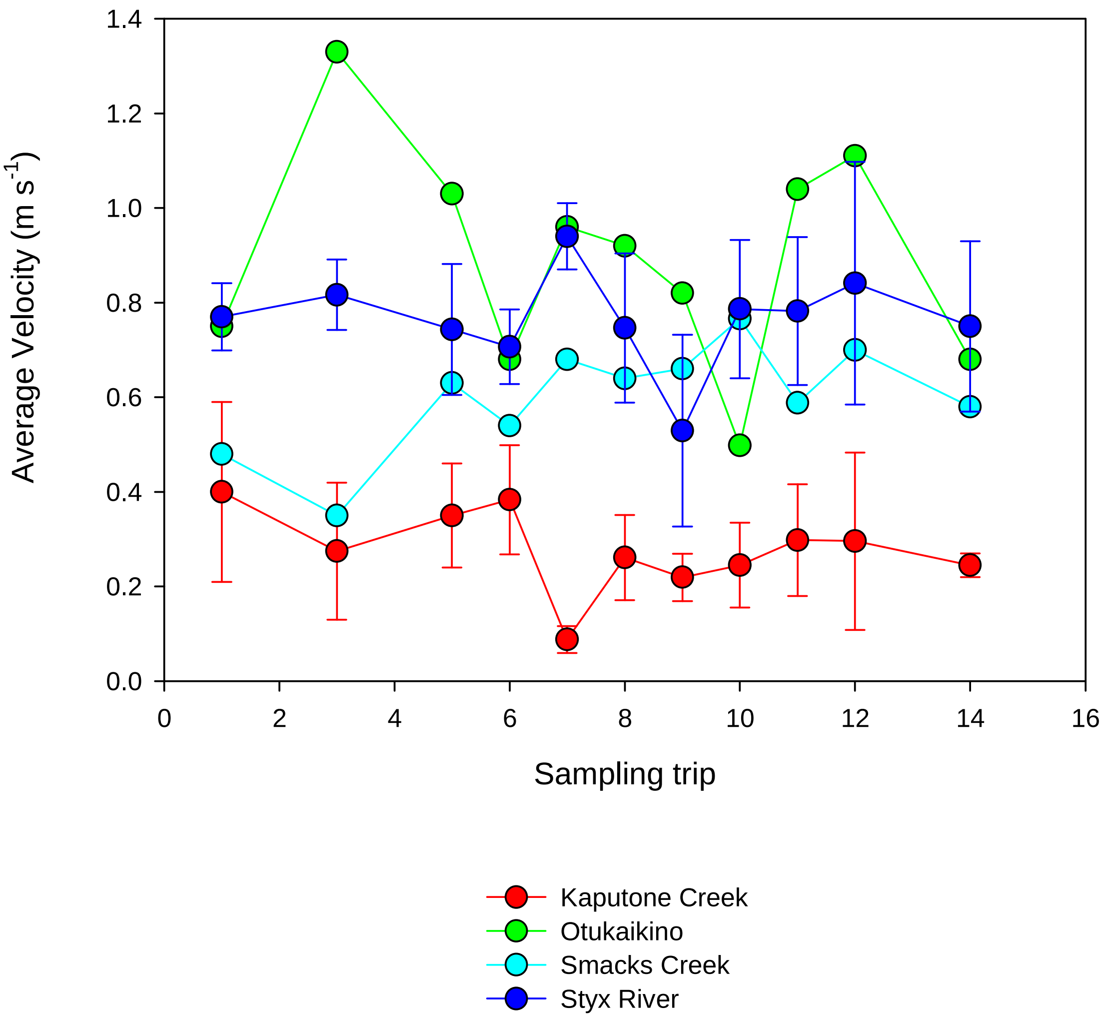

Figure 19. Average instream velocity in the four waterways during the monitoring period.

Data describing the bank material on the left and right banks was examined. A total of 178 observations had been made over the 11 sampling trips. The vast majority (92%) of observations described the bank material at each site as being dominated by "earth". The "other" bank material category was found only at Kaputone Creek and the Styx River on the first two sampling occasions, while the "rock" bank category was found on two occasions only in Kaputone Creek. Other bank material categories (brick/concrete, and wood) were recorded only once at Smacks Creek and Kaputone Creek respectively.

Examination of data describing bank stability showed that the majority of observations described the banks as being "moderately stable" at all four sites (Figure 20). Bank stability varied most at Kaputone Creek, where all five stability classes were observed, and least at Smacks Creek, where bank stability was assessed as being either extremely stable, or moderately stable.

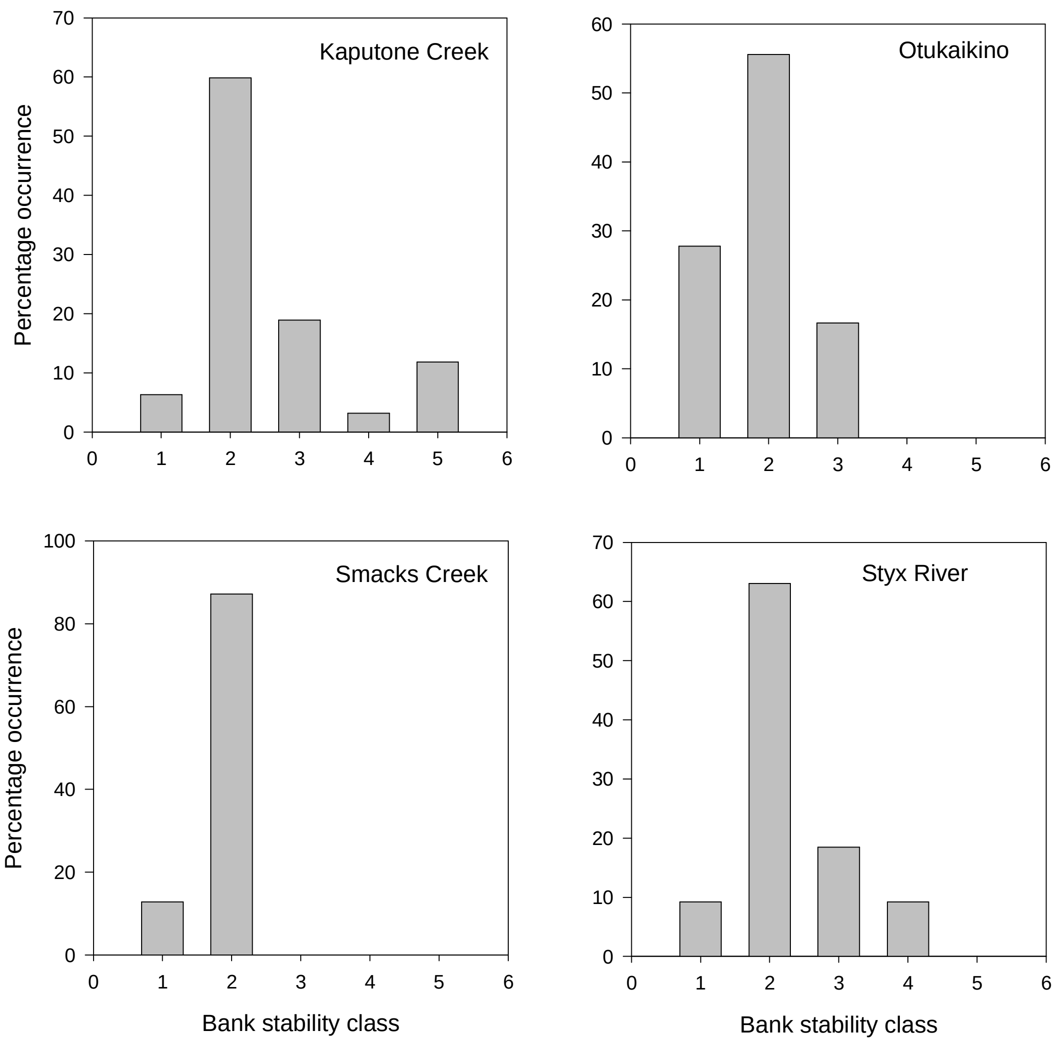

Figure 19. Percent occurrence of different bank stability classes in the 4 waterways over time. Note the wide range of stability classes in the Styx River and Kaputone Creek, possibly reflecting a combination of inter-operator variability and the fact that these two streams had three sites within them, which may have increased the number of different bank stability classes.

Volunteers also collect information on the predominant land use type (horticultural, lifestyle blocks, reserve, grazing land, and urban) in the general vicinity of the survey site. This is done for the true left and true right banks. Land use data was subsequently summed for each bank, and for each sampling occasion. Examination of this data over time showed that the land use assessments generally did not change during the period of the survey. However, there were times when the assessment of land use differed greatly between successive sampling trips (Figure 21). For example, the true right bank in the Styx River had been assessed as "Lifestyle" on 9/10 sampling occasions, whereas it was assessed as "Urban" on the thirdsampling trip. Land use assessments on the true left bank here were assessed as only "Horticultural" on 5/10 sampling occasions, both "Horticultural" and "Reserve" on three sampling occasions, and only "Reserve" on two sampling occasions. Such changes are more likely to reflect differences between the assessments made by the volunteer monitors, rather than absolute changes in land use.

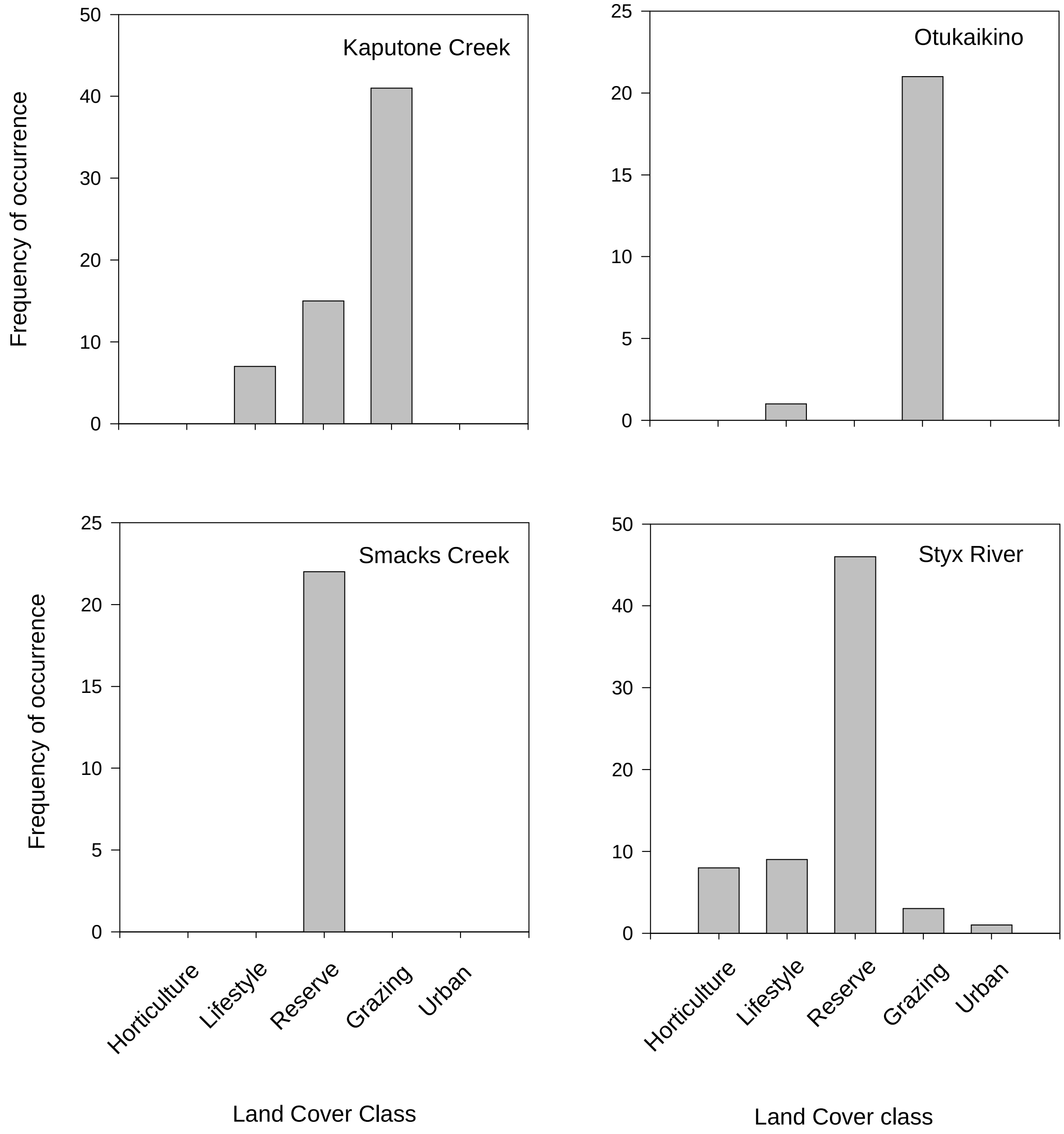

Figure 21. Percent occurrence of different land cover classes in the 4 waterways over time. Note the wide range of land use classes in the Styx River and Kaputone Creek, possibly reflecting inter-operator variability.

Examination of the riparian vegetation data showed that the Styx River had the most diverse vegetation structure (15 classes present), Kaputone and Smacks creeks had intermediate diversity of vegetation (12 classes), and Otukaikino the lowest diversity (six classes). Un-managed grass was the most commonly encountered vegetation type (41%), followed by rushes and exotic deciduous trees (10%), and low groundcover (7%). Unvegetated areas, coarse native vegetation, ferns and native vegetation were the next most commonly encountered vegetation types (4%).

Data summarising riparian vegetation was summed for the upper and lower banks on the true left and right banks respectively, and from each sampling site in each stream. This gave information describing the total vegetation cover at each site on each sampling occasion. Summed cover class variables therefore ranged from 0 (no cover present for that plant type) to 36 (cover class = 3 for both upper and lower banks on the true left and right banks at all three sites). Examination of the most common vegetation types showed clear differences between waterways, and a large variability over time (Figure 22). Exotic deciduous trees (e.g. willows) and undermanaged grass were most common at Kaputone Creek, and the Styx River. Combined cover classes of the left and right banks, and upper and lower banks, revealed a large degree of variation at both these rivers. For example, total combined cover of willows varied from 1 to 13 at the three sites in the Styx River, and from 1 to 9 in Kaputone Creek, while combined cover of unmanaged grass varied from 13 to 27 in the three sites in the Styx River, and 12 to 36 at the three sites in Kaputone Creek. Such a large amount of variability of these dominant plants in each waterway over time was surprising, especially given their ease of identification, and the fact that they are unlikely to vary this much naturally. Cover of low ground plants was highest in the Styx River, but again highly variable. Cover of rushes did not appear to differ between the different waterways, but was also highly variable.

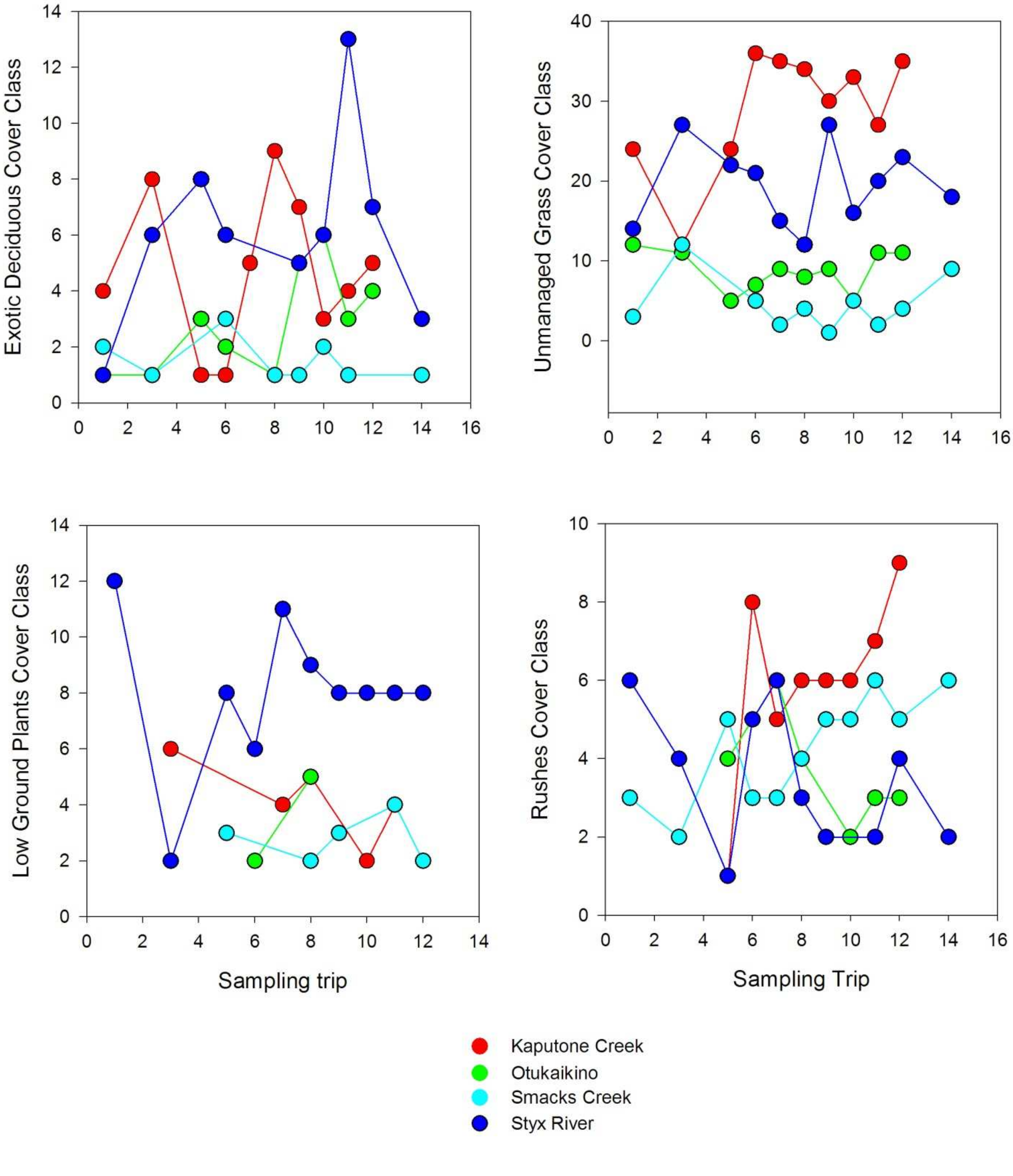

Figure 22. Total cover of dominant riparian vegetation classes in the four waterways (all sites, left and right, and upper and lower banks combined) during the monitoring period.

The riparian vegetation was also analysed to determine whether the different waterways supported different vegetation types. Results of this analysis showed that the riparian vegetation did differ between the four waterways, although there was a considerable degree of overlap (Figure 23). Vegetation at the Otukaikino stream appeared to be most distinctive, as it was characterised by the second lowest amount of willows, and unmanaged grass, and the highest cover of exotic shrubs. Vegetation structure at Kaputone Creek and the Styx River varied the most, as indicative of the large spread in the ordination scores.

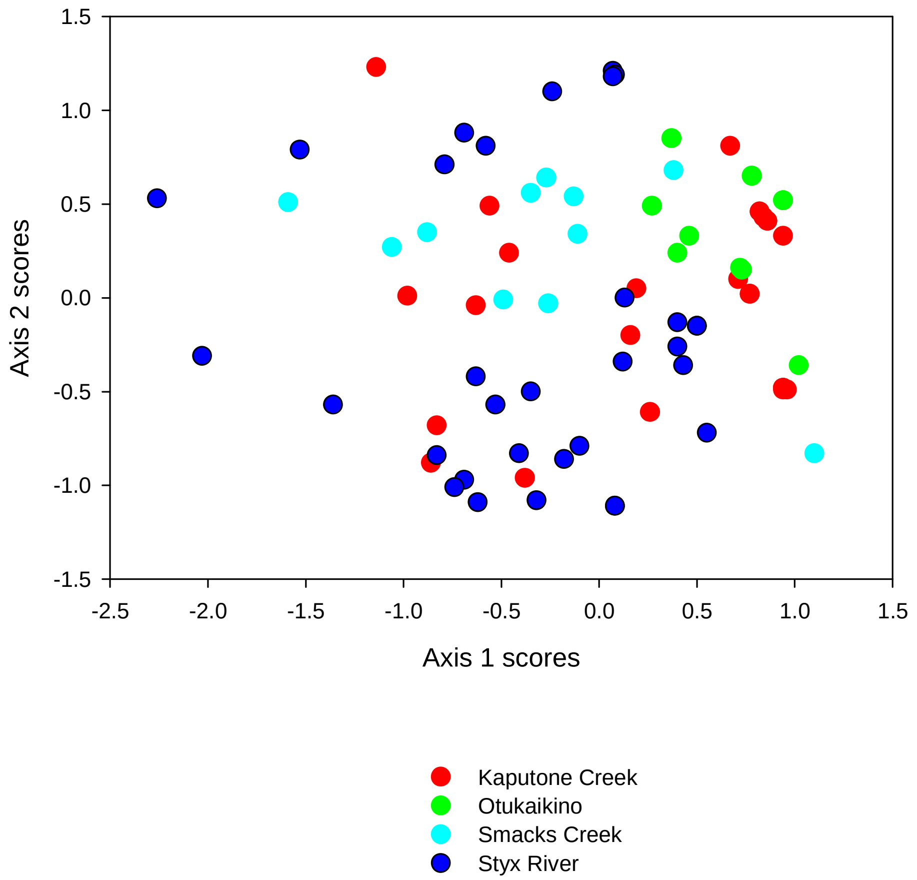

Figure 23. Results of an ordination analysis showing differences in the riparian vegetation between the four waterways. Note the lack of strong sample clusters, with the exception of the Otukaikino, suggesting that riparian vegetation structure in the other waterways was relatively similar.

3.3.2 Habitat data – between waterway differences

Examination of habitat data collected from the three sites at Kaputone Creek and the Styx River revealed interesting patterns. Within Kaputone Creek, significant site differences were observed for sediment depth, the substrate index and water velocity (Figure 24). Fine sediments were deeper at Site 1 (Belfast Rd) in Kaputone than the other two sites, and the calculated substrate index was largest at Site 2 (Ouruhia Domain; Figure 24). Water velocity was also greatest at Site 2 during the study. Significant temporal variability was observed for macrophyte depth, which declined at Site 1 in Kaputone Creek. Although we could not test for statistical variability over time for substrate index or velocity, examination of the data showed that the substrate index varied little within sites over time, while measured water velocity varied to a greater extent (Figure 24).

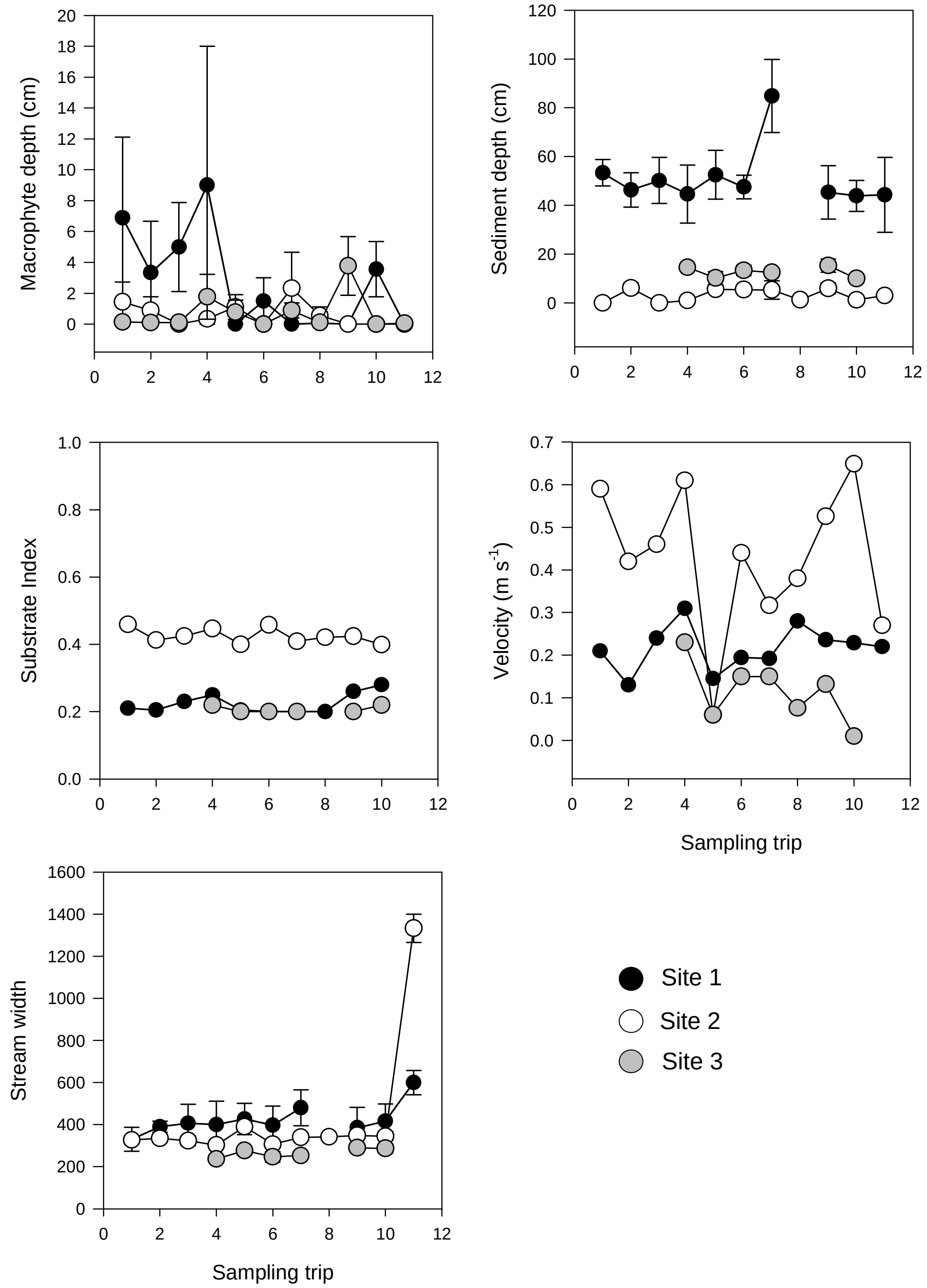

Figure 24. Average macrophyte depth, sediment depth, and stream width, calculated substrate index and measured velocity from the three sites in Kaputone Creek over the study period.

Macrophyte depth was significantly higher in Sites 2 (Styx Mill Conservation Reserve) and 3 (Main North Road) in the Styx River, with the exception of the last sampling occasion, when it was highest in Site 1 (Headwaters; Figure 25). Macrophyte depth also varied significantly over time, but without any obvious patterns. Fine sediment depth also differed between sites and was generally deepest at Site 2, and shallowest at Site 1. It also varied significantly over time, and increased at Sites 1 and 3. Stream width was significantly widest at Site 2 and 3 in the Styx River, and narrowest at Site 1. Stream width did not vary significantly over time at any site (Figure 25). The calculated substrate index was greatest at Site 1, but this did not appear to vary greatly over time within each site. Water velocity was greatest at Site 3 in the Styx River, and lowest in Site 1. Velocity appeared highly variable at Site 2, but was much less variable at the other two sites (Figure 25).

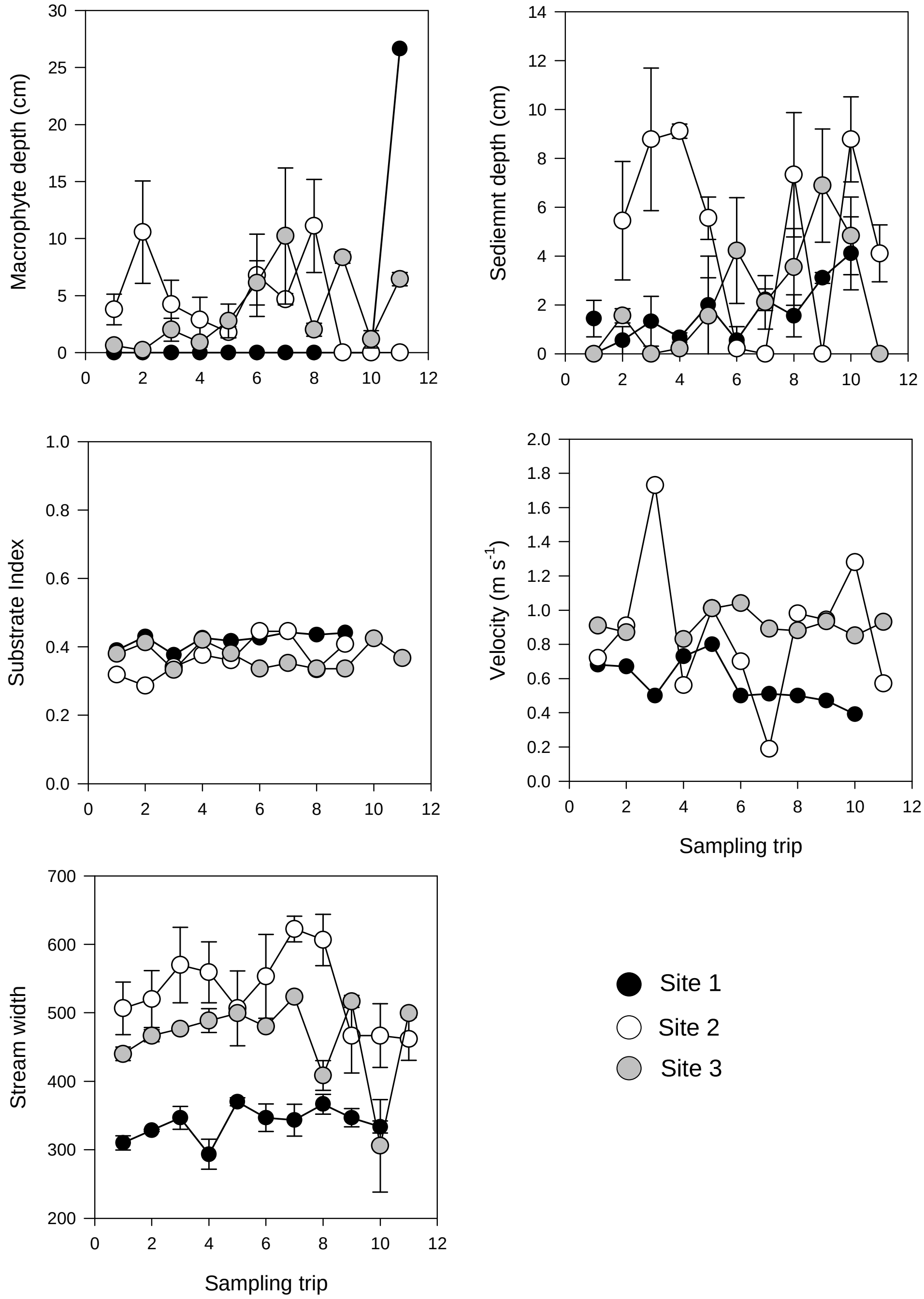

Figure 25. Average macrophyte depth, sediment depth, and stream width, calculated substrate index and measured velocity from the three sites in the Styx River over the study period.

3.3.2 Interactions between invertebrates and habitat

Analysis of invertebrate and habitat data again highlighted the distinctive invertebrate communities found in each of the four waterways. These were seen to be controlled by habitat variables such as the depth of soft substrate, substrate size, and water velocity, as well as by water depth (Figure 26). Thus, samples from Kaputone Creek were characterised by deep soft substrate, a small substrate index, and slowly flowing waters. The invertebrate communities in that waterway were very different to those from fast flowing sites with coarse substrates and less deep fine material.

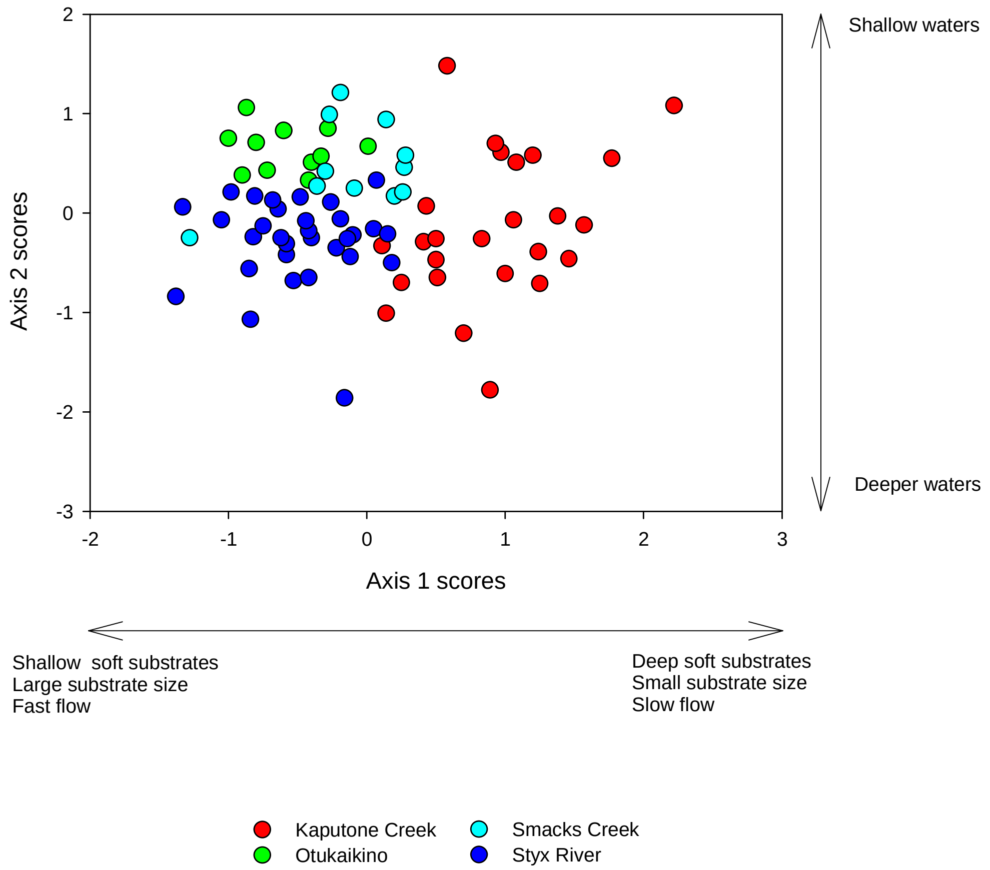

Figure 26. Results of an ordination analysis showing differences in invertebrate composition between the four waterways, and habitat variables that appeared to influence these communities in each of the waterways.

4.0 Discussion

Volunteers associated with the Styx Living Laboratory Trust have been monitoring streams since 2005. To date, 11 sampling trips have been made. This report was prepared to analyse and report upon the results of the invertebrate and habitat monitoring, and to make recommendations for future monitoring by the SLLT volunteers. Such a task is especially pertinent considering the large commitment by the 33 volunteers over the five-year period that the monitoring has been conducted. In this report, we undertook the following tasks:

1. commented on differences between volunteers and QA/QC protocols
2. analysed the invertebrate data to detect differences in community compositions between sample sites, or overtime
3. examined relationships between invertebrate and physical data
4. made recommendations on ways to modify the valuable work undertaken by the community volunteers

Feedback on the monitoring work done to date, as well as recommendations made, is hoped to ensure the continuation of volunteer monitoring by the Styx Living Laboratory Trust.

4.1 Comparisons of volunteer and QA/QC data

The fact that the SLLT has arranged to have proper QA/QC checks on the invertebrate data collected by the volunteers is highly commendable. One of the key findings of these QA/QC reports was the need to ensure consistent identification of invertebrates. In particular, the early QA/QC reports recommended merging of the original taxonomic groups into higher levels. Based on these QA/QC reports, and grouping taxa to these high levels, we were able to collate the invertebrate data obtained from individual sampling occasions into a single dataset. Analysis of the merged and corrected volunteer data showed that it gave consistent results to that obtained through the QA/QC process. This finding is extremely important, as it gave confidence in using all of the invertebrate data collected by volunteers for the analysis presented in this report. It is also a good testament to the skill and dedication of volunteers, and they are to be commended for this.

Analysis of habitat data, however, showed considerable variability in some of the measured parameters - even when such variability was considered unlikely. For example, assessment of land use at each site was shown to vary considerably overtime (and presumably between volunteer), when in fact such changes would be considered highly unlikely. Given the importance of collecting the quality data, it is consequently recommended that some form of QA/QC checking is done on the habitat data as well as the invertebrate data. This is acknowledged to be problematic, as any QA/QC checking would need to be done by a trained observer in the field at the same time that the volunteers are making their measurements as well. Refresher training of volunteers on how to consistently measure, observe and record the habitat data may also reduce the variability.

4.2 Volunteer information

The finding that 33 volunteers had assisted with the monitoring over the five-year period was surprising, as was the finding that only 10 were regarded as being actively involved. In order to increase the retention of volunteers, the SLLT needs to determine what has motivated the long-term volunteers to continue, as well as understand the reasons others leave. Some form of formal induction protocol could be investigated, as well as some form of "exit interview" so that the SLLT board members could better understand what motivates volunteers, and what makes them leave. Discussions with some of the volunteers have also highlighted concern at the fact that many of the habitat variables that are collected seem to take considerable time, and showed little difference between sampling trips. Without any form of feedback as to the need or otherwise to collect particular data, it is easy to understand why morale of some volunteers may have been declining.

4.3 Invertebrate communities

Results of this analysis showed that the invertebrate communities differ greatly between the four waterways monitored. The invertebrate communities in Kaputone Creek were characterised by micro-crustaceans and pea clams, whereas communities in the Styx River, Smacks Creek, and the Otukaikino were dominated by amphipods, cased or free-living caddis flies and mayflies. Community composition appeared to be more variable in Kaputone Creek, and least variable in the Otukaikino. Differences in the invertebrate community composition between the four waterways was shown to reflect in part differences in some of the measured habitat parameters. In particular, the depth of soft substrate, substrate composition (expressed as the substrate index) and water velocity were shown to be important parameters influencing invertebrate communities. Communities at the slow flowing Kaputone Creek sites, which were characterised by deep fine substrate, and a small substrate index were consequently very different to those from the other three waterways which had faster flowing water, coarser substrates and less deep fine material.

Examination of the temporal data from the four waterways showed few consistent patterns with regards to annual or seasonal variation: indeed densities of only three taxa (fly larvae, micro-crustaceans, and spiral snails) differed over time between the waterways. However, these temporal differences were thought to reflect random differences between sampling periods, and were not associated with any trend in increasing or decreasing percentage abundance.

Communities also differed within waterways, and in particular in the Styx River. Here, the percentage abundance of amphipods, cased caddis, and spiral snails were highest at S1 (Headwaters), and the percentage abundance of mayflies was highest at S2 (Styx Mill Conservation Reserve). With the exception of mayflies, very few temporal differences were observed to the major invertebrate groups over time in any of the three sites in the Styx River.

Given the large differences in the habitat conditions between the four waterways, it is not surprising that their invertebrate communities were so distinctive. It is also not surprising that our analysis has thus far failed to detect any significant shifts in invertebrate community composition in any waterway over time, or in any of the sites within a waterway. Invertebrates are well known to respond to a number of environmental parameters including water chemistry, habitat condition, and overall land use, and these have been monitored by the volunteer groups. It was beyond the scope of the study to include the water quality data, as with the exception of data collected from the Styx Mill Conservation Reserve, most of the water quality monitoring sites are different to those of the invertebrate sites. Examination of habitat conditions within the waterways revealed no significant trends over time, suggesting that no activities are occurring within the catchment that are likely to affect habitat conditions, and therefore invertebrate communities.

Data obtained from the Avon River have shown that changes to invertebrate communities may only manifest themselves over many years. The invertebrate communities there have been sampled extensively on three occasions: in 1980 (Robb 1980) and 1990 (Robb 1992), and again in 2003 (McMurtrie and Taylor 2003). This data provides an opportunity to assess whether invertebrate communities in the Avon River have changed over this period. Invertebrates have also been sampled from the Styx River during the same period, giving us the ability to determine whether invertebrate communities in the Avon are changing more than those in the Styx catchment. Any divergence in behaviour may reflect differences in the quantity and quality of stormwater inputs into the rivers as the land use in each catchment has urbanised and intensified.

The number of taxa recorded in the Avon River changed over the three sampling periods; 21 in 1980, 28 taxa in 1990, and 30 taxa in 2003. This increase can be explained by improvements in collecting techniques and advances in taxonomic resolution during the latter studies. However, the ability to detect changes in densities of large and easily caught and identified aquatic insects such as mayflies would not have changed. Despite the more intensive sampling in 2003, there was a marked decrease in mayfly distribution over the three sampling periods (Figure 27). In 1980, the common grazing mayfly *Deleatidium* was found in all six of the Avon sites, and was the most abundant taxa at one site. The filter feeding mayfly, *Coloburiscus*, which requires fast flowing water and clean substrates, was also common at one site in the CBD in 1980. In comparison, *Deleatidium* mayflies were found at only two sites in 1990, where they were not common, and were absent in 2003.

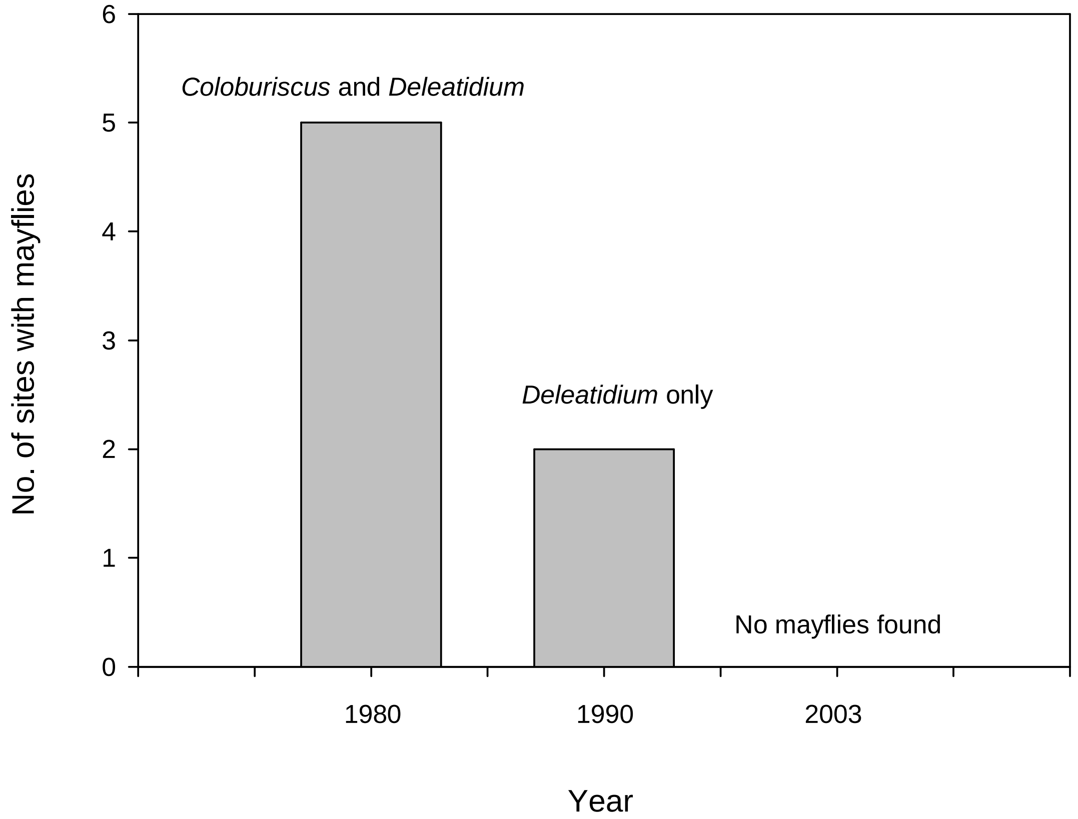

Figure 27. Graph showing the number of sites where mayflies had been collected from the Avon River in Christchurch over time.

The most common invertebrate taxa within the Avon now include a snail (*Potamopyrgus antipodarum*), two crustaceans (*Paracalliope fluviatilis*, and ostracods), oligochaetes, orthoclad chironomids, and the caddisfly *Oxyethira*. Examination of the caddisfly fauna in the Avon River has shown an increase in the distribution of purse-case caddisflies over time as well. Disappearance of sensitive mayfly taxa, and an increase of more pollution tolerant taxa such as molluscs, chironomids, oligochaetes, and purse-case caddisflies indicate that invertebrate health of the Avon River has declined over the past 25 years. This has been attributed to a combination of ongoing urban development in the catchment, and increasing amounts of sediment-laden stormwater inputs - both of which are known to adversely affect the ecological health of waterways.

The number of invertebrate taxa recorded in the Styx River remained relatively stable over the past 25 years, with 20 taxa in 1980, and 18 taxa in 2004. Unlike in the Avon River, the mayfly *Deleatidium* was still found at all three sites in 2004, and was regarded as being common (i.e., with relative densities > 10%) at one site. Purse-case caddisflies were either absent, or rare in the Styx River, while free-living and stony case caddisflies were still common here. The general stability of the invertebrate communities in the Styx River is thought to reflect the fact that this catchment is much less urbanised, and the fact that dominant land use here has not changed dramatically, with the possible exception of the development of the Northwood housing estate to the north of the Styx Mill Conservation Reserve, and for Regents Park and Redwood Springs. The former subdivision is below the location of any of the sampling sites, while Redwood Springs is located in the area of the upper Styx River, near Gardeners Rd. This area has only recently been developed, and it may take some time (possibly decades?) for changes in stream health to be detected as a result of this housing development.

These results highlight a potential dilemma for the volunteers and the monitoring work they do. If land-use activities around four waterways currently studied are not changing dramatically (and with the possible exception of the Redwood Springs subdivision, there is no reason to believe that they are), then there is no reason why the invertebrate communities in these waterways would change.

However, following the devastating 2011-2012 Christchurch earthquakes, more land within the Styx catchment is now being fast-tracked for new urban development, especially as thousands of houses in unsuitable red-zoned land in Christchurch need to be rebuilt. There is now more urbanisation planned for the catchment, including Highsted (to the south of Styx Mill CR), the Styx Centre (south of Northwood Supacentre), redevelopment of the meatworks area (in the Kaputone area), Highfield (east of Redwood) and Prestons (east of Marshlands Rd). Although much of these areas are downstream of the wadeable areas of the waterways which are sampled for this monitoring programme, such development may place additional pressures on the health of the Styx, and may also have implications for the overall Styx Vision. New techniques are consequently needed to allow volunteers to monitor the larger, non-wadeable areas of the Styx so that any adverse effects of future development can be monitored.

However, even with potentially large urban expansion within the Styx catchment, the results from the Avon River study had shown that dramatic changes are observed only after a 25 year or so period. Given the fact that invertebrate monitoring is done to a fairly low intensity, with little instream replication, only large changes to invertebrate community composition would be detected. This suggests that the current volunteer monitoring is unlikely to detect any differences at all in waterways such as the Kaputone Creek, where the invertebrate communities are currently dominated by taxa tolerant of highly degraded conditions. Such conditions are unlikely to get worse, so the community here is expected not to change. The Otukaikino is located in farmland, where it is unlikely that major land-use changes would occur (unless this land is converted to residential development as part of the Christchurch rebuild). However, the Otukaikino site is used as a control because the catchment is much less urbanised, and not likely to change. Use of such control sites is vital, as it allows assessments to be made of changes in invertebrate composition due to large scale factors such as climate. Catchment conditions within the upper Styx River, and Smacks Creek, are also unlikely to change dramatically, as they are already characterised by residential property, or the current conservation reserve. Whilst there may be an effect of stormwater run-off from residential properties within the Styx and Smacks Creek, this effect is likely to be only noticeable over many years, and certainly not in a 2-5 year period that the current data is based on. Conditions with the lower portion of the catchment may, however, change more, but as yet these sites are not monitored.

The question has to be asked as to whether the current six monthly monitoring of the four waterways is sustainable for volunteers to continue with, and whether it is necessary in order to detect potential reduction in the ecological health of these waterways. The great advantage of the six monthly monitoring is that it keeps the volunteers well-trained and motivated. If monitoring were reduced to an annual, or even two year basis, it is likely that volunteers would lose practice, and that morale may subsequently decline.

The question of whether the current sites continue to be monitored also needs to be addressed. As mentioned, invertebrate communities in Kaputone Creek represent those of a highly degraded ecosystem. Given this, the need to continue to monitor there may be questioned. However, it may be possible that restoration efforts are put into improving habitat conditions within the Kaputone Creek catchment by, for example, planting native riparian vegetation close to the banks, augmenting the river flows, and possibly dredging fine sediments which had accumulated in this river and replacing these with coarse substrates. Note that this could only be done if the source of the fine sediments into this river were identified and stopped.

The fact that the Styx River represents one of the healthiest waterways close to Christchurch is a strong argument in continuing to monitor its invertebrate communities. This is especially pertinent with the proposed rebuilding of residential areas within the lower ortions of the Styx. As mentioned, one of the difficulties faced with the data collected thus far concerns the unequal site replication within the four waterways. Thus, we have three sites in Kaputone and the Styx River, but one site only in the Otukaikino and Smacks Creek. If monitoring in the Kaputone were stopped, then the extra time and resources could be used to select additional sites in both Smacks Creek and the Otukaikino. Other sites could also be identified in the lower portions of the Styx, but only if suitable techniques could be developed to allow the volunteers to safely monitor the health of this larger, deeper waterway. Another alternative approach would be to consider monitoring more sites on an annual basis, where some sites are consistently monitored in spring, and other sites consistently monitored in the autumn. Thus, for example, the three sites in the Styx River and Kaputone Creek could be monitored every spring of each year, while the current sites plus the addition of two extra sites in the Otukaikino and Smacks Creek (or in the lower Styx River) could be monitored every autumn of each year. Although this would limit the ability to examine between river changes, it would give us greater ability to detect changes within a river over time. It would also maintain the skills of the volunteers by using them twice a year.

4.4 Habitat data

The volunteers currently collect a lot of habitat data, and feedback from them has highlighted a number of concerns, particularly with the need to collect some of the more labour intensive data. When deciding what habitat variables to collect, a number of factors should be considered including:

1. ease of collection
2. known significance to invertebrate communities
3. minimising between operator variability

Some of the environmental parameters collected were quantitative (i.e. obtained by measuring a particular item such as water depth or velocity), while others were based on assigning a particular variable to a class (i.e. stream bank stability assigned to one of five classes). By measuring the quantitative variables, there is less room for between operator variability. Using categorical variables, and assigning particular parameters to a class can often be open to operator interpretation. This would explain the often wide divergences of some of the habitat data. Although easy to collect, unless there are very strict definitions which the volunteers know and consistently apply, the use of categorical variables is questioned. Furthermore, analysis of data with categorical variables is somewhat problematic, as it relies only on the count of data belonging to specific classes.

Table 4 lists the habitat variables currently collected, and comments on the on the ease of collection of the variable, its known significance to invertebrate communities, and whether it is quantitative or qualitative. Good habitat variables would score a 2 or 3 based on these three criteria. Examination of Table 4 shows that only two parameters (water velocity, and soft sediment depth) scored a 3, and could thus be regarded as essential to continue to collect - despite being easy. Stream velocity was measured by timing the length of time it took for an orange or a tennis ball to float 10 m. This seems to be a low-cost, yet fairly pragmatic way of measuring this variable, which was shown to greatly influence invertebrate communities. Our analysis also detected no significant differences between velocities obtained with an orange, or those with a tennis ball.

Five other habitat parameters scored 2, and could thus be regarded as desirable to collect. The substrate assessment scored only a 2 reflecting the fact that it is relatively difficult and time-consuming to collect. However, unlike a visual assessment of percentage cover of different substrate sizes, it has the advantage of being quantitative, and therefore subject to less between operator error. Our analysis showed that derived substrate index differed greatly between waterways, and at sites within a waterway. It was also identified as an important habitat parameter influencing invertebrate communities. However, because this data was collected from only one reach per site, it was not possible to determine whether this varied significantly over time. Examination of the substrate index at each site showed it fluctuated around a long-term mean, and did not vary greatly. Given the length of time taken to collect this data, combined with the fact that it does not appear to change significantly over time, it is recommended that this habitat parameter not be collected on a six monthly basis. Instead, collection could be done only annually, or every two years.

Habitat parameters that scored either 1 or 0 are regarded as adding little to the information collected by the volunteer monitoring, especially when the aim of this is to assess stream health. These were shown by our analysis to have a high degree of inter-operator variability due to their non-quantitative nature, and the fact that they displayed little influence to invertebrate communities.

Table 4. List of the habitat variables collected by the volunteers showing their usefulness according to their ease of collection; as affecting invertebrate communities, and as being quantitative. Each variable is scored 1 (Yes) or o (No), and the overall habitat value score calculated.

Variable	Ease of collection	Affecting invertebrates	Quantitative	Habitat value Score
Free water depth	Y	N	Y	2
Macrophyte depth	Y	N	Y	2
Soft sediment depth	Y	Y	Y	3
Width	Y	N	Y	2
Velocity	Y	Y	Y	3
Substrate (Wolman walk)	N	Y	Y	2
Substrate (Visual assessment)	Y	Y	N	2
Instream organic matter	N	N	Y	1
Land use	Y	?	N	1
Bank material	Y	N	N	1
Bank stability	Y	N	N	1
Riparian Vegetation	N	N	N	0

It is thus recommended that the habitat collection protocol be reviewed in light of these findings, and altered where necessary. It is also suggested that at least some water quality monitoring be done at the same sites that invertebrates are collected. The current water quality monitoring program in the Styx River collects samples monthly, and such a high frequency would not be necessary for the invertebrate component. However, collecting at least some basic water chemistry information may prove beneficial to future analysis of this data.

5.0 Recommendations

Following analysis and interpretation of the data presented in this report, a number of recommendations are made for future monitoring by the SLLT volunteers.

1. As with the invertebrate data, QA/QC checking of habitat data is necessary to ensure consistency between different operators and to ensure that data is accurately recorded.
2. Review the types of habitat data that is currently being collected so that only data which is easy to collect, which affects instream health, and which preferably is quantitative (and therefore subject to less subjectivity by volunteers) is collected. Also, it is recommended that water quality parameters (e.g., DO, conductivity, pH and conductivity) be measured at the same time as invertebrate samples are collected.
3. Hold regular refresher training courses (e.g., every 2 years) to cover aspects of both field work (both invertebrate collection and recording habitat information) and laboratory work identifying invertebrate communities.
4. Implement (or continue with) a formal induction protocol for new volunteers, as well as formal "exit interviews" so that the SLLT board members could better understand what motivates volunteers, and what makes them leave.
5. Consider changing the location of some of the current sampling sites to sample sites where the CCC has implemented (or plans to) any restoration activities within the stream. It is also important to have replicate sites within individual streams, so that some degree of within stream variability can be ascertained. In doing so, it may be possible to continue on with a 6 monthly sampling programme (and therefore maintain volunteer’s

interest and skill levels) and sample one set of streams in spring, and the other set in autumn.

6. Consider designing and implementing a sampling protocol for volunteers to safely and easily sample the lower areas of the Styx River. This is particularly important in lieu of the Christchurch earthquakes, where more land within the lower Styx catchment is being fast-tracked for new urban development.
7. Ensure that any future data collected by the volunteers is entered onto the existing Excel spreadsheets, and backed up. Someone in the SLLT or the volunteers needs to become a database manager to look after all data and to ensure that all new data is added as it is collected, as it represents an extremely valuable resource.
8. Encourage the preparation of data reports at regular intervals to provide feedback to the volunteer and other interested groups as to the state and trends of ecological health of waterways in the Stxy catchment. As with Regional Council State of the Environment monitoring, a suggested frequency for this would be every 5 years, although smaller "report card" type reports could be produced at more regular intervals.
9. All data and reports should be made available to volunteers and the general public via The Styx web page, and possibly via media releases.

6.0 Acknowledgements

Thanks to all the volunteers from the SLLT who have given up so much of their time to carefully and regularly collect and process all the invertebrate samples over the past six years. Thanks also to EOS Ecology and ECan staff for the QA/QC validation work, which has contributed greatly to our confidence in using the volunteer –derived data. Thanks also to Michele Stevenson (ECan) for review comments, and assistance with arranging and running training sessions with the SLLT volunteers. Finally, the hard work and foresight of Christine Heremaia and the CCC is acknowledged for establishing the SLLT, and in the vision behind it to protect the health of the Styx River and its catchment.

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Appendix 1.

Comparisons between volunteer data and QA/QC data were made by a two-way repeated-measures analysis of variance (ANOVA). ANOVA is a statistical test in which the observed values of a particular variable (in this case invertebrate % abundance) is broken into components attributable to different sources of variation. In its simplest form, ANOVA tests whether or not the means of several groups are equal – in this case it was testing whether the means of the different invertebrate % abundance differed between observations made by the community volunteers, or the QA/QC processing, and also whether the means were different between the different waterways. The repeated measures design uses the fact that the same sites in each waterway were sampled over time, and all were subject to variation caused by processing type, and by each waterway. This statistical test allowed us to determine whether the percentage of individual taxa differed between the volunteers and QA/QC, and between the 4 waterways sampled. Another useful feature of the two-way ANOVA design is it calculates an interaction term between processing type and waterway. This allows us to determine whether there are differences in processing efficiency between the two groups and between the different waterways. The repeated measures part of this analysis also tested whether there were any differences in the relative abundance of different taxa over time, and whether any temporal differences were consistent between the twin processing types, and waterways.

We performed another statistical analysis called ordination to determine whether the invertebrate composition data generated by the volunteer groups was able to discriminate between the Styx River, the Kaputone stream, Smacks Creek and the Otukaikino, as well is that of the QA/QC data. Ordination is a statistical technique that graphically represents the location of samples based on the similarity of measured parameters (in this case the relative abundance of all the different invertebrates at a site) such that samples with similar invertebrate communities are grouped on an *x*-*y* graph, while samples with different communities are far apart. For example, if large differences occurred in sample processing by the community group and the QA/QC analyses, then samples from the same river would be separated on the basis of processing type.