

# The Effectiveness of Restoring the Radcliffe Road Drain

A C O M P A R I S O N   W I T H   T H E   S T Y X   R I V E R

The Styx  
Pūrākāuni



S U M M E R   S T U D E N T   S C H O L A R S H I P   2 0 0 6 / 2 0 0 7

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# The effectiveness of restoring the Radcliffe Road Drain A comparison with the Styx River

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February 2007

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## **PREFACE**

The Styx River ecosystem is an important natural asset located on the northern fringe of Christchurch city. In order to protect its natural and cultural values in the long term, a long-term vision has been developed and is now being implemented. Details of the vision can be found on the Styx website <http://www.thestyx.org.nz/>

The vision recognises that not enough is known about the river and its values. In order to obtain a better understanding, the Styx Living Laboratory Trust has been established to actively promote the Styx River and its associated catchment as a place for research and learning. The Trust is working with its partners in the establishment of the Styx Summer Student Scholarship Programme. Each year over the summer break student(s) are funded to undertake research on some aspect of the Styx River ecosystem. Not only is more learnt about the Styx, but the students also gain valuable work experience that will benefit them on their chosen career paths.

This report by Guinevere Coleman, the summer student for 2006 – 2007, documents her research into the effectiveness of restoring the Radcliffe Road Drain through comparing the restored site with other sites along the Styx River. Her report highlights the need for continued research on habitat restoration in order to achieve functioning ecosystems.

This scholarship was funded through the Styx Living Laboratory Trust, Lincoln University and their summer student programme, and the Shirley Papanui Community Board through its special projects funding. The Trust appreciates the work of Guinevere Coleman and the support of its partners in making the Styx Summer Student Scholarship Programme a success.

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Chairperson  
Board of Management  
Styx Living Laboratory Trust



## ABSTRACT

Part of the Radcliffe Road drain, a tributary of the Styx River in Christchurch, New Zealand, has been restored. The restoration consisted of planting of riparian vegetation, widening the drain and adding some gravel substrate; one end of the drain has been left as a box drain. This study examined the effects of this restoration on the invertebrate community within the drain. Samples were collected from both the restored section and the box drain, and compared with samples taken before the restoration occurred and with samples taken from the Styx River in gravel and silt substrate. The invertebrate community did not vary considerably in the Radcliffe Road drain, and consisted mostly of *Potamopyrgus* snails, oligochaetes and Diptera larvae. Before restoration, greater proportions of snails, and fewer oligochaetes were found. Although gravel was added to the drain, the silt build-up on top of this substrate, along with the lack of re-colonising invertebrates is seen as a major factor in the prevention of re-colonisation by 'sensitive' invertebrates. Physical factors such as water velocity, depth and turbidity may also have contributed. The invertebrate community in the Styx River varied considerably between the silt and gravel substrates, with greater numbers of mayfly and caddisfly larvae being found in the gravel.



## INTRODUCTION

The Styx River is a small (54.8 km<sup>2</sup>), spring-fed catchment, about 23.8 km long (Taylor *et al.* 2000). Despite the dramatic land-use change the catchment experienced with the arrival of humans, and the subsequent urban growth of Christchurch City, the Styx River still retains many of its natural values. As part of a 40-year vision to restore the entire river system to its pre-human state, restoration projects are being established along the length of the river.

The important ecological values of the Styx River have been recognised by the Christchurch City Council and, as a result, the Styx Mill Conservation Reserve was created. In order to make planning, restoration and management efficient and cost effective, there is a need to monitor the environment and biology, determine the success of the restoration and adapt the management accordingly (Fagan and Meurk, 2004). Macroinvertebrates are particularly useful for biomonitoring since they are found in all freshwater environments, are relatively easy to sample and identify (Stark *et al.* 2001), and are good bio-indicators due to their specialised habitat selection (Boothroyd and Stark, 2000). Invertebrates are also an essential food item for fish and birds in the Styx River (Taylor, 1999; Taylor *et al.* 2000). A good understanding of the invertebrate community is essential in order to improve food availability for the fish and bird inhabitants of the Styx River; and allow the re-introduction of some fish and bird species.

Regular monitoring of the benthic invertebrates and physical properties of the river occurs in pre-determined stations along the length of the Styx River. This monitoring has established the ecological values of the Styx River, with invertebrate species being found there that are rare or not seen at all in other Christchurch rivers. For example, four mayfly species have been recorded in the Styx River, whereas only the common *Deleatidium* mayfly has been recorded in other urban Christchurch streams (Taylor *et al.* 2000); and four caddisfly species, common throughout New Zealand but not recorded in Christchurch waterways, have been recorded in the Styx River (Winterbourn *et al.* 1981). To enhance the biodiversity values of the Styx River it is important to restore and monitor as many tributaries of the Styx River as possible. Regular monitoring occurs in Kaputone Stream and Smacks Creek, as well as in the Styx River.

## AIM

The aim of this study is to determine the impact of restoration of the Radcliffe Road drain on the invertebrate community within the waterway.

A section of the Radcliffe Road drain, which drains into the Styx River, was restored in 2004. The drain development transformed an approximate 200 m stretch of the hedge-lined drain (Fig. 1) to a widened stream with native vegetation along the banks. This vegetation is now well established. The upper reaches of the drain, which diverts away from the road, runs around farmland and so has been left unrestored. The last ~50 m stretch of the drain remains as a box-drain and grass bank before emptying into the Styx River. The upper end of the restored section is mostly gravel, with silt starting to cover the substrate in the slower moving areas of the stream. Further downstream the substrate is predominantly silt. As well as improving aesthetic values, it is hoped that the ecological values of the drain have also improved. Stream restoration is based on the premise that all streams should meet some defined ideal standard which is usually quantified with respect to undisturbed reference streams (Suren, 2000). Given that the Styx River is considered to be of relatively high water quality and ecological value it provides an appropriate reference site for the Radcliffe Road drain. By comparing the restored section of the Radcliffe Road drain to the relatively undisturbed Styx River we can gain a general idea of how successful the restoration has been.

The section of the Styx River that flows through the Styx Mill Conservation Reserve is considered to be a good quality habitat, and so-called 'sensitive' invertebrate species (Ephemeroptera and Trichoptera) (Suren and McMurtrie, 2005) are commonly found there. The substrate varies within the river and areas of deep silt can be found close to areas of gravel. By sampling both the gravel and silt areas of the Styx River we can gain an idea of what species are found in the two substrates and compare those results with the Radcliffe Road data. Before the restoration occurred, the invertebrate community was sampled in three sites along the Radcliffe Road drain by Shelley McMurtrie of EOS Ecology in 2001. Data from this study allows a comparison to be made between the invertebrate community before and after restoration.

## METHODS

### **Existing Styx River invertebrate samples from volunteer programme:**

The Styx Living Laboratory Trust coordinates the Invertebrate Monitoring Programme. This programme involves volunteers collecting invertebrate samples at pre-selected sites twice a year. The invertebrates are identified to a basic taxonomic level (e.g., caddisfly larvae, mayfly nymph) and the samples are preserved for possible future analysis and auditing. As part of this study, the invertebrate samples were examined in order to identify the invertebrates down to a lower taxonomic level (genus and species, wherever possible), in order to gain a better understanding of the species living within the Styx River. A reference collection was made of these samples and is kept in the Styx Laboratory for further reference and auditing if necessary. Invertebrates were identified using the keys from Winterbourn *et al.* (2006).

### **Styx River samples:**

Four sites along a stretch of the Styx River within the Styx Mill Conservation Reserve were sampled (Fig. 10) on 21 November 2006 (late spring). Sites were selected on the basis that there was both silt and gravel substrate close to each other, and the river was accessible enough to wade in (Fig. 11-14). Two samples were taken from each substrate at each site. Site one was located approximately 200 m downstream from the footbridge below the Park Ranger's house on Hussey Road, site two was the existing Invertebrate Monitoring Programme sampling site just above the footbridge, site three was located approximately 50 m upstream, just below the second footbridge, and site four was approximately 100 m upstream from this bridge (Fig. 10). The gravel substrate was sampled semi-quantitatively with a kick net (600  $\mu$ m mesh net, 35 cm x 25 cm attached to a 1.5 m pole) sampling over a 30 by 30 cm area marked by a quadrat. The net was placed on top of the substrate on the downstream edge of the quadrat. The quadrat area was then disturbed by kicking the substrate for approximately 30 seconds, and the disturbed matter was then collected into the net. These samples were sorted on-site and invertebrates taken back to the laboratory for identification. Invertebrates were identified using the keys from Winterbourn *et al.* (2006). Silt tends to clog up kick nets making it difficult to filter out the invertebrates, so for this substrate a trowel was used to scoop the top layer of silt within the quadrat into a container. This sample was then filtered through a 600  $\mu$ m sieve with a hose.



**Radcliffe Road drain:**

The site was sampled on 23 November and again on 19 of December. The first sampling day was treated as a pilot study, but the data collected then were added to the second sampling date's data for statistical analysis. Along the roadside stretch of the drain, four sites were sampled: two in the restored section, and two in the remaining boxed-drain section on 19 December. Site one had a gravel substrate (average 2 cm diameter stones) covered in silt (1-2 cm depth), site two was gravel/stones covered in deeper silt (5-10 cm depth) and sites three and four had deep silt (10-25 cm depth). Samples were collected in the same way as the silt samples in the Styx River described above. These samples were then compared with the silt substrate samples from Styx River.

The samples from the Radcliffe Road drain were compared with sampling by Shelley McMurtrie of EOS Ecology on 31 of January and 3 of February, 2001. These samples were collected at three sites along the Radcliffe Road drain before restoration began.

**Physical variables testing:**

Conductivity, pH, turbidity, depth, water velocity, and dissolved oxygen were tested at each sample site in both the Styx River and Radcliffe Road drain. Conductivity was measured using a TDSTestr 3 conductivity probe; pH using Shindengen ISFET pH meter; turbidity using a Orbeco Hellige portable turbidimeter model 966, all sourced from Waterwatch, Lincoln University.

**Data analysis**

The samples taken in both the Styx River and the Radcliffe Road drain were compared to determine whether there was a difference between the invertebrate community in silt substrate compared with gravel substrate, and also to determine the similarities of the invertebrate communities in silt substrate between the two streams.

As sampling methods were different between the silt and gravel substrates, and quadrat size was different between the before and after restoration samples in the Radcliffe Road drain, the number of individuals in each taxa were converted to percentages. The total numbers of individuals found in each quadrat were different; therefore, the figures showing the percentage of individuals from each taxa represent proportions only, not comparative numbers.

The data were square root transformed to reduce over-dominance by very abundant groups. Principal Component Analysis (PCA) was used to make non-parametric comparisons of community similarity.



**Figure 1.** Satellite photograph of the Radcliffe Road drain showing approximate locations of the four sampling sites. Image: Google Earth Images, 2007 Europa Technologies.



**Figure 2.** Radcliffe drain 2001 (before restoration). Photo courtesy of Shelly McMurtrie, EOS Ecology, 2001.



**Figure 3.** Top of Radcliffe Road drain restoration (flowing around farmland before entering the restored area).





**Figure 4.** Restored Radcliffe Road drain looking from top fence down to first bridge



**Figure 5.** Restored area looking from first bridge towards top of restored section and adjacent farmland, showing the approximate location of sites 1 and 2.





**Figure 6.** Radcliffe Road site 1 (approximately 50m downstream of top of restored area)



**Figure 7.** Radcliffe Road Site 2 (20m upstream of first bridge)



**Figure 8.** Radcliffe Road Site 3 – top of box drain



**Figure 9.** Radcliffe Road site 4 – box drain





**Figure 10.** Satellite photograph of the Styx Mill Conservation Reserve, with approximate locations of the four sampling sites. (Image: Google Earth Images, 2007 Europa Technologies).



**Figure 11.** Styx River Site 1



**Figure 12.** Styx River Site 2



**Figure 13.** Styx River Site 3



**Figure 14.** Styx River Site 4



## RESULTS

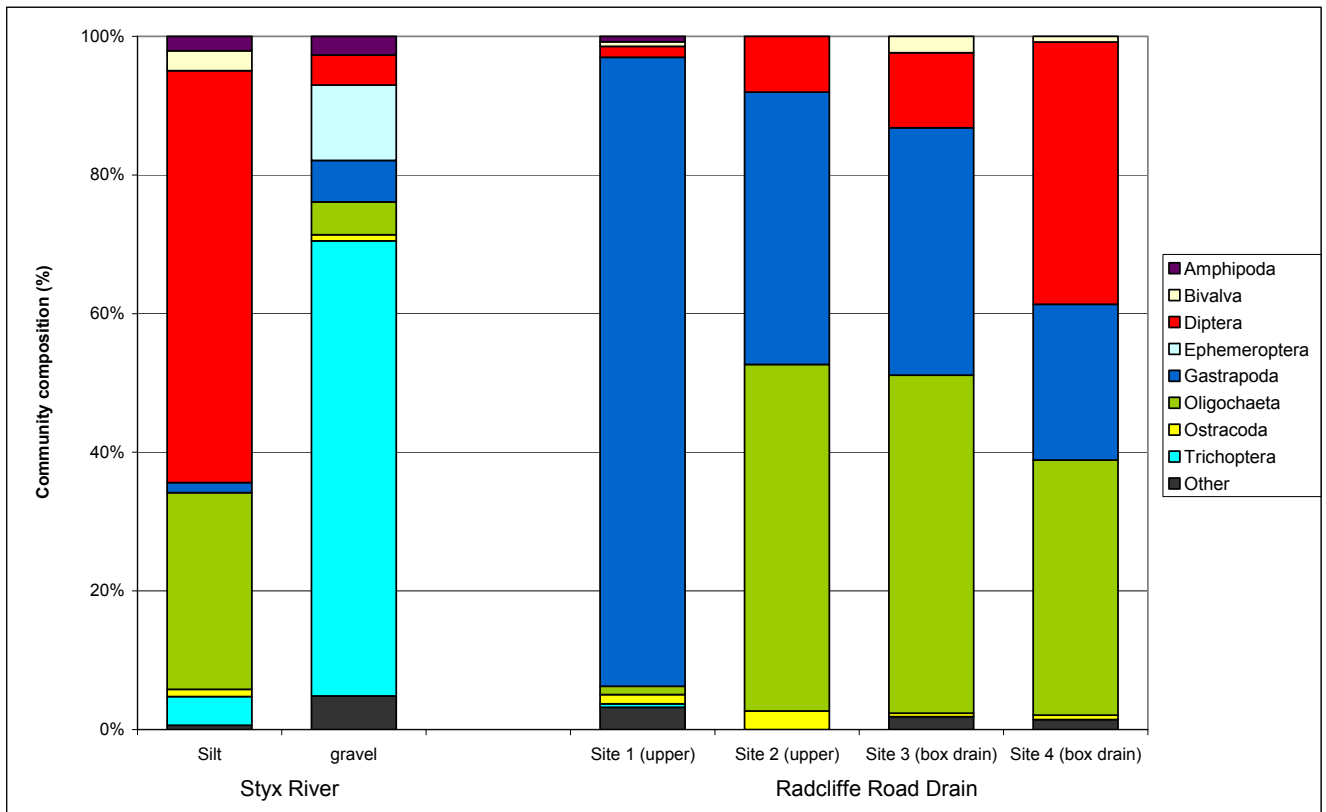
Data from the physical variables testing (table 1) show the major physical differences between the Radcliffe Road drain and the Styx River are the depth, velocity, and turbidity. The Styx River is deeper, faster, and less turbid than the Radcliffe Road drain. Conductivity, total dissolved solids, and pH are all similar between the two sites.

Table 1: Radcliffe Road drain and Styx River variables (measured on the day of sampling) (Averages are calculated from 3 measurements, apart from depth which is averaged from 12 measurements per site).

	Radcliffe Road				Styx River			
	Site 1	Site 2	Site 3	Site 4	Site 1	Site 2	Site 3	Site 4
Depth (cm)	5.25	6.83	11.83	14.00	42.08	27.00	31.00	43.92
Velocity (m/sec)	0.44	0.02	0.13	0.12	0.51	0.64	0.63	0.41
Conductivity ( $\mu\text{S/cm}$ )	93.33	90.00	100.00	100.00	110.00	110.00	116.67	113.33
Total dissolved solids (mg/L)	4.67	4.50	5.00	5.00	5.50	5.50	5.83	5.67
pH	7.47	7.43	7.73	7.97	6.97	6.80	6.87	7.23
turbidity (NTU)	10.03	10.17	11.63	14.57	4.03	3.63	3.43	3.17

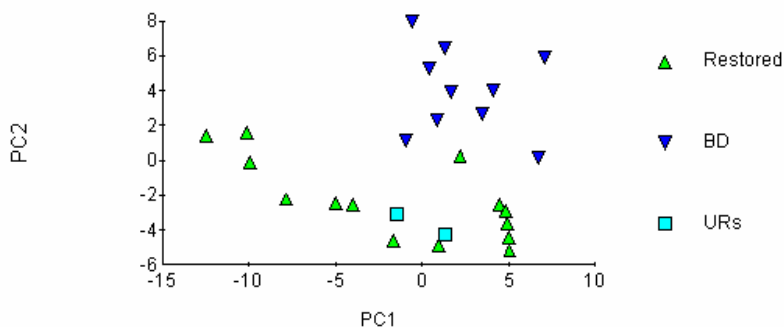
### Restored and non-restored section of the Radcliffe Road drain.

There is no obvious difference in community composition between the restored and non-restored section of the Radcliffe Road drain (Fig. 15). Site 1 does have a larger proportion of *Potamopyrgus* snails, and fewer oligochaetes compared with the other three sites.



**Figure 15:** Percentage of individuals in each different invertebrate taxon group found in the Styx River (gravel and silt sites) and the Radcliffe Road drain (four sites, all silt substrate, apart from Site 1 which had both gravel and silt). (Note: As sampling did not occur in exactly the same locations before and after restoration this cannot be used as a direct comparison, just a general indication of how the general areas have changed)

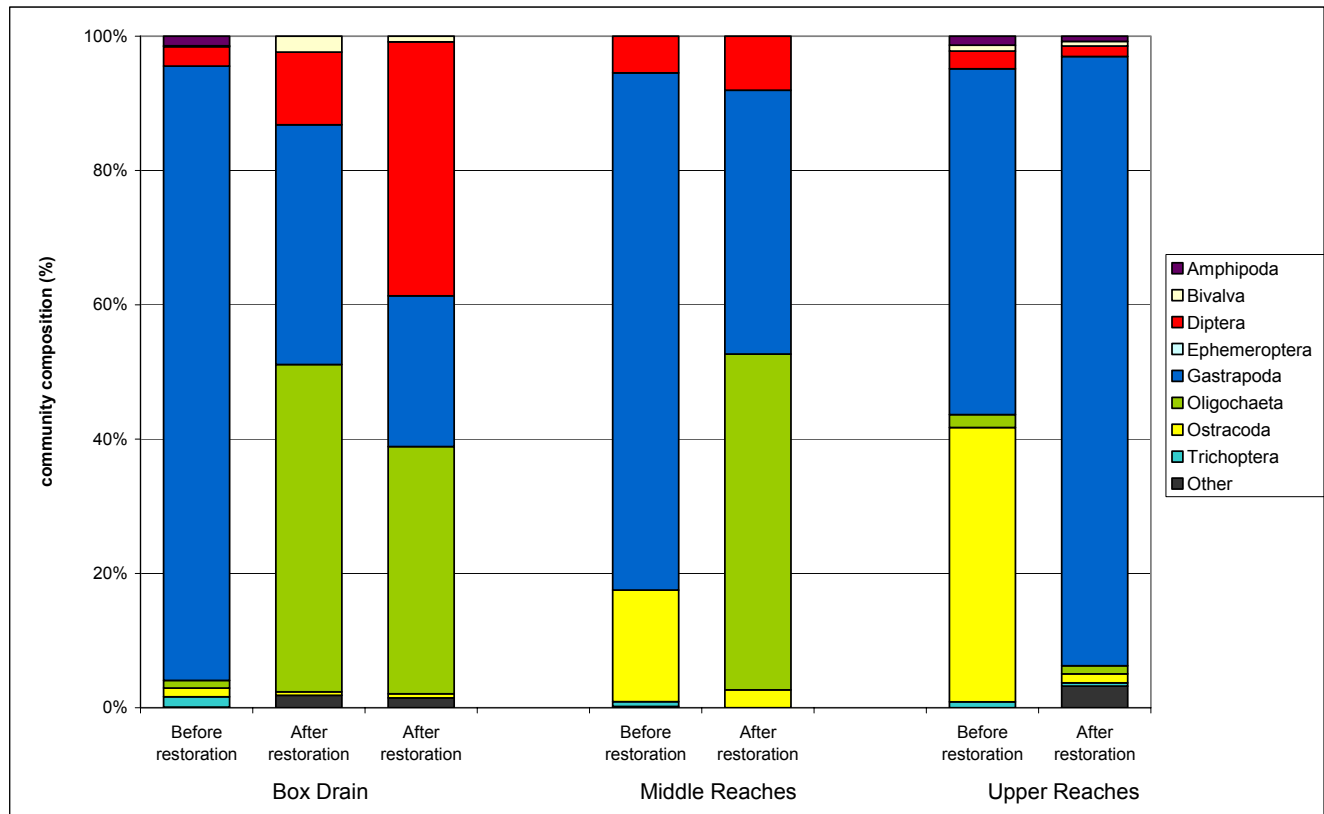
Principal Component Analysis shows that the box drain samples are more similar to each other than the restored section (Fig. 16). This is most likely due to the smaller number of *Potamopyrgus*, and a greater number of oligochaetes and chironomids.



**Figure 16.** Principal Component Analysis plot for the Radcliffe Road drain showing community similarity between samples taken in the restored and box drain sections. (Restored=restored section, BD=Box drain, URs=Unrestored section). High PC1 values are a reflection of fewer *Potamopyrgus*, and high PC2 values appear to be a reflection of high numbers of *Chironomus zealandicus* and oligochaetes, and lower numbers of ostracods. See appendix 3 for details. Unrestored refers to two samples taken on 23 November in the section of drain between the box drain and the Styx River.

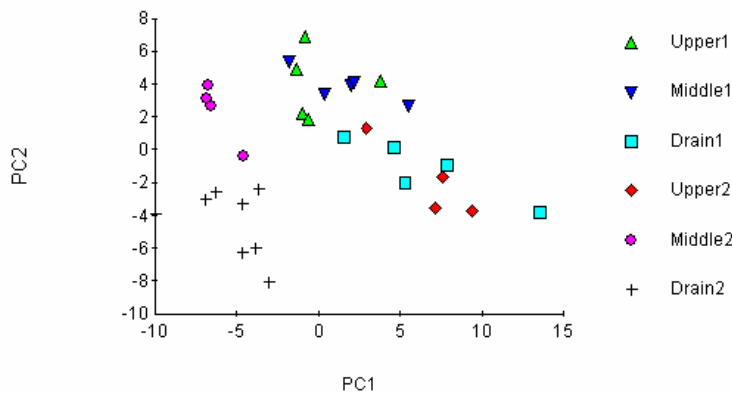
### Radcliffe Road drain before and after restoration

Before restoration the Radcliffe Road drain contained a majority of *Potamopyrgus* snails, along with ostracods, and a relatively small number of oligochaete worms (Fig. 17). Notably, also present were Chironomidae (non-biting midges) (*Chironomus*, Tanypodinae and Orthocladiinae), copepods, Muscidae, and *Oxyethira albiceps* (caddisfly). The samples taken after restoration show a different community composition. *Potamopyrgus* was less dominant in the box drain and middle reaches, and more dominant in the upper reaches. Oligochaetes were more prominent overall, particularly in the box drain and middle reaches, whilst ostracods were a lot less prominent. The community composition of the box drain has changed quite considerably, despite the fact that the box drain has not undergone any restoration (Fig. 17). Before restoration, electric fishing found the common bully, upland bully and longfinned eel all present. No electric fish monitoring was conducted during this sampling (post-restoration), but the common bully was seen at site 3 (top of the box drain).



**Figure 17:** Percentage of individuals in each different invertebrate taxon group found in the Radcliffe Road drain before and after restoration in the three major sampling areas. (Note: As sampling did not occur in exactly the same locations before and after restoration this cannot be used as a direct comparison, just a general indication of how the general areas have changed) (Before restoration data care of Shelley McMurtrie of EOS Ecology, 2001).

Principal Component Analysis shows that the post-restoration samples from the box drain are most similar to each other, whereas the other samples do not show any clear clumping (Figure 18). This is likely due to the lower number of *Potamopyrgus*, and higher numbers of oligochaetes and chironomids in the box drain after restoration.

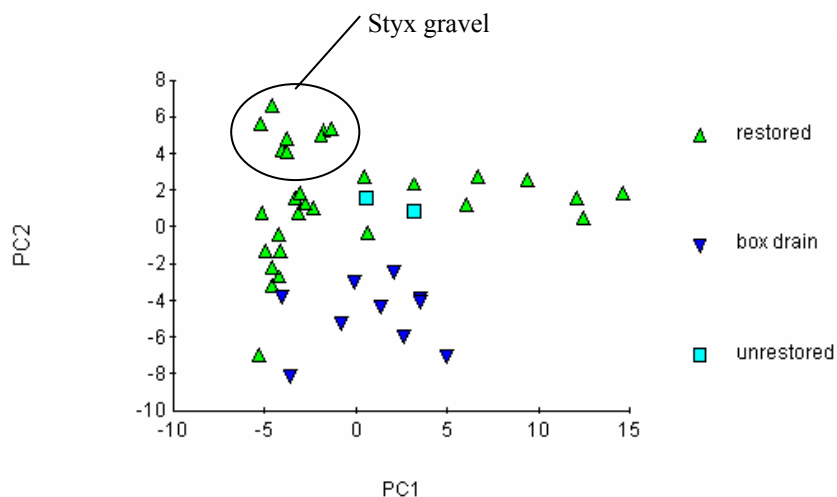


**Figure 18.** Principle Component Analysis plot for the Radcliffe Road drain before and after restoration, showing community similarity between samples taken in the upper, middle and box drain sections. High PC1 values are a reflection of fewer *Chironomus zealandicus* and oligochaetes, and high numbers of *Potamopyrgus*; and high PC2 values appear to be a reflection of high numbers of ostracods, and lower numbers of oligochaetes. See appendix 3 for details.

### Radcliffe Road drain compared with the Styx River

The gravel substrate within the Styx River hosts a much greater species diversity compared with the silt substrate within the same area of the river. Most notable is the higher percentage of Trichoptera (caddisfly larvae), and fewer Diptera larvae (Fig. 15). The Radcliffe Road drain samples appear to be more similar to the silt samples from the Styx River compared with the gravel samples, however, the fewer *Potamopyrgus* in the Styx River is a major difference.

Principal Component Analysis shows that none of the samples appear to be particularly similar to one another, apart from the gravel samples from the Styx River (Fig. 19). The slight grouping of the gravel samples appears to be a reflection of the higher numbers of *Deleatidium* and cased caddisfly larvae, and the lower numbers of *Chironomus zealandicus* and oligochaetes.



**Figure 19.** Principal Component Analysis plot for the Radcliffe Road drain and Styx River samples showing community similarity between samples taken in the restored and box drain sections of the Radcliffe Road drain and the Styx River (all marked as “restored”). High PC1 values are a reflection of higher numbers of *Potamopyrgus*, and high PC2 values appear to be a reflection of high numbers of *Deleatidium* mayflies and cased caddisfly larvae, and lower numbers of *Chironomus zealandicus* and oligochaetes. See appendix 3 for details. Unrestored refers to two samples taken on 23 November in the section of drain between the box drain and the Styx River



## Invertebrate taxa found in the Radcliffe Road drain and Styx River Conservation Reserve

Invertebrate taxa	Family	Species	Racliffe Road before restoration	Radcliffe Road after restoration	Styx River silt	Styx River gravel
<b>Crustacea</b>						
Amphipoda		<i>Paracalliope fluviatilis</i>	X	X	X	X
Cladocera		<i>Daphnia</i> sp.			X	
Ostracoda (seed shrimp)		spp. indet.	X	X	X	X
<b>Insecta</b>						
<b>Diptera (two-winged flies)</b>						
	Chironomidae (non-biting midges)	Tanypodinae spp. indet. Orthoclaadiinae spp. indet. <i>Chironomus zealandicus</i>	X X X	X  X	X  X	X   
	Tipulidae (crane flies)	spp. indet.	X	X	X	
	Muscidae	spp. indet.	X	X		
	Simuliidae (sandflies)	<i>Austrosimulium australense</i>		X	X*	X*
	Sciomyzidae (marshflies)	<i>Neolimnia</i> sp.		X		
<b>Trichoptera (caddisflies)</b>						
	Hydrobiosidae	<i>Hydrobiosis</i> sp. <i>Costachorema</i> spp. <i>Psilochorema</i> sp.	X   	X   	X  X*	X X X*
	Hydropsychidae	<i>Aoteapsyche colinica</i>				X
	Hydroptilidae	<i>Oxyethira albiceps</i>	X	X	X*	X*
	Leptoceridae	<i>Oecetis unicolor</i> <i>Hudsonema alienum</i> <i>H. amabile</i>	   	   	X X* X	 X* X
	Conoesucidae	<i>Triplectides obsoletus</i> <i>Pycnocentrodes</i> spp. <i>Pycnocentria evecta</i>	X   	   	X X X	X X X
<b>Ephemeroptera (mayflies)</b>						
		<i>Deleatidium</i> sp.				X
<b>Coleoptera (beetles)</b>						
	Elmidae	spp. indet.				X
<b>Arachnida</b>						
	Acarina (mites)	spp. indet.			X	X
<b>Molluscs - Bivalva</b>						
	Sphaeriidae	spp. indet.	X	X	X	
<b>Molluscs – Gastropoda (snails)</b>						
		<i>Physella</i> sp.	X	X		
		<i>Potamopyrgus antipodarum</i>	X	X	X	X
<b>Annelids</b>						
Oligochaeta (worms)		spp. indet.	X	X	X	X
Hirudinea (leeches)		spp. indet.			X	
<b>Platyhelminthes (flatworms)</b>						
		spp. indet.	X	X	X	X
Total number of taxa			15	15	22	20

\*Known to be found recently in this location, but not collected in this study

## DISCUSSION

The Radcliffe Road drain had few major differences between the restored and non-restored (box drain) sections. Even though site one (upper restored) has a larger proportion of *Potamopyrgus* snails and fewer Diptera larvae and oligochaetes, site 2 (middle restored), which is also restored, does not share this result. This difference at site one is likely to be due to the gravel substrate found there. The trend of fewer Diptera larvae and oligochaetes in gravel substrate compared with silt substrate is also seen in the Styx River, and is not surprising as these taxa are commonly associated with sandy habitat (Winterbourn, 2000). Although the proportion of *Potamopyrgus* is lower in the other drain sites, it was still common at those sites. Snail taxa are known to prefer a stony substrate (Collier *et al*, 1998), but a study by Holomuzki and Biggs (2006) found that snails burrowed into surrounding sand substrates where they consume algae and heterotrophic biofilms (bacteria and fungi). This means that although the snails prefer to live on solid substrate, they are capable of living within the silt, explaining why their numbers remain high regardless of changing sediment.

The restoration of the Radcliffe Road drain does not so far appear to have had any major positive effect on the invertebrate community within the drain, in terms of encouraging 'sensitive' species to colonise. The total species composition appears to have changed since the restoration along the length of the drain, even in the un-restored box drain. The most obvious change appears to be the increased numbers of oligochaete worms and *Chironomus* species. Most notable is the decrease of the caddisfly *Oxyethira albiceps*, since only three were found along the drain. The common bully was seen at the top of the box drain, in approximately the same location as before restoration. Without conducting electrofishing in the drain, it is impossible to tell whether the upland bully and longfinned eel are also present.

The different communities found in the Styx River gravel and silt substrates show how much of an effect substrate has on the invertebrate communities within a river. The samples from the different substrates were usually taken within a few metres of each other, yet the invertebrates found within the area varied considerably. Although this demonstrates the effect of the substrate, a direct comparison with the Radcliffe Road drain is not possible. Given the environmental differences between the Styx River and the Radcliffe Road drain, we cannot say whether a change in substrate in the Radcliffe Road drain would have the same effect as seen in the Styx River. The measurement of physical variables showed some differences in the water environment (Table 1) between the two water bodies. The Styx River is deeper, faster, and less turbid than the Radcliffe Road drain, which should provide a more

desirable environment for freshwater invertebrates (Jowett *et al* 1991). The Styx River is also fed by a number of springs and two major tributaries, so the opportunity for invertebrate migration is considerably larger.

Although the difference in species composition between the two substrates within the Styx River are significant, this could have been due to the different methods of sampling used for gravel and silt substrate. By using the kicknet, only those species that live on the surface of the substrate and not those within the substrate are collected. In contrast, by using a trowel to scoop the top layer of silt sediment, species within the substrate are collected. This also results in some of the surface sediment being washed away, particularly in faster flowing water. Unfortunately it is almost impossible to use a kicknet on silt substrate, and digging into the gravel substrate is also almost impossible. In future, placing a kicknet in the direct flow of the silt being washed off the surface could help in catching any invertebrates that may be getting lost in the process. Kicknet sampling was also used in the pre-restoration sampling in the Radcliffe Road drain. This method could have resulted in cased caddisfly larvae being found in the Radcliffe Road drain, since they occupy the surface of substrate. However, random kicknet samples taken along the drain did not result in any live cased caddisfly larvae, other than *Oxyethira albiceps*, being found. This difference in sampling method may account for the large increase in chironomids and worms found in the post-restoration sampling. However, chironomids are primary colonisers. The random kicknet sampling failed to turn up any taxa not found using the scooping method, so we can say with some confidence that the sampling method was effective.

The major environmental factor that appears to be restricting the colonisation of the Radcliffe Road drain is silt deposition. Increased sediment entering the river has been attributed to changing landuse around the river, including increasing numbers of market gardens and new subdivisions (Taylor *et al.* 2000). The silt deposition is most likely to be caused by a combination of the restoration process removing the all vegetation and loosening the base sediment, sediment input from surrounding farmland and the road (Quinn, 2000), and water velocities not being fast enough to wash sediment downstream. Dredging of the sediment and laying down gravel substrate may alleviate the problem; however, without reducing the input of silt, it is quite likely sediment will continue to be a problem (Hicks and Duncan, 1993). It has long been accepted that fine inorganic substrate is unsuitable habitat for aquatic insects (Taylor *et al.* 2000; Suren and McMurtrie, 2005). Excessive siltation can cause low oxygen levels, loss of interstitial space and loss of food (Ryan, 1991; Taylor *et al.* 2000). Suren and Jowett (2001) found that some invertebrates (many mayfly, caddisfly and amphipod species) will

actively leave areas where silt is depositing. This leads to the domination of silted habitats by snails, worms and midges (fly larvae) (Jowett *et al.* 1991). Sand deposition prevents upstream movement, presumably because the substrate lacks stability, and increased suspended sediment levels are associated with increased drift rates (Ryan, 1991). It has been found that high sediment levels caused a reduction in invertebrate density and diversity and to a shift in the fauna from a mayfly dominated community to one with higher abundances of Coleoptera, Diptera, and Mollusca (Death, 2000). In a study of New Zealand rivers, Quinn and Hickey (1990) found that silt or sand substrate, or gravel overlain with sand, had a large effect on invertebrate abundance and taxonomic richness. Mayflies, in particular, are very sensitive to silt and changes to flow and temperature regimes that occur as a result of catchment development (Taylor *et al.* 2000). A study by Jowett *et al.* (1991) looked at the habitat preferences of many of New Zealand's stream invertebrates. The study found that, generally, taxa were more abundant in water less than 0.75 m deep and in gravel or coarser substrates, and no taxa showed a clear preference for fine substrate (although *Potamopyrgus* and Chironomidae were more abundant in finer sediment) or deep water. *Aoteapsyche* spp. preferred coarse substrate and water velocities of more than  $0.75 \text{ m s}^{-1}$ , whereas *Pycnocentrodes* spp. were associated with similar substrate but lower water velocities ( $0.2\text{-}0.8 \text{ m s}^{-1}$ ). *Potamopyrgus antipodarum* and Chironomidae were associated with low to moderate velocities ( $0.0\text{-}0.75 \text{ m s}^{-1}$ ). So, though the water depth is not discouraging other taxa, the low water velocities and the presence of silt appear to be major reasons why the Radcliffe Road drain is dominated by snails and chironomids, as opposed to mayflies and caddisfly larvae.

Overall, the restoration of the Radcliffe Road drain does not yet appear to have had the desired effect of encouraging a wider invertebrate diversity. One reason behind this may be that only the lower reaches of the drain have been restored. The upstream reaches of the drain flow through farmland and along the side of the road, resulting in the input of sediment and waste into the drain. This environment is not ideal for invertebrates to colonise and breed. Restoring only islands of good habitat then requires invertebrates to migrate into the area (Suren, 2000). Migration occurs from both up and downstream (Bond and Lake, 2003). As the downstream drift is the more important pathway, it is essential there is an undisturbed upstream source of colonists (Suren, 2000). There are unlikely to be invertebrates such as mayfly and caddisfly larvae living in the unrestored upper reaches so it is unlikely they would be drifting into the restored area, thus colonising it. Upstream migration is also important (Suren, 2000) and since the Radcliffe Road drain flows directly into the Styx River we could assume there would be some migration occurring from there. Reasons for this not being the case (in terms of mayfly and caddisfly taxa) could be the lack of those invertebrates in the Radcliffe Road section of the Styx River, or

possibly due to there being a stretch of un-restored section of the drain before reaching the restored section, and the adults are not flying far up enough to find it. As a result, even though the restored stretch of the Radcliffe Road drain may be a suitable environment for more 'sensitive' invertebrates, they are unable to colonise it. This may mean that in order for any restoration to be effective, beyond being aesthetically pleasing, restoration of upper reaches and/or the entire reach leading to the main river may need to be considered.

## INTRODUCTION OF FAUNA

When restoration occurred, the entire drain was cleared and re-planted. This means that none of the previous invertebrate inhabitants would have survived through the restoration. As a result, the entire restored area would have to be re-colonised. It may take a number of years for some invertebrates to find their way to the area, and so re-sampling in the future of the stream may result in a different outcome compared with this study. There was some evidence in this study, in the form of empty cases, that some cased caddis larvae were present in the drain. This may suggest that caddis larvae are actually colonising the restored area, and given time their numbers will increase.

The conclusion that the restoration efforts have not had a satisfactory outcome in terms of insect diversity is not uncommon in stream restoration. Suren and McMurtrie (2005) investigated the effects on invertebrate composition after restoration in five urban Christchurch streams. Restoration of these streams resulted in changes to the riparian vegetation, substrate, instream organic matter and stream velocities. Despite the apparent change to 'good habitat' very little change in the invertebrate community was found. This may have been due to the relative lack of change to the instream environment, or the inability of colonising insects to find these enhanced 'islands' in amongst the urban sprawl; along with excess sedimentation and reduced base flows perhaps preventing successful colonisation. They concluded that simple enhancement of the riparian vegetation is not enough to improve the habitat for stream invertebrates. Even though the goal of many of the stream enhancements was to improve the habitat for more sensitive invertebrates such as mayflies and stoneflies; and decrease the numbers of snails, worms, and ostracods, enhancement design did not address this. Streams that had undergone channel modification (including the addition of coarse substrate) as well as planting appeared to improve the invertebrate community, however the results were variable.



Larson *et al.* (2001) also found in a study in USA that there was little biological improvement in streams following the addition of large woody debris; and Walsh and Breen (2001) in a study in Australia found that adding coarse cobbles to urban streams had little impact on their invertebrate communities. Charbonneau and Resh (1992), however, found significant improvements in invertebrate communities following stream enhancement activities. This stream, however, flowed from a relatively undisturbed headwater catchment, which would have provided a continual source of new colonists to drift into the newly restored area Suren (2000). This finding adds further to the suggestion that the Radcliffe Road drain restoration will only be fully effective if the upper reaches of the drain are restored as well.

## **FUTURE RESEARCH**

Other metrics such as the Macroinvertebrate Community Index of Stark (1993) or diversity indices (Boothroyd and Stark 2000) could be used to better understand the invertebrate community within the Radcliffe Road Drain. However, given the small size of the reach concerned, and the relatively poor diversity found there, this would not be a priority. More important research efforts should be aimed towards looking at how to modify restoration efforts so that the invertebrate, fish and bird communities are restored more efficiently. This could include determining the order of which a stream is restored, such as restoring the upper reaches first so that re-colonisation is more efficient, adding more gravel substrate, removing silt deposits, and increasing the flow rate.

In order to conclusively determine the effects of the restoration of the Radcliffe Road drain it would be useful to look at other environmental variables such as shading, temperature, periphyton growth/algae species, and dissolved oxygen. The use of electrofishing would also be an advantage to determine whether upland bullies and longfinned eels are still present as well as the common bully that was seen. To gain an understanding of the overall positive and negative effects of restoration of urban drains/streams in Christchurch there is a need to compare other restored/non-restored streams. This would allow conclusions to be reached on the effects of having the non-restored section downstream of the restored section and the effect this has in terms of invertebrate drift downstream. If the streams had a variety of substrates then there would be further evidence to recommend restoration of the streambed as well as the riparian vegetation.

## **ACKNOWLEDGEMENTS**

This scholarship was funded by the Styx Living Laboratory Trust, Shirley Papanui Community Board, and Lincoln University. Thank you to Kelly Walker for her invaluable assistance with sampling and advice throughout this project, John Marris and Dr Eric Scott for their quality supervision and helpful advice throughout this project; Shelley McMurtrie of EOS Ecology for kindly allowing the use of data collected before the restoration of the Radcliffe Road drain; Alison Lister for her valuable statistics knowledge; Kelvin Nicholl (Waterwatch, Lincoln University) for lending the equipment for measuring water variables; members of the Styx Living Laboratory Trust for their help and use of the laboratory facilities.

## **BENEFITS OF THE SCHOLARSHIP**

I have found the Lincoln Summer Scholarship beneficial in terms of gaining valuable research and working experience, as well as improving my research skills. I have found it particularly beneficial to experience research outside of set classroom projects, where I could decide on my own project and the methods I was to use to conduct it, and being responsible for getting the work completed. I have gained valuable knowledge in identifying freshwater invertebrates, as well as using an identification key, which I hope will come in handy in future study. It was a good experience to be involved with people who conduct this type of work as part of their job, and to be involved with a wide range of individuals, all with their own fields of expertise to call upon. In terms of the project, it was useful to experience first hand the problems associated with the restoration of a river, the amount of work involved to organise volunteers, and the number of people needed to see through such a project. Working with volunteers and seeing how they view the project was important, especially as they are people who have no experience in the field or in identifying invertebrates, yet they are keen to help out on a regular basis. Although I had originally planned to carry out other research within the Styx Mill Conservation Reserve, including terrestrial invertebrate sampling, this was unfortunately not able to be completed. We were able to adjust the research accordingly and there were no major setbacks in completing the project. This was a good experience, as I now feel confident that if in future research I encounter any such obstacles, I will be able to adjust my project accordingly.

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