NIWA

Taihoro Nukurangi

A consideration of aspects of the Styx River ecology, and its implications for whole-river management

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Executive Summary

The Christchurch City Council (CCC) commissioned NIWA to review the existing knowledge of the ecology of the Styx River, with particular emphasis on the aquatic plant, invertebrate and fish communities. This review has been undertaken to assist the CCC to produce a strategy that aims to manage further development within the catchment so that environmental impacts are minimised. In undertaking this review, NIWA highlighted gaps in our current ecological knowledge of the Styx River, and distinguished those elements that can be undertaken by either specialists or non-specialists.

Surveys of aquatic plants have shown a marked reduction of the native macrophytes *Potamogeton cheesemanii* and *Myriophyllum propinquum* since 1953. This decline has coincided with stream re-alignment work, and reflects the intolerance of these species to physical disturbance. However, in recent years (early 1990s), *P. cheesemanii* has spread in the upper catchment.

Potamogeton crispus, an exotic macrophyte that is considered invasive, appeared in Kruses Drain in the mid-1970s, and has now spread throughout the lower river where it has become co-dominant with *Elodea canadensis. P. crispus* could be controlled effectively in localised areas by selective weeding; an appropriate technique in sensitive areas with high ecological values such as between Harbour Road and the tidegates.

Invertebrate taxonomic richness in the Styx catchment is significantly higher than that in the nearby Avon and Heathcote catchments. This most likely reflects the lower density of urban development in the Styx catchment. Waterways in the Styx thus present regions of high biodiversity within the greater Christchurch area. Taxonomic richness in the main Styx River has declined from a total of 75 taxa in 1979, to only 62 taxa in 1988, but the reasons behind this are unknown. In contrast, taxonomic richness in Kaputone or Smacks Creeks has not changed significantly over the same period.

The potential effects of further catchment modification are discussed, and it is recommended that a monitoring strategy be established to assess the impact of the current development activities on the invertebrate communities. Such monitoring strategy can either be directed at detecting large scale changes to the Styx Catchment, or at assessing the impacts of current land development.

The Styx River has a freshwater fish fauna comprising 10 species, of which only brown trout *(Salmo trutta)* is introduced. Eight of the nine native fish require sea-access, so consideration (and evaluation) of fish passage throughout the catchment is necessary. Fish diversity is comparable to that of the Avon and Heathcote Rivers, and would be described as 'fair' for a small modified catchment.

There are concerns about the perceived low numbers of brown trout in the area, which may reflect poor spawning success. The quality, quantity, and ease of access to suitable spawning areas by adult trout needs to be evaluated.

There is potential to improve native small-fish habitat in the lower tributaries, and thereby reduce predation pressure by larger trout and eels.

INTRODUCTION

The Styx River is a small (54.8 km2) spring-fed catchment to the north of Christchurch city that drains land with either suburban, horticultural, agricultural, or industrial landuse. The pre-European landscape of the Styx River was largely raupo swamp and grassland. There is anecdotal and scientific evidence that the river ran over a gravel substrate, and had flax-lined banks. Intensive horticulture (market gardens and orchards) and agriculture soon developed within the catchment, reflecting the good quality of the peaty soils characteristic of this area. As a result of this landuse change, most of the indigenous vegetation cover was removed in this process, and many of the waterways were straightened to improve their drainage efficiency. The growth of the meat and wool processing industries in the early 1900's lead to the development of the town of Belfast within the catchment; and associated impacts on the waterways associated with urban development and industrial activity. The latter half of the twentieth century has also been characterised by a northward growth of Christchurch, and this population growth is leading to extensive urbanisation of parts of the catchment that traditionally have not been urbanised.

The Christchurch City Council (CCC) wishes to protect, and enhance the present ecological values of the river, before further damage to the river environment occurs as a result of continued land development. The first stage in this process was to consult with stakeholders to identify the needs and aspirations for the river as a cultural, ecological, and recreational resource.

This next stage, and the purpose of this report, is to review what is known about the river's aquatic macrophyte, invertebrate and fish ecology, and identify specific issues that are impinging on these communities as a result of past and present catchment conditions. Key monitoring elements will be identified, along with areas where the community can get involved in future research and environmental monitoring.

Measurable goals (or ecological aspirations) that are realistic for the catchment are then outlined and gaps in our present knowledge that prevent these goals from being achieved will be highlighted. Finally, potential further research efforts that can fill the identified knowledge gaps will be discussed.

2 REVIEW OF THE CURRENT KNOWLEDGE ON INSTREAM BIOLOGICAL COMMUNITIES

2.1 Aquatic macrophytes

Until the mid-1970s, there had been few systematic studies of the aquatic macrophyte vegetation in the Styx River catchment. The larger in-stream macrophytes had been surveyed by Connor (1953), and this work provides a useful historical baseline for subsequent changes. Although no detailed investigations were undertaken for the next 20 years, good information is available from 1977 onwards as a series of surveys were made at five-year intervals for the former Christchurch Drainage Board (now the CCC: Robb 1980; Carroll and Robb 1986; Robb 1989; Robb *et al.* 1994). These studies became increasingly detailed over time, especially in the 1994 report, and they remain the only complete vegetation surveys of the catchment. Other studies during this time have either focused more on the riparian vegetation than the in-stream macrophytes (e.g. Partridge and Roper-Lindsay 1989; McCombs 1997) or have been restricted to limited regions of the catchment (e.g. Walsh *et al.* 1999).

Table 1 presents an overall summary of the predominant in-stream vegetation recorded in these reports, including the true aquatic macrophytes, shallow marginal species that often spread into the edges of the river, and the free-floating macrophytes such as duckweed *(Lemna minor)* and azolla *(Azolla filiculoides).* Both these species have remained common over time, and the distribution and abundance of many other species have also remained relatively stable. The Styx River is a slow-flowing lowland stream in a predominantly rural catchment, and those species characteristic of such conditions (e.g the stonewort *Nitella hookeri* and filamentous green algae) have remained especially common.

The greatest changes have occurred in the tall-growing submerged aquatic macrophyte species. Two native species that were common at the time of Connor's (1953) study *{Potamogeton cheesemanii* and *Myriophyllum propinquum)* have decreased dramatically, *M. propinquum* in particular having retreated to a small population in Smacks Creek. The period during which these species declined coincided with much of the stream re-aligning that was carried out between Marshlands Rd and Brooklands Rd, and it is likely that this disturbance was at least partially responsible for their decline. *P. cheesemanii* had become rare by 1989, but subsequently increased its abundance slightly in the upper river. The other major change has been the appearance of the introduced *Potamogeton crispus* in Kruses Drain by the mid-1970s (1980 report) and its subsequent spread through the lower reaches of the river, where it has become co-dominant with a much longer-established introduced species, *Elodea canadensis.* At the time of the last (1994) survey, the upper catchment remained free of *P. crispus,* with *E. canadensis* and starwort *(Callitriche stagnalis)* being the main introduced species there. A small infestation of the oxygen weed *Lagarosiphon major* appeared in the mid-1970s, but was promptly eradicated by the Drainage Board and has never recurred. Abundance of *E. canadensis* has fluctuated, decreasing by the mid-1980s and subsequently recovering. This fluctuating biomass is normal and frequently observed for this species in other parts of New Zealand and overseas, and is likely to occur again in the future. Its disappearance below Kainga Rd since 1994 may be another example of this behaviour, or it may have been displaced by *P. crispus,* which is more tolerant of desiccation and may therefore be better adapted to this tidal area.

Table 1

Interpretation of changes in the stream macrophyte communities in the Styx River based on surveys published between 1953 and 1994. The abundance of species is described as ranging from - (not recorded) to + + + + + (common or dominant throughout the river system); ND (not determined) = species outside the scope of the earlier studies but that may well have been present at the time; * = exotic species. Species not recorded in surveys are not necessarily absent from the catchment. Some Latin names have changed since the reports were published; the names used here are those currently accepted.

Species	Connor 1953	Robb 1980	Carroll and Robb 1986	Robb 1989	Robb *et al.* 1994
Aquatic macrophytes					
*Potamogeton crispus**	-	+	+++	++++	++++
Potamogeton cheesemanii	+++	+	++	+	++
Myriophyllum propinquum	+++	++	+	+	+
*Elodea canadensis**	+++++	++++	+++	++++	++++
Nitella hookeri	+++++	+++++	++++	+++++	++++
*Callitriche stagnalis**	-	++	+++	++	+++
*Lagarosiphon major**	-	(+)	-	-	-
Ruppia spp.	ND	+	+	+	+
Hydrocotyle sp.	ND	ND	++	++	++
Filamentous algae	+++++	++++	++++	++++	++++
Bryophytes	ND	++	+++	++++	++
Shallow emergents					
*Rorippa microphylla**	ND	++++	+++	+++	++++
*Agrostis stolonifera**	ND	+	+++	++	+
*Glyceria fluitans**	ND	+	+++	++	++++
Mimulus spp.*	ND	ND	+++	+++	++++
Free-floating species					
Azolla filiculoides	+++	++	+++	+++	+++
Lemna minor	+++	+++	+++	+++	+++

The area between Kainga Road and the tide gates has been identified as particularly valuable (Robb *et al.* 1994) and this area was surveyed recently (Walsh *et al.* 1999). Changes from 1994 to 1999 in this area include an apparent increase in abundance of *P. crispus* at the expense of *E. canadensis,* and the presence of the native turf-forming species *Lilaeopsis novae-zelandiae* in sheltered backwaters. Since the current tide gates were installed in the early 1970s, this area has steadily become less brackish and more fresh in character, which is consistent with the expansion of these species and starwort there.

The community of shallow emergent species has changed considerably less in the catchment, at least since the mid-1970s when they were first studied in detail. After 1991, when the Council adopted a less vigorous control programme for these plants, they generally increased in abundance along the river, with the exception of *Agrostis stolonifera* (creeping bent). Creeping bent is tolerant to disturbance, and consequently would have been favoured more by the pre-1991 management programme. There also appears to have been little change since 1994, as most of the shallow emergent species shown in Table 1 were also recorded by McCombs (1997).

The salt-tolerant vegetation below the tide gates has not been recorded in such detail, but species such as *Leptocarpus similis* (oioi), *Juncus maritimus, Schoenoplectus pungens* (three square), and *Zostera novazelandica* (seagrass) have all been recorded in various reports.

2.1.1 Intrinsic values of aquatic plants

No nationally or regionally rare plant species were recorded in the various surveys. Some plant species, e.g., *Nitella hookeri, Myriophyllum propinquum, Potamogeton cheesemanii* and mosses, are desirable in that they do not form dense growths that can decrease hydraulic efficiency. These plants are less disturbance-tolerant than the two common exotic species that are found throughout the catchment *(P. crispus* and *E. canadensis)* and prefer stable water regimes and especially minimal disturbance of the channel and substrate. Harvesting regimes to control *P. crispus* and *E. canadensis* should therefore avoid disturbance of the native species where possible. *M. propinquum* is particularly intolerant of disturbance and has a low competitive ability. It is unlikely to recolonise the main river unless disturbance to the channel and flow is minimal. It is also never likely to dominate the exotic species.

The spread of *P. cheesemanii* in the upper river in the early 1990s is encouraging; this species can tolerate some flow variability and should continue to expand provided disturbance of the channel and substrate is avoided. The other natives appear to have been resilient to changes in river management over time and are likely to persist unless severely stressed. One exotic species that is often regarded as beneficial, as it tends not to form dense weed beds, especially in deeper water, is starwort. This plant is also competitive and disturbance-tolerant and is likely to be resilient to most management practices.

2.2 Invertebrate communities

2.2.1 Review of existing knowledge

The invertebrate communities of the Styx River and its tributaries (Smacks Creek and Kaputone Creek) have been extensively surveyed by the then Catchment Drainage Board (CDB) in 1979 and again in 1987 - 1988. These surveys sampled invertebrates from many sites along each waterway, and assigned each taxa a score based on relative abundance.

The most widespread taxa encountered in the Styx catchment in both surveys were snails, including *Potamopyrgus antipodarum, Sphaerium novae-zealandiae* and *Physa* sp, worms (Oligochaetes), midges (Chironomidae), and the amphipod *Paracalliope fluviatilis.* These taxa occurred in over 50% of the 81 sites sampled. They are common in slow flowing streams, and make up a nucleus of invertebrate taxa that are present in urban streams throughout Christchurch (Suren *et al* 1998, 2000)

Of the three waterways examined in his study, Robb found that Smack's Creek supported the highest number of taxa (a mean of 20.5 species), while Kaputone Stream supported the least number of taxa (mean of 11.4). The Styx River supported a mean of 14.9 taxa. A total of 75 taxa were recorded in the 1979 survey, while only 62 taxa were recorded in the 1988 survey. Both these numbers of taxa are much higher than found by Robb (1992) in an extensive survey of 216 sites from 13 streams in Christchurch Robb (55 taxa), and Suren *et al.* (1998) in a survey of streams draining the Christchurch region (54 taxa). Additionally, Suren (1993) found only 18 taxa in seven sites in the Avon River, and five sites in the Heathcote River. Based on the 1988 surveys, and assuming that taxon richness has not declined further over time, the Styx Catchment could be regarded as significant in that it supports a diverse assemblage of invertebrate species in an area near Christchurch.

The reasons for the observed decline in taxonomic richness in the Styx River between each CDB survey (1979 and 1988) were unknown, but speculated to be "due to chance differences in the timing of weed-cutting and channel maintenance operations prior to sampling" (CDB 1989). Whether this speculation is true is unclear, but the decline in taxonomic richness was only observed in the Styx River and not in Kaputone or Smack's Creek. This finding suggests that it was not a catchment-wide effect, and may indeed have reflected small-scale changes such as weed-cutting to the Styx River.

There was a high diversity of caddisfly larvae in both the 1979 and 1988 surveys in the Styx River (13 and nine species respectively) and in Smacks Creek (nine and 12 species respectively). This high diversity is comparable with the findings of Main (1995) who recorded 14 caddisfly taxa from eight rural streams surveyed throughout Canterbury, and is much higher than six caddisfly taxa recorded in a survey of Christchurch urban streams (Suren 1993). Mayfly species were also relatively common throughout the Styx River (four taxa) and Smacks Creek (three taxa). These taxa in particular are very sensitive to silt and changes to flow and temperature regimes that occur as a result of catchment development. Only one species of mayfly (the common leptophlebid mayfly *Deleatidium)* has been recorded from Christchurch urban streams (Suren 1993), reflecting the fact that these streams are in a more "degraded" condition than those in the Styx catchment.

2.2.2 Use of invertebrates in monitoring

Macroinvertebrates have long been used as biological indicators of a stream's health. Unlike water quality measurements, which can vary greatly with flow, and which tell very little about the actual biological effects, the invertebrate community in a stream is effectively an expression of the long-term water quality and habitat conditions in a stream. Moreover, invertebrates are relatively easy to collect and identify, and have relatively well-known responses to different environmental variables (Penny 1985, Winterbourn 1985, Rosenberg and Resh 1993). Moreover, invertebrates are important food items for fish and water-birds.

Central to the use of invertebrates as indicators is the use of pollution and diversity indices: single numbers to convey information about the often complex nature of the invertebrate communities (Norris and Georges 1993, Hellawell 1986). Such metrics quantify some aspect of biological communities that change in a predictable manner as a result of human disturbances (Diamond *et al.* 1996). Commonly used metrics are *species richness, enumerations of indicator taxa,* measures of *diversity* and *biotic indices.* Additionally is the use of multivariate techniques such as *ordination,* which plot the location of sites according to their invertebrate communities, so that samples clustered together have more similar communities than samples that are more separated.

These metrics are commonly used in studies throughout New Zealand. In particular, the Macroinvertebrate Community Index (MCI) of Stark (1993) has been widely adopted for use as a *biotic index* by many biologists (e.g. Quinn *et al.* 1992, Stark 1993, Main 1995, Donald 1995, Quinn *et al.* 1997). This index was originally developed to assess *organic pollution* in 27 streams in Taranaki (Stark 1985). It was derived by examining the abundance of a number of invertebrate taxa in otherwise similar streams that were assigned *a priori* to one of three water quality classes based on their degree of organic pollution. Taxa with high MCI scores are indicative of "clean" water, and consequently regarded as being "sensitive" to pollution. Conversely, taxa with low MCI scores are indicative of organically enriched water. Thus sites with high MCI scores are regarded as being "healthy", while those with low MCI scores are regarded as being "degraded".

Although the validity of using the MCI in many streams is unquestioned, there is a potential problem in using this index to score the invertebrate fauna usually associated with lowland streams such as occur in the Styx River. The invertebrate fauna here is dominated by taxa such as snails and oligochaetes, which can tolerate slow flowing water and fine grained substrata. These taxa are regarded as indicative of "degraded" streams by the MCI score (Stark 1993), but are normal constituents of even "healthy" lowland streams. To overcome this problem, Suren *et al.* (1999) developed an Urban Community Index (UCI) based on a national survey of 58 urban streams. This index allocates each invertebrate taxa a specific score based on an ordination of the original data. Unlike the MCI score which is based on water quality criteria, the UCI score is based on *habitat criteria.* Taxa with high UCI scores are indicative of fast flowing, stony bottomed streams, while taxa with low UCI scores are indicative of slow flowing, muddy streams (Suren *et al.* 1999).

To see how useful invertebrates are at monitoring changes in the Styx catchment, we calculated three biological metrics for the CDB data. We calculated taxonomic richness, MCI scores and UCI scores for all the sites, and examined how these changed over time.

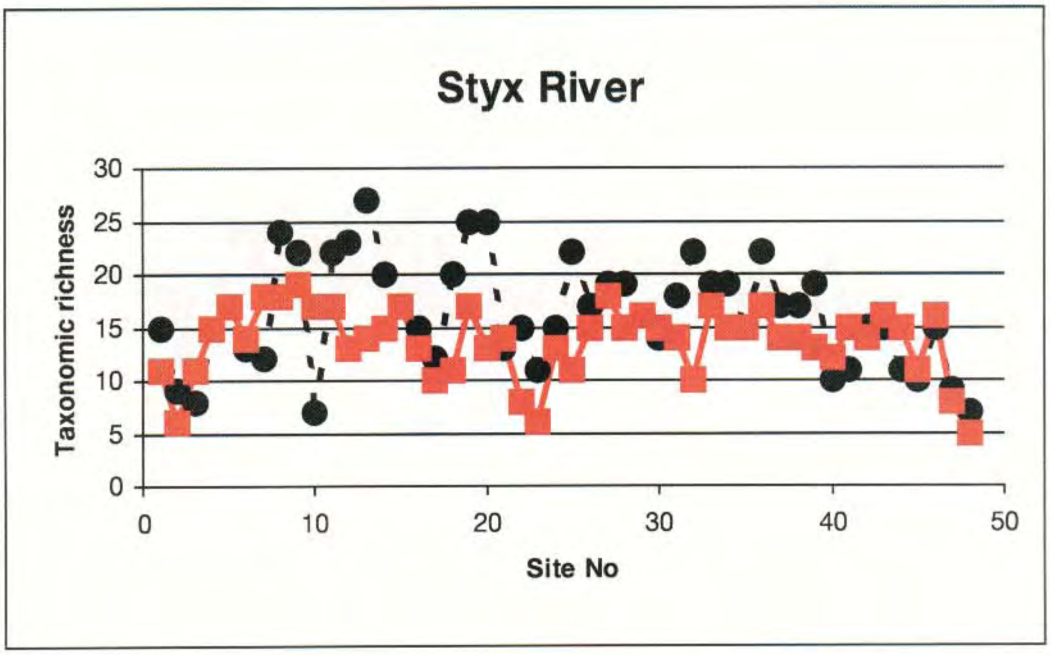
Taxonomic richness varied between each site along both the Styx River and Kaputone Creek (Fig. 1). Although no apparent longitudinal pattern to taxon richness in the Styx River in either year was evident, richness increased at downstream sites in 1980 in Kaputone Creek. This increase was not evident here in 1989, however. There was also a significant increase in taxon richness in the Styx River between the two sampling periods ($t = 2.917$, $P < 0,05$), but no significant increase occurred in either Kaputone or Smacks Creek.

Calculated MCI scores for the Styx River showed a marked longitudinal decline at lower sites (Fig. 2), suggesting a decrease in water quality throughout the catchment. As mentioned, however, the MCI was not developed for slow flowing streams, and so this decrease may be more of a reflection of changes in habitat condition of the river. An additional consideration is the fact that the lowermost sites in the Styx River are in an estuarine environment, where the MCI in not applicable. MCI values were consistently higher in the 1988 survey than the 1979 survey ($t = 4.029$, $P < 0.05$), suggesting that the invertebrate communities in the latter survey were considerably different to those of the earlier one, and represented a more "healthy" ecosystem. MCI scores in the Kaputone Creek were also considerably higher in the 1988 survey ($t = 3.311$, $P < 0.05$), suggesting that the fauna at this site had also changed, and that taxa with higher MCI scores were more common. Such changes may reflect differences in water quality, or in differences in instream habitat that favoured those taxa with higher MCI scores. Unlike the Styx River, there was no longitudinal trend in MCI scores along the length of the Kaputone Creek (Fig. 2), reflecting the fact that it does not become estuarine.

As mentioned, the use of the MCI may not be strictly correct in these waterways, as organic pollution may not be an issue, and as the streams may naturally be soft bottomed, especially as they have a low gradient. When the sites were scored by the UCI method, no major decrease in UCI score was evident in the Styx River on either sampling date, especially between sites 20 and 47 (Fig. 3). The UCI score is more of a measure of habitat conditions than the MCI, and suggests that habitat conditions along the river do not necessarily become more degraded along the river. Of particular interest are the higher UCI scores in the Styx in 1988 than in 1979 at sites 3-19 (Fig. 3), suggesting that the habitat conditions here had improved, and that taxa indicative of fast flowing stony streams were more prevalent. Such sites could be considered as having a high biological value to the biodiversity of the Styx catchment. The fact that many of these sites are in the vicinity of major current landuse development is of concern, as these sites may be adversely affected by the effects of development.

The UCI scores in Kaputone Creek displayed no major longitudinal patterns, but were slightly lower in 1988 than they were in 1989 ($t = 2.165$, $P < 0.05$; Fig. 3), suggesting that the habitat quality and invertebrate communities in this stream had deteriorated slightly between the two surveys.

Examination of the 1979 and 1988 CDB data has revealed a number of interesting trends. Firstly are the natural longitudinal changes in the stream benthos along the Styx River as it flows toward the sea. Such changes are, however, absent in Kapatone Creek, as this site lacks the same estuarine area. It is clear that the invertebrate communities have also changed between the two sampling periods, although the underlying cause of this change is unknown. Examination of the 20 most commonly distributed taxa has shown that the occurrence of some taxa (e.g., the snails *Sphaerium novae-zealandiae, Physa, Gyraulis corinna* the midge *Chironomus zelandicus,* the flatworm *Cura pinguis,* and the caddisfly *Hudsonema amabilis)* has increased over time (Fig. 4). Other taxa (e.g., chironomids, the caddisflies *Triplectides obsolete,* and *Oxyethira albiceps,* and the shrimp *Paratya)* have decreased over time (Fig. 4). These changes are important to document as they reflect changes in stream health, as well as changes to the potential food items available to fish.



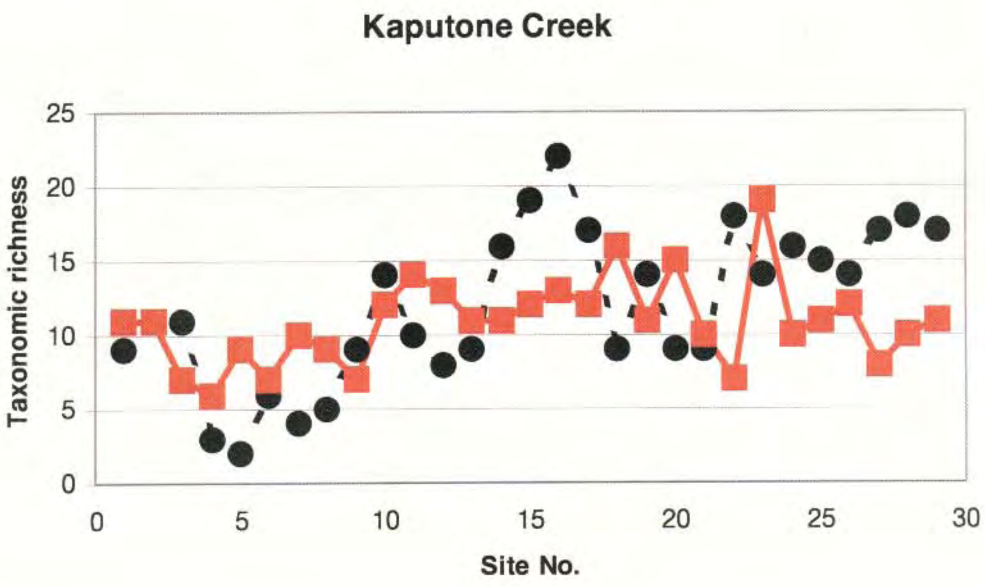


Figure 1. *Taxonomic richness at sites in the Styx River and Kaputone Creek in 1979 (Black circles) and in 1988 (Red squares)*

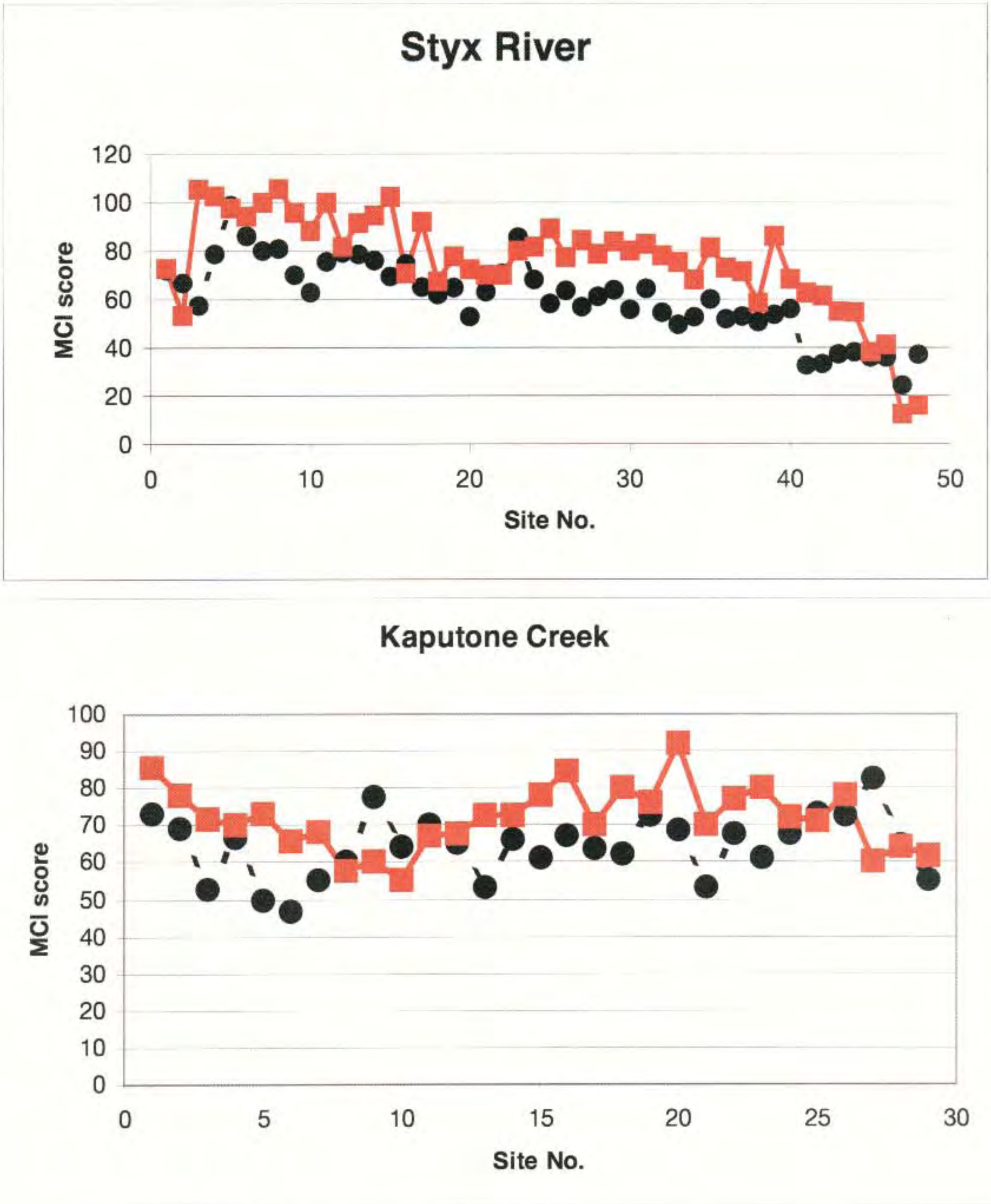


Figure 2. *Calculated MCI scores at sites in the Styx River and Kaputone Creek in 1979 (Black circles) and in 1988 (Red squares). Note how the MCI scores decrease along the Styx River, reflecting the change in physical habitat and entrance into an 'estuarine' environment.*

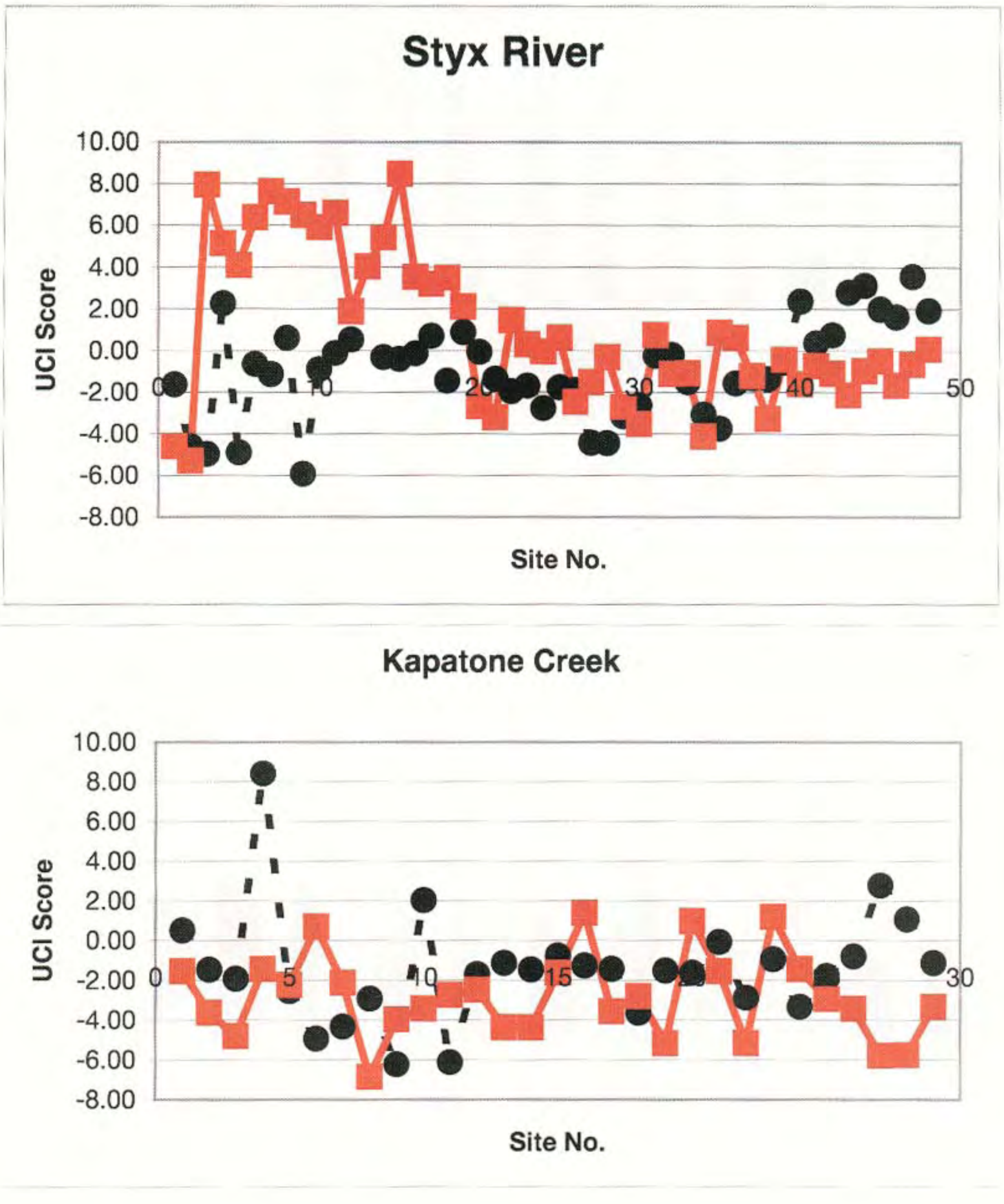
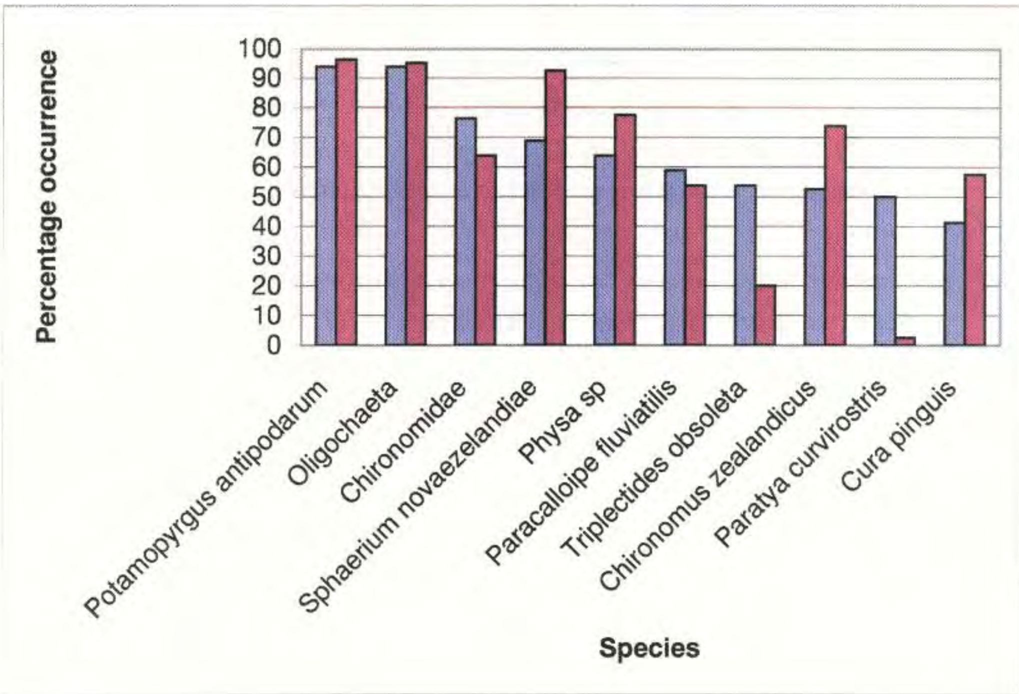


Figure 3. *Calculated UCI scores at sites in the Styx River and Kaputone Creek in 1979 (Black circles) and in 1988 (Red squares). Note how the UCI scores do not decrease along the lower reaches of the Styx River, suggesting that the physical habitat quality remains fairly constant in this river.*



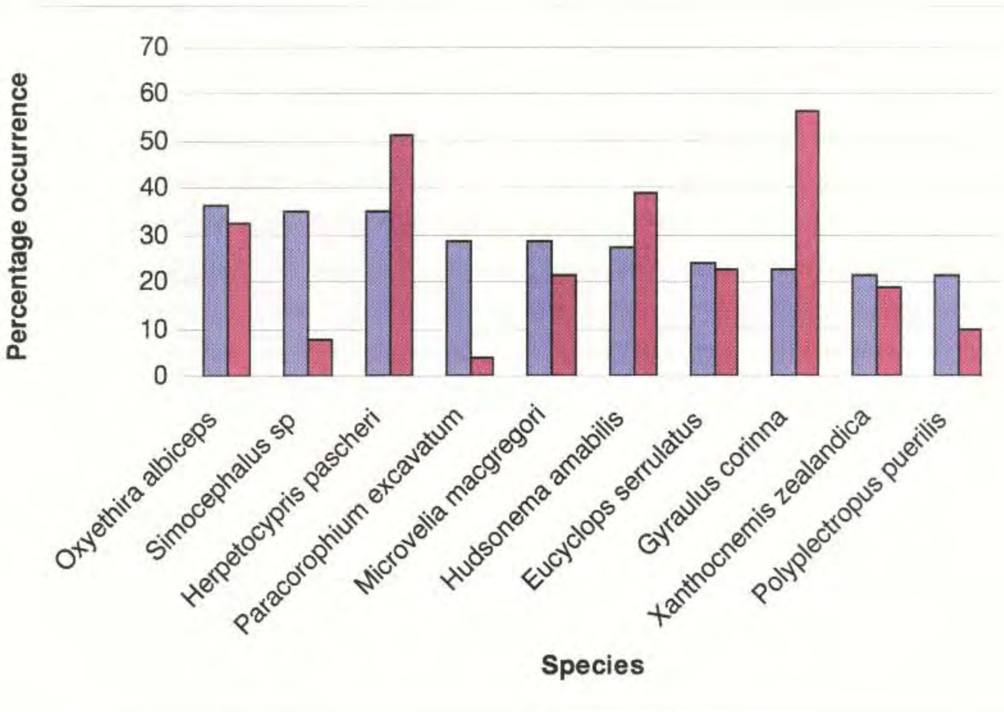


Figure 4. *Comparisons of the percentage occurrence of the 20 most widespread taxa found in the 1979 and 1988 CBD surveys of the Styx River catchment showing how the percentage of sites where each taxa was found has often changed over time.*

The fact that the CDB surveys were conducted using a standard method makes comparisons between sampling periods possible. In this way, it is possible to monitor long-term changes to stream health. If invertebrates are to be used for further monitoring work, it would be worthwhile to survey at the same sites as in the CDB surveys, preferably using the same techniques. In this way, any changes in the invertebrate communities between 1988 and now could be quantified.

It would also be worthwhile to measure the stream habitat in some way, for example by using the new USHA or SHMAK protocols that NIWA has developed. In addition, it would be beneficial to survey as many sites as possible prior to any further significant catchment modification occurs, in order to resurvey the same sites after development has been completed to assess the impacts of this development. Such information would provide valuable details of the long-term impacts of catchment development, and may help identify ways in which any adverse effects can be avoided, mitigated or remedied.

Ideally, an invertebrate monitoring programme should be set up as soon as possible to quantify properly any adverse effects of the current catchment development that is occurring. Implementation of an invertebrate monitoring programme would depend on what goals the CCC has set for such a programme, but could include sampling the stream as in the original CDB surveys. In this way, any further long-term changes in the invertebrate communities could be assessed. An alternative sampling programme would be to assess the impact of the current development activities. Sites should be chosen upstream and downstream of the development activities, and monitored over time. Although it would have been preferable to commence such an upstream-downstream monitoring programme *before* the development started, the long term effects of this can still be monitored with an upstream - downstream approach. This approach however also needs paired sites in a "control" catchment.

2.3 Fish ecology

The only known comprehensive fish survey of the Styx River was conducted in 1990 (Eldon and Taylor, 1990), and the fish and invertebrate values in the Styx River were reviewed in 1999 (Taylor 1999). Other NIWA reports on specific issues in the Styx catchment have also considered the effects of the Kaputone weir on fish passages (Sykes et. al 1998), and have summarised fish values in the Bottle Lake region (Taylor and Sykes 1999).

Fish diversity of the Styx River is comprised of 10 species; nine natives, and the introduced brown trout. This is typical for a developed catchment with multiple landuses (National Freshwater Fish Database, FFDB), but ranks low when compared nationally to unmodified catchments. In addition to the resident freshwater fish, yellow-eyed mullet, a marine itinerant, is found in the lower river.

The fish, in order of probable abundance are, shortfin eel, longfin eel, brown trout, common bully. Other fish such as lamprey, common smelt, inanga, giant bully, upland bully and black flounder are also found. None of these species are regarded as regionally or nationally rare or endangered. This fauna is similar to that in the Avon and Heathcote Rivers, except for the presence of bluegill bully and the occasional reports of salmon in the Avon and Heathcote rivers (FFDB). Saltwater Creek, another small coastal spring-fed catchment to the north of the Styx supports 12 freshwater fish species. In contrast to these streams is Kaikorai Stream, south of Dunedin, a modified rural stream with encroaching suburban development. This stream supports only seven freshwater fish species.

Several freshwater fishes, now absent from the Styx catchment, may have inhabited the river in the past. The native bluegill bully has a marine life-stage and prefers fast-flowing stony streams with little silt, a flow-type now generally lacking in the Styx. The bluegill bully may well have inhabited the middle reaches of the river before the substrate became extensively silted. Along with other Canterbury catchments, the giant kokopu and mudfish, were probably widespread before wetland drainage took place.

The overall fish environment of the Styx River is considered vulnerable from potential effects of subdivision development, siltation, and pollution from a variety of sources (Eldon and Taylor, 1990). In the past, a number of fish kills that were attributed to chemical pollution have taken place in the catchment. Some of these pollution sources have recently ceased to discharge into the Styx, but there is still evidence of other unknown pollution sources (M. Main, Environment Canterbury, pers. comm.).

Eight of the nine native freshwater fish species have a marine phase in their lifecycles, and migrate upstream into the rivers in the winter and spring. Because of the naturally easy gradient of the catchment, access to potential habitats may be compromised for some species because of in-stream obstructions.

Brown trout are a valued aesthetic and recreational resource of the Styx River (WSU 1999), reflecting their recreational value, and they are perceived as indicators of good water quality. However, there is a widely held view that the trout fishery is in decline, and observed trout numbers based on surveys have indicated lower numbers in recent years (Nicholas Moody, Guardians of the Styx, pers. comm.). Trout redd counts by NIWA (Eldon and Taylor, 1990) and the North Canterbury Fish and Game Council, (redd survey 1999), have also indicated trout spawning has declined appreciably during the 1990's. However, individual trout condition is fair to good, and has not declined between 1979 and 1990 (Hayes, J. W. 1979, Eldon and Taylor, 1990). An observation during the 1990 fish survey is pertinent here:

"During the trout spawning surveys, the extent of clean gravels in the headwaters seemed inadequate to provide spawning sites for the number of trout present. ...adult trout captured above Gardiners Road were found to have retained a full complement of the previous winter's eggs .." (Eldon and Taylor, 1990)

These results suggest that there may be a problem with trout spawning and subsequent recruitment of juvenile fish in the Styx.

A fairly intensive catch-and-release fyke-netting exercise in the lower Styx River in early March 2000 revealed poor catches of eels, especially large specimens of either species (D. Jellyman, NIWA, pers. comm.). The recent survey catch of 45 eels in 10 effective overnight net-sets ranks poorly compared with the results of the 1990 study (Eldon and Taylor 1990), where shortfins were rated as 'abundant', and longfins as 'common' in the lower reaches (using similar gear). The average size of recently-captured eels was relatively small compared to other rivers, and even compared to the Styx River statistics for 1990. The mean shortfin length in the recent survey was 471 mm (maximum = 720 mm), compared with 548 mm (maximum = 900 mm, netted) in the earlier study. For longfins, 454 mm (maximum = 620 mm) compared with 460 mm (maximum =800, netted). While the fyke-netting exercise is not conclusive by itself, there is an indication the fishery in March 2000 was depleted. It could be that the lower river had been recently commercially fished, and uncaught fish had not recolonised the fished reaches.

MANAGEMENT ISSUES PERTAINING TO THE RIVER ECOLOGY

The Styx catchment has undergone, and is undergoing major changes to its landuse. The original pre-European native vegetation has long been replaced by pasture, market gardens and orchards, and this is now undergoing a change into urban development. Worldwide, there has been a well-documented negative effect of urbanisation on streams (Suren 2000), and in particular on the stream invertebrate communities. Given the importance of many invertebrates as food for fish and water-birds, any changes to the stream invertebrate fauna as a result of catchment development are likely to affect these higher trophic levels, and as such, have a negative impact on many valued components of the Styx River. Expected changes to the invertebrate communities are typified by a decline in the richness and density of so-called 'sensitive' insect taxa such as Ephemeroptera, Plecoptera and Trichoptera (i.e. EPT taxa) and an increase in densities of so-called 'pollution tolerant' organisms such as oligochaetes, chironomids and snails. These changes will in turn affect fish, as these animals selectively feed on different invertebrate species.

According to the CDB surveys of 1979 and 1988, the invertebrate communities in the Styx catchment were relatively "healthy" and less impacted than the invertebrate communities of the Avon and Heathcote Rivers. This probably reflects the fact that the Styx catchment is less urbanised than those draining the Avon and Heathcote Rivers. As such, it is expected to have better habitat quality, higher flows, and better water quality. Given the fact that urbanisation usually reduces the biological values of urban streams, it is likely that catchment development of the Styx will also result in deleterious impacts. Part of a catchment management strategy is thus to consider whether such impacts are acceptable, and, if not, to develop ways in which such impacts can be avoided, mitigated or remedied.

A number of issues can be addressed to minimise the adverse impacts of catchment development, particularly that associated with urbanisation. These include developing an ecologically sensitive macrophyte management strategy to enhance native plants, but reduce the biomass of invasive species, developing ways to minimise sediment input from landuse activities, and altering a stream's flow regimes. Minimising the inflow of contaminated stormwater is also an important issue, as is the enhancement of instream habitat values for native fish. Finally, from a fisheries perspective, ensuring an unimpeded fish passage for diadromous species is vital if these species are to continue to utilise the whole river reach. These issues are discussed in more detail below.

3.1 Excessive aquatic macrophyte growth

A major issue in productive lowland rivers such as the Styx is the compromise between control of excessive weed growth, and maintaining sufficient macrophyte biomass to provide the habitat and stability in a river that leads to maximum biodiversity. *P. crispus* and, to a lesser extent, *E. candensis,* may require on-going management to prevent excess biomass, but the harvesting practice should avoid completely removing these species, should avoid disturbing the substrate or channel, and should avoid disturbing the native species as much as possible. This is especially so in the upper river where the native *P. cheesemanii* has been increasing in abundance and is likely to be sensitive to disturbance.

Excessive growths of aquatic macrophytes impede water flow (and recreational use) in channels and result in surface flooding during periods of high flow, or may form offensive decomposing masses during low flow. *Potamogeton crispus,* with its ability to form dense growths, has been the major focus of nuisance weed growth in Christchurch waterways, where harvesting and managed salt intrusions have been used for its control. Dense growths requiring harvesting have been observed in the Styx, and it is likely that some control of this species will be required in the future. Mechanical cutting as practiced by the Council in some rivers at present is likely to be suitable. The selective weeding of *P. crispus* in the Avon loop has also proved to be very effective in controlling this species. It is not likely to be applicable to large areas of the catchment, as it is labour-intensive, but could have value in localised areas that are identified as being valuable, such as the area between Kainga Rd and the tidegates. However, *P. crispus* tolerates disturbance well and grows rapidly in response to disturbance such as harvesting (Sabbatini and Murphy 1996), and the plant will always be a feature of the lower river. The most recent survey, however, identifies areas in the upper Styx that are free of this species. It may be possible to maintain this condition provided its early identification and eradication are a priority. Areas free of *P. crispus* are those most likely to be suitable for re-colonisation of native species that tend to form smaller biomass that does not cause hydraulic problems.

Other species present in the Styx River that are known to be potentially invasive or of nuisance value are the filamentous algae, *Elodea canadensis, Rorippa* spp. and *Glyceria fluitans* (Snelder et al. 1995). None of these have been reported as causing severe problems in the Styx in the past and all are long established. *E. canadensis* grows very rapidly, but does not tend to form such dense beds as *P. crispus. Rorippa* is usually restricted to shallow water but can form dense biomass and may need some harvesting. *Glyceria fluitans* has not produced excessive growth in the Styx as yet, but is currently a significant problem in the Selwyn River. Filamentous algae are very common in the river but their biomass becomes high only during periods of sustained low flow during the summer. Not present in the Styx, but a considerable threat to it, are the large oxygen weeds *Lagarosiphon major* and *Egeria densa.* Both of these plants have been recorded in other rivers in the Christchurch area where they form very dense growths and cause severe hydraulic problems. Early identification and eradication of them, as was achieved for *L. major* in the late 1970s, is thus a management priority.

Submerged aquatic plants are generally beneficial for fish populations, as they provide habitat and shelter, for not only fish, but also for invertebrates and periphyton that fish ultimately depend upon. However, while aquatic macrophytes are conducive to increasing fish diversity and abundance, there are occasions, even for fish values, when removal, or cutting is the best option. In particular, trout spawning gravels should be relatively clear of excessive macrophyte cover prior to the commencement of spawning in July. Trout spawning areas in the Styx River recommended for weed clearance were tabulated in an earlier report on aquatic macrophyte management (Appendix I. Snelder *et. al.* 1995). Plants such as *P. crispus* and oxygen weeds can form extremely dense growths, that provide poor habitat for fish as they impede fish navigation and, in severe cases, can cause de-oxygenation of water. Exotic macrophytes provide the same habitat as native species and, given that they are now well-established throughout the river, need to be managed for their habitat value rather than eradicated. From a management point of view, therefore, a harvesting regime for *P. crispus* should be established that prevents excessive growth of this species but still retains some growth for habitat considerations. The lowest biodiversity in river systems is usually associated with areas where no aquatic macrophytes are permitted to grow.

Maintaining healthy vegetation between Kainga Rd and the tide gates continues to be a priority, and the vegetation there is diverse and has high intrinsic value. It is the only area known to support the native turf-forming species *Lilaeopsis novae-zelandiae,* which is valuable not only for habitat but also for binding soils and increasing water clarity. Low-impact ways of removing some of the *P. crispus* will be desirable here.

3.2 Siltation issues

Feedback from stakeholders clearly shows that excessive siltation is regarded as highly detrimental to the aesthetic, recreational, and ecological values of the Styx River (WSU 1999). Given the levels of silt in the Styx, this perception is probably justified. The depth of the sediment in the lower and middle reaches was considered to be responsible for the general rise in water level below Radcliffe Road (Eldon and Taylor 1990).

Excessive siltation can cause both low oxygen levels in both the water column and the streambed. This is particularly true when there is organic matter bound in with the sediment, as anaerobic bacteria break this material down producing sulphur-rich metabolic compounds. Such anaerobic conditions are particularly common in warm weather, when bacterial respiration levels are naturally high. Oxygen demand by invertebrates and fish is also higher in warmer water, leading to oxygen stress or possibly death in extreme cases. Invertebrate communities in silted habitats differ to those in unsilted habitats, reflecting the fact that some invertebrates (e.g., many mayfly and caddisfly species and amphipods) will actively leave areas where deposited silt covers the streambed (Suren and Jowett 2000). This can lead to a reduction in species diversity in silted habitats, and the fauna can become dominated by snails, worms and midges (e.g., Jowett et al 1991, Harding and Winterbourn 1995, Quinn et al 1997). Such changes in invertebrate composition can have far reaching effects on fish and bird communities, especially if preferred food items are lost from silted habitats.

Silted habitats also lack suitable refuges for small fish from predators, because many small fish would otherwise use interstices amongst the stones to escapement predation (Jowett and Boustead 2000). This would be particularly true if overhanging banks and vegetation were also unavailable.

Siltation and excessive growths of filamentous algae were suggested to be reducing the quality and quantity of brown trout spawning habitat in the Styx River (Eldon and Taylor, 1990). Brown trout deposit their eggs in gravels, and these eggs require a good oxygen supply from the percolating water current. Although brown trout can clean the gravels of silt during redd construction, excessive suspended silt loads may block the interstices during the time egg are developing in the gravels, reducing the vital oxygen-carrying water supply. However, many trout will not spawn in a silted habitat at all, and while a female fish will produce eggs, she will not spawn, and the eggs will be resorbed back into the body tissue. Trout in this condition have been found in the Styx River (Eldon and Taylor 1990).

The historically clean-bottomed nature of the river attests to naturally low levels of suspended sediment and sediment input early last century. The historical equilibrium of low sediment input and low sediment transporting capacity has been replaced with higher sediment input and possibly even lower sediment transport capacity. The Styx lacks the current velocities and rain-induced freshes to re-suspend and transport present levels of suspended sediment. Therefore, the natural consequence of this is a gradual accumulation of sediment. The present-day problem with silt deposition was noted by Eldon and Taylor (1990), and the cause of the problem, while not determined, was thought to arise from the removal of riparian vegetation, and horticultural activity too close to waterways. This conclusion was later ratified by a detailed study into the sedimentation in the Styx River catchment and Brooklands Lagoon (Hicks and Duncan, 1993). During one storm event, a disproportionate amount of suspended silt (as measured at Marshland Road) was from Quaids Drain, a market-gardening sub-catchment, and Homers Drain (draining a residential area). The authors claimed that landuse changes involving more market-gardening or more rapid urbanisation would increase the catchment sediment yield, although the yield from urbanisation would be temporary, until the new development 'matured'. Little sediment passes downstream of the tidegates, because aquatic macrophytes upstream of this point facilitates its sedimentation. Sedimentation rates in the Styx River upstream of Radcliffe Road were low (<2 mm/yr) in 1993. However, since this report, potential sources of sediment may have increased with catchment development, and the hydraulic efficiency of sediment transport (because of increased macrophyte growth) may have decreased in the river.

The reported practice of unrestricted stock access to extended length of the water channel (WSC 1999) accelerates riparian soil erosion creating water pollution, and damaging the stream substrate. Such obvious factors that reduce aquatic ecological values, are easily rectified with riparian fencing and the provision of water troughs.

Subdivision development is another potential source of sediment input, with newly developed urban areas exporting up to 30 times more silt than in their pre-developed state (Williamson 1993). However, riparian strips, and detention basins may help reduce the sediment entering the river as a result of catchment development, and discharge of urban stormwater into the river may assist downstream transport of the accumulated silt.

The relationship between sedimentation rates, weed height, hydraulic conveyance and biological values in the Styx River has been recommended (Hicks and Duncan, 1993). If biological values can be retained while maintaining less macrophyte growth, then hydraulic efficiency will improve sediment transport downstream. If sediment yield (input) in the river can be reduced to a minimum, dredging will gradually remove the sediment load from the river.

3.3 Changes to flow regimes

A fundamental feature of streams in developed catchments is their highly modified shape and hydraulic efficiency. In order to minimise flood risks, streams are often realigned, and instream roughness elements that reduce the hydraulic efficiency are often removed. Additionally, increased impervious material in catchments results in higher runoff during rainfall events, leading to short-lived but high flows. These high flows commonly scour banks, which are then often reinforced to minimise erosion. The increased drainage efficiency in these channelised streams, coupled with the high runoff from impervious areas can result in a gradual lowering of the water table in urban areas, leading to a reduction in a stream's base flow.

Such changes to a stream's flow regime can affect instream communities both directly and indirectly. Direct effects include physical scouring of biota from the stream during periods of high flow. This is especially pertinent in channelled streams with smooth sides and banks, and where animals can not seek shelter from high flows. Indirect effects often arise from the increased low flows of channelled streams, and include dewatering, an increase in water temperature to possibly lethal values for many invertebrates, a reduction in dissolved oxygen levels, and accumulations of filamentous algae that can smother instream habitats.

3.4 Contaminated stormwater

A universal problem with urban development is that contaminated stormwater is discharged into streams from the impervious surfaces. Stormwater typically contains four types of pollutants: suspended solids, nutrients, toxicants and general rubbish. Many of these often exceed recommended toxicity levels for aquatic invertebrates, and consequently cause significant impacts to stream communities. Guidelines for recommended water column concentrations of these materials exist (e.g., US EPA, ANZAAC guidelines). However, *water quality* per se may not be as important as *sediment contamination,* as most of the biota dwell in or on the sediments. Another confounding factor is that total sediment contaminant concentrations may not be a good indicator of toxicity to invertebrates because many contaminants (e.g., heavy metals) can be bound up with organic matter (i.e. chelated), increasing their overall molecular size and reducing their biological effects.

The complexity of stormwater issues has lead to pragmatic options aimed at minimizing inputs. Treatment of contaminated stormwater is often attempted by using detention ponds and constructed wetlands. These assist in the removal of suspended solids and other pollutants through physical and biological processes. Although they are commonly used to treat stormwater, they are not always highly efficient at mitigating the adverse impacts of urbanization on biological communities. Maxted and Shaver (1996) found that invertebrates such as mayflies, caddisflies and stoneflies were absent from streams below detention ponds in Delaware, U.S.A., and that the ponds did not appear to attenuate the impacts of urbanisation on invertebrate communities once the watershed was covered by more than 20% impervious material. In a New Zealand study, Hickey (1999) studied the efficiency of two ponds that were built on streams draining urban and industrial catchments in Auckland. The industrial stormwater was more toxic and contained higher levels of contaminants that the urban stormwater, but the industrial pond achieved a high efficiency of reducing contaminant loads (79% and 95% from baseflow and stormflows, respectively). In contrast, the pond that drained the urban catchment was only about 55% efficient at removing heavy metals from the water column during both baseflows and stormflows. Despite the high efficiency of heavy metal removal at the industrial site, the outflow water here still exceeded US EPA guidelines for acute and chronic exposure for invertebrates.

There is community interest in the ecological health of the Brooklands Lagoon, and whether the marine life is safe to eat (WSU 1999). Assessing the lagoon's ecological health would help address community concerns, especially given the increasing importance of the lower river, and its ecological links with the sea. Public health issues are beyond the scope of this report, but probably timely. The lower river is of specific interest to the local rununga for mahinga kai, and it has been estimated that 57% of fish species caught in the Waimakariri estuary were potentially used directly by people, highlighting its 'food basket' potential (Eldon and Kelly 1985).

Sediment and fish samples from the lagoon and other lower-river sources could provide good baseline data on existing contaminant levels, if they are evaluated prior to further major subdivision construction. Contaminants would include heavy metals (copper, zinc, cadmium, mercury, lead), aromatic hydrocarbons and ketones (from road runoff), and possibly DDT levels given the horticultural history of the catchment. Core samples would provide a historical profile of contaminants, and therefore a pre-impact 'baseline' to work with. The assays will also provide a way of monitoring the combined effect of contaminants from large sub-division developments in the whole catchment. While planned retention basins, buffer strips and swales may assist in converting heavy metals to there less toxic (chelated) forms, it is conceivable that each of the respective subdivision contaminant discharge levels could be below set environmental guidelines, but the **cumulative** effect in the sediments could be damaging to the environment, and possibly human health, as many of the listed contaminants accumulate up through food chains into the larger longer-lived predators which often hide in the sediment (e.g. eels).

3.5 Habitat quality

As mentioned, previous landuse changes in the Styx catchment has resulted in significant changes to the waterways draining this catchment. Habitat value in the modified streams is likely to be low, reflecting factors such as channelisation, loss of riparian vegetation, increased siltation, presence of excessive macrophyte growths etc. All these factors generally result in a reduction of instream "health", as expressed in the invertebrate and fish communities that can tolerate such conditions. Habitat quality is known to have a demonstrable impact on invertebrate communities (Suren et al 1998), and variables such as riparian vegetation, bank stability and modifications, substrate packing and composition, and organic material within the stream play apparently key roles. These variables are relatively easily manipulated by managers, and are targeted by the CCC in many of their current restoration activities.

Suren et al (1998) developed the USHA system to assess the habitat quality of urban streams, and to help managers identify habitat variables that were possibly limiting instream biological health. NIWA has also recently developed the SHMAK (Stream Health Monitoring and Assessment kit) kit, in collaboration with Federated Farmers. This kit was designed for non-specialists to obtain a scientifically rigorous assessment of stream health by assessing influential and discernible environmental factors in streams. Both these assessment methods may be useful in providing relatively easy and robust assessments on instream habitat quality in selected streams, and to help monitor the effectiveness of any habitat improvements that may be undertaken.

There is considerable scope in improving sea-going native fish habitat in the catchment's lower reaches. This is particularly important for providing rearing grounds for inanga, common bullies and shortfin eels. Currently, the many small waterways, wetlands, and channelised drains (e.g., the mainstem feeders piped under Lower Styx Road, a portion of the Marshlands drain network within the Styx catchment (Walters Road, Marshlands Road), and the Bottle Lake Wetland) are unsuitable for trout, and are close to the sea. Such conditions make them ideal locations to enhance native fish populations, if permanent water can be retained. An example of how habitat restoration can enhance the fish communities has been shown by work on a small tributary running through Janet Stewart Reserve, where fish diversity increased following habitat enhancement (NIWA correspondence to CCC).

3.6 **Fish** passage

Eight of the nine native freshwater fish species in the Styx River require sea access to complete their lifecycles. Most native fish fry migrate upstream from the sea, and culverts or weirs with a free-fall and/or fast laminar water flow can deny or inhibit fish access to all upstream habitats (McDowall 1990). The ecological damage wrought by instream obstructions depends on the location of the weir, the fish fauna below the structure, and the amount of fish habitat potential upstream. Fish access was not reported on in the focus group discussions (WSU 1999), probably because most non-specialists are not aware of the high sea-dependence of the fauna. However, with the Styx River having such a high proportion of diadromous (sea-migrating) fish, and a naturally low-lying and (pre-European) accessible catchment, fish passage is an important issue. One small weir in the Styx catchment has been shown to severely restrict the upstream penetration of two native fish species (Sykes et al., 1998), substantially reducing fish diversity in Council-restored reaches a short distance upstream. From a discussion with the 'Guardians of the Styx', we understand that this structure has now been removed. We recommend that instream structures in the catchment need to be assessed for their capacity to restrict fish passage, and where necessary recommend ways in which there obstructive nature on fish passage can be ameliorated. The longitudinal distribution of species could also be evaluated by 'spot-fishing' at the same time as evaluating instream obstructions. This would fill in the 'gaps' in our knowledge of their distribution conducted in 1990.

ECOLOGICAL GOALS FOR THE STYX RIVER

This discussion reflects on ecological aspirations for the river based on the Focus Group Discussions run by the CCC (WSU 1999), but tempered by management issues that we have highlighted above. Measurable and realistic goals need to be developed for establishing a strategic management plan, and evaluating ecological progress during its implementation.

4.1 Maintain and protect diversity of the indigenous biota (flora and fauna).

Biotic diversity is measurable as species richness, and high species richness implies the existence and utilisation of a diverse range of habitats. Species richness is controlled by a combination of instream habitat and water quality variables, and by **a** rivers hydrological regime. Given that the waterways within the Styx catchment flow from spring sources over a fairly uniform gradient, the range of habitats encountered are expected to be relatively limited. Despite this, there are good data on the macrophyte, invertebrate and fish communities, and the catchment has been shown to support a more diverse invertebrate community than found in the Avon and Heathcote Rivers. This high diversity probably reflects the lack of urbanisation in the Styx catchment, and the consequent better water and habitat quality in some, but not all of the river's sources.

An overarching goal of any management plan would be to maintain, or improve the species richness of the waterways of the Styx River. Because instream obstructions have been demonstrated to reduce fish biodiversity within the Styx River catchment, the necessity of all instream obstructions should be carefully considered in light of their potentially damaging effect on the fish fauna.

4.1.1 Maintenance of macrophyte diversity

The native aquatic plants *Myriophyllum propinquum,* and *Potamogeton cheesemanii* in the lower river have been replaced by aggressive exotic adventives like P. *crispus.* However, *P. cheesemanii* is increasing its distribution in the upper reaches and this should be encouraged. A suitable management goal would thus be to increase the distribution of *P. cheesemanni* in the main river, and keep the distribution of *P. crispus* under control.

4.1.2 Minimise the input of silt and ameliorate the effects of siltation

As discussed, siltation has broad implications for stream ecology, and while some siltation is unavoidable, excessive siltation is clearly detrimental to ecological values. Siltation, both suspended and settled, is quantifiable and could be monitored using the SHMAK kit and direct measurement. In particular, it is important that trout redds have low suspended and substrate sediment levels. A suitable management goal would be to have a decrease in suspended and interstitial silt levels throughout the catchment, especially between the confluence of Smacks Creek and the Main North Road to a level comparable to trout spawning areas in the Avon River.

4.1.3 Buffer strips

Overhanging riparian vegetation can moderate stream temperatures, provide terrestrial food (insects) for fish, stabilise banks, and control soil runoff. At present, stock have unrestricted access to the channel in some waterways, and this activity causes considerable ecological damage by destabilising the banks and substrate. This can lead to increased siltation, and organic enrichment of streams from the direct entry of droppings. Appropriate management goals would be to extend buffer strips along water courses wherever possible, and to fence all stock from stream access throughout the catchment, regardless of water channel size.

4.1.4 Enhance instream habitat conditions

A suitable management strategy for the Styx River may be to manage the middle reaches as brown trout spawning areas, as manage other small streams as habitats for native fish. Habitat objectives would need to focus on providing clean gravels, and substrates large enough to allow small fish and invertebrates to evade predation. Overhanging vegetation would also provide important habitat cover for fish and invertebrates. Managing excessive macrophyte production in areas would minimise the channel from becoming chocked by these plants, and increase the habitat complexity by providing a mosaic of vegetated and unvegetated areas.

4.1.5 Improve native fish habitat in the lower river tributaries and waterways

There is significant potential to increase the area of native fish habitat in lower tributaries and drains of the Styx River. This is especially pertinent as these small, coastal waterways are generally unsuitable for trout. Enhancement of such streams would in part offset possible displacement of native fish by trout in the mainstem.

KNOWLEDGE GAPS

The following knowledge gaps constrains our understanding on the management issues

1 What is the optimal macrophyte harvesting regime for maximising both biotic

values, yet minimising sedimentation in the lower river ?

While results from this experiment would be river-specific, it would assist in maximising competing objectives in the lower river. This task would require input from a range of specialists for a relatively short period of time.

Where are the current principle sources of sediment in the catchment ?

This knowledge will allow us to quickly troubleshoot the major sources of sediment input into the waterways, initiate mitigation, and consequently reduce the overall sediment input into the river as soon as possible. These data could be obtained by non-specialists undertaking standardised water clarity tests at confluences throughout the catchment during storm events.

What are the long-term changes in stream health in the middle and upper reaches associated with catchment development?

Consideration should be given to some form of follow up invertebrate survey similar to the early CDB surveys, although not to the same extent. However, as with any biological monitoring, there should be clearly defined goals and objectives in place, and some of the original CDB sample sites should be resurveyed if indications of long-term temporal trends in stream health are required. The USHA protocol may also be of considerable use in some of the streams in the Styx catchment. An additional consideration is the use of tools such as SHMAK, which can be undertaken using non-specialists. For this, community participation is essential to have year-to-year consistency in *sampling and effort, as well as a high degree of motivation and observation skills by participants. The lower reaches are not negotiable by foot, and unsuitable for the SHMAK protocol. Monitoring of the lower reaches may require specialist input.*

How effective are stormwater treatment devices that may be put in place to minimise any adverse impacts of catchment urbanisation ?

This knowledge complements that gathered from monitoring temporal changes in biological health throughout the catchment. Assessments of stream health, water quality, and sediment contaminant levels above and below stormwater discharges could be made to assess the impacts of these on receiving waters. Such work could be done using a combination of specialist and non-specialists.

What is the extent and quality of trout spawning habitat?

This knowledge will allow us to determine if the lack of suitable spawning areas are contributing to the apparent decline in the trout fishery. This survey would require a high degree of specialist knowledge regarding trout spawning preferences, and will involve the use of specialised equipment.. This work would be unsuitable for non-specialists.

Where are the locations of instream obstructions, do they restrict fish passage, and to what extent are they restricting fish distribution?

Investigation of this issue would require an appreciation of the swimming limitations of the resident fish fauna, fish habitat preferences, and electric-fishing expertise. This work would be unsuitable for non-specialists.

How can the lower Styx catchment drains be improved for native fish habitation and biodiversity, and yet remain relatively unattractive for trout ?

Currently these habitats have not been evaluated for fish values, or native fish habitat restoration potential. Ecological knowledge of this area will allow recommendations to be made on which waterways are best suited for restoration, and how the restoration can be implemented to maximise native fish values.

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