THE NATURE OF AUCKLAND LOWLAND STREAM INVERTEBRATES, AND ASSESSING THE EFFECTS OF URBAN DEVELOPMENT.

Stephen Moore, Landcare Research, Mt Albert Research Centre, Auckland

ABSTRACT

Biological monitoring has been used to assess the state of urban stream health for many years in New Zealand. However, the ability to assess the effects of urban development and stormwater discharges on stream communities may be limited by natural background habitat factors that limit the life-supporting capacity of a stream.

Auckland lowland stream macroinvertebrate (and fish) communities are dominated by species suited to slow-flowing waters, non-stony substrata, relatively warm water temperatures and, sometimes, low dissolved oxygen levels. The natural scarcity of "sensitive" macroinvertebrate taxa in many lowland streams significantly affects the results of indices such as the MCI and EPT (and their derivatives).

This places greater importance on the limited numbers of "sensitive" taxa that do occur at the higher quality Auckland lowland sites. This paper identifies these Auckland indicator species, and discusses differences between two large biological datasets, an urban stream dataset (courtesy of the Auckland Regional Council), and a rural stream dataset (assessment of environmental effects surveys completed by Harrison Grierson Consultants and Landcare Research).

KEYWORDS
Auckland lowland streams, biological monitoring, macroinvertebrates.

1. INTRODUCTION

Macroinvertebrates have been used as indicators of urban stream health for many years in Auckland. Surveys of aquatic biota have been undertaken for several purposes, including:

- assessments of environmental effects (AEEs) of urban development
- discharge consent compliance monitoring
- state of environment monitoring
- community monitoring programmes
- environmental education projects.

It is frequently difficult to compare results between these biological surveys because they are often undertaken independently, using different sampling methods, and involving issues of client confidentiality. This is unfortunate because analysis of the combined datasets from these many surveys would reveal much about the nature of Auckland's aquatic resources. This paper compares results from two major datasets, one featuring 76 sampling sites in mostly rural streams (18 different surveys), and the other featuring 64 urban sampling sites (one large urban stream survey). The data from these 140 sites are used to describe the nature of Auckland lowland stream communities, and identify which components of these communities show most potential as indicators of the effects of urban development.

The ability to assess the effects of urban development and stormwater discharges on stream communities can be limited where background habitat factors reduce the life-supporting capacity of a stream. Knowledge of the frequency of occurrence of different macroinvertebrate groups within this large Auckland dataset will help place new survey results in perspective. Researchers would find it useful to refer to such a dataset when they:

- find unusual taxa – have these taxa been recorded in the area before?
- look for indicator taxa – which "sensitive" taxa can reasonably be expected to occur in Auckland streams?
- wish to compare their numbers of taxa (taxonomic richness) with data from similar sites
- wish to compare biological index values (EPT, MCI, SQMCI, etc.) with data from similar sites.

2. METHODS

2.1 RURAL STREAM ASSESSMENTS OF ENVIRONMENTAL EFFECTS (AEEs)

The AEE surveys involved assessments of 76 rural sites and were carried out by Landcare Research and by Harrison Grierson Consultants Limited (HGCL). These assessments focused on macroinvertebrate and fish communities as indicators of ecosystem "health". While fish are of greater public interest, macroinvertebrates are particularly useful as indicators not only because they are usually abundant, easy to sample, and important in aquatic food chains, but also because there is an increasing amount of knowledge of their water quality and physical habitat requirements.

Sampling sites were chosen in:

- stream reaches that may be affected by proposed or current urban development activity;
- the predominant habitat types of that reach; and
- micro-habitats considered likely to support the greatest fish and macroinvertebrate species richness.

Macroinvertebrates were collected using "kick nets" with 0.5-mm mesh. Macroinvertebrate samples were analysed in accordance with the protocols developed for the application of the Semi Quantitative Macroinvertebrate Community Index (SQMCI) as described in Stark (1998).

Most of the 18 AEEs were designed to investigate the potential effects of proposed urban development in Auckland's urban fringe, including sites in Rodney District, North Shore City, Waitakere City, Manukau City and Papakura City.

2.2 URBAN STREAM SURVEY

Also discussed in this paper are data collected by the National Institute of Water and Atmospheric Research (NIWA) as part of an urban stream classification project for the Auckland Regional Council (ARC). The NIWA/ARC macroinvertebrate sampling methodologies were similar to those of the Landcare Research/HGCL AEEs, using the kick net sampling technique with 0.5-mm mesh nets (Allibone et al., 2001). Laboratory methods differed, however:

- NIWA/ARC counted fixed numbers (300 or 100 individuals), while Landcare Research/HGCL used the full-sample semi-quantitative approach.
- NIWA/ARC preserved samples with alcohol, while Landcare Research/HGCL used formaldehyde.

3. RESULTS AND DISCUSSION

3.1 THE NATURE OF AUCKLAND LOWLAND STREAMS

Stream macroinvertebrate communities are always affected by physical habitat conditions relating to topography, flow regime and catchment position. The effects of physical habitat conditions (including natural or man-made channel disturbances) may mask the effects of water quality conditions on the stream biota. Many of the species considered to be indicators of "good" water quality are usually associated with fast-flowing, stony-bedded streams, and may not be present in slow-flowing, muddy/weedy Auckland streams, regardless of water quality.

The mostly rural sites sampled by Landcare Research/HGCL around the fringes of the Auckland urban area reflect the lowland, low gradient landscape. These streams were generally small and slow flowing, and habitats were pool-like, with muddy beds and weedy or grassy margins. Pasture grasses and invasive introduced plant species such as willow weed, wandering Jew, blackberry and gorse typically dominated the riparian vegetation. Such vegetation often provided little shade over the stream channel, and therefore the stream water was prone to significant heating during sunny summer days. Relatively few streams were bush-covered, fast-flowing or with rocky beds (riffle-like habitats).

Physical disturbances of stream channels were frequently encountered in these rural streams. Stock damage of stream banks, poorly installed farm track or road culverts, and sediment-laden runoff from disturbed soil were commonly observed at these sites.

Descriptions of the NIWA/ARC urban stream sites, and of the few Landcare Research/HGCL semi-urban stream sites, showed a wide range of physical habitat types. These habitats reflected stream gradient, bed composition and the degree of urban influence. Urban streams tend to have more evidence of modification such as past channel straightening, and reinforcement with concrete, gabion baskets and various bed matting products. Channel reinforcement is often required in urban streams to counter the increased erosion risks associated with large impervious surfaces and urban stormwater systems that are designed for rapid drainage. High flows during rainstorms, and low flows during dry spells tend to be more severe in urban streams, and the effects on the stream biota are particularly harsh in drain-like stream channels where most instream cover has been removed. The urban streams were sampled during periods of low flow however, and therefore many were shallow, slow flowing and muddy bedded.

Rural streams tend to have more meandering channels, and these channels often include frequent wetland-like habitats, and ponds (many of which were formed by small man-made farm dams). While there is little shade from woody riparian vegetation over most of these small rural streams, there is often abundant shade

produced by low-lying bank-side and emergent grasses, watercress, willow weed and other introduced water-margin plants.

3.2 THE NATURE OF MACROINVERTEBRATE COMMUNITIES IN AUCKLAND LOWLAND STREAMS

Low gradient, slow flowing, muddy/weedy, and poorly shaded streams tend to support relatively low numbers of macroinvertebrate taxa. Most taxa associated with high quality, "clean water" streams, such as the mayflies and stoneflies, require moderate to fast current speed to aid respiration or feeding. Many of these taxa are intolerant of water temperatures above 20°C and such temperatures are common in unshaded Auckland slow-flowing streams. Mayflies and stoneflies are not among the 20 most frequently recorded taxa in the 76 Landcare Research/HGCL (mostly rural) samples. The macroinvertebrates found most frequently in the rural sites and/or the NIWA/ARC urban sites (Table 1) are all known to be tolerant of warm, slow-flowing, muddy/weedy streams.

The NIWA/ARC urban stream dataset showed numerous similarities to the Landcare Research/HGCL rural stream dataset. However, an important difference between the datasets is the absence of the generally tolerant flatworms and mites from the NIWA/ARC data. Both of these groups were commonly recorded at the rural sites. The absence of these two groups in the NIWA/ARC data may relate to sampling or analysis methodologies, because both groups are found in a wide range of habitats, and have been frequently observed by the Author in urban streams. Landcare Research and others have found ethanol to be a poor preservative of soft-bodied taxa such as flatworms, oligochaete worms and proboscis worms, and ethanol preservative was used by NIWA/ARC in their urban stream samples. The absence of mites is more difficult to explain because they are adequately preserved in ethanol. Two other groups of small invertebrates, the ostracod and copepod crustacea, were also commonly recorded in the rural dataset but not in the urban dataset.

Table 1: Frequency of occurrence of the most common macroinvertebrate taxa found in the Landcare Research/HGCL (rural) samples, compared with the NIWA/ARC (urban) samples

	Frequency of occurrence	
Taxa	**Landcare Research/HGCL rural samples**	**NIWA/ARC urban samples**
Oligochaete worms	97%	75%
Potamopyrgus snails	78%	77%
Cura flatworms	77%	0%
Mites	73%	0%
Orthoclad midges	60%	58%
Ostracod crustaceans	55%	14%
Amphipods	53%	38%
Xanthocnemis damselflies	52%	63%
Physa snails	48%	53%
Chironomus midges	38%	53%

Table 1 shows that three particularly tolerant taxa, *Xanthocnemis* damselflies, *Physa* snails, and *Chironomus* midges, occurred more frequently in the NIWA/ARC urban stream dataset, than in the Landcare Research/HGCL rural dataset. Images of these most common taxa are shown in Appendix A.

Some differences between the rural and urban datasets are likely to relate to physical habitat types. Most of the swimming or water surface taxa found in open water habitats, including ostracods, copepods,

amphipods, *Microvelia* bugs, and dytiscid beetles were noticeably more common in the rural dataset than in the urban dataset (Table 2), the exception being *Sigara* waterboatmen (more common in the urban dataset). Stable pond and wetland habitats are generally uncommon in urban areas because of the history of drainage works designed to remove water quickly. Ponds in urban areas tend to be man-made and subjected to more rapid pulses of inflows during rainstorms.

Table 2: Swimming and water-surface macroinvertebrate taxa occurrence in the Landcare Research/HGCL (rural) samples and in the NIWA/ARC (urban) samples

	Frequency of occurrence	
Pond-dwelling taxa:	**Landcare Research/HGCL rural samples**	**NIWA/ARC urban samples**
Ostracod crustaceans	55%	14%
Amphipods	53%	38%
Microvelia bugs	42%	0%
Copepod crustacea	20%	0%
Dytiscid beetles	18%	2%
Culex mosquitoes	16%	9%
Sigara waterboatmen	10%	22%

The macroinvertebrate taxa generally considered indicative of "good" water quality conditions, and commonly found in Auckland lowland streams, were found more frequently in the Landcare Research/HGCL rural dataset than in the NIWA/ARC urban dataset (Table 3). Images of these taxa are shown in Appendix B. These taxa include the mayflies, stoneflies, caddisflies (ephemeroptera, plecoptera and trichoptera, or EPTs) and beetles that are considered to be intolerant of high levels of nutrient enrichment. These "sensitive" groups are also intolerant of high water temperatures (likely to occur in unshaded urban streams) and low dissolved oxygen (also associated with warm temperatures and slow base flow current speed).

Table 3: Taxa generally considered indicative of "good" water quality conditions – occurrence in the Landcare Research/HGCL (rural) samples and in the NIWA/ARC (urban) samples

	Frequency of occurrence	
Indicators of "good" water quality	**Landcare Research/HGCL rural samples**	**NIWA/ARC urban samples**
Paralimnophila craneflies	42%	13%
Polyplectropus caddisflies	32%	8%
Acroperla stoneflies	29%	2%
Hydrophilid beetles	23%	3%
Zephlebia mayflies	22%	16%
Paranephrops crayfish	19%	3%
Psilochorema caddisflies	15%	3%
Neozephlebia mayflies	11%	0%
Ptilodactylid beetles	11%	6%

There are some notable groups missing from the list of frequently occurring "sensitive" taxa in Table 3. Slow-flowing runs and pools, rather than riffles generally dominate the Auckland lowland streams sampled by Landcare Research/HGCL and by NIWA/ARC. These Auckland datasets therefore show few records of

some of the common riffle-dwelling taxa that dominate faster-flowing streams in other regions. These taxa include:

- *Deleatidium* mayflies (associated with stony riffles)
- *Coloburiscus* mayflies (associated with "clean" gravelly streams)
- *Austroclima* mayflies (associated with "clean" gravelly streams)
- *Pycnocentria* caddisflies (associated with gravelly riffles/runs)
- *Pycnocentrodes* caddisflies (associated with gravelly riffles/runs)
- *Olinga* caddisflies (associated with gravelly riffles/runs)
- *Hudsonema* caddisflies (associated with gravelly riffles/runs)
- *Helicopsyche* caddisflies (associated with "clean" gravelly streams)
- Elmid beetles (associated with gravelly riffles/runs)
- *Archichauliodes* dobsonflies (associated with stony streams).

"Sensitivity scores" have been assigned to 140 New Zealand invertebrate taxa for the calculation of Macroinvertebrate Community Index (MCI) values (Stark, 1998; Winterbourn et al., 2000), but only 40 of these taxa occurred in more than 10% of the lowland Auckland samples collected by Landcare Research/HGCL. Fifty of the 140 taxa have not yet featured in any of these samples. Clearly the list of potential indicator groups, particularly among the "sensitive" species, is limited in these lowland habitats.

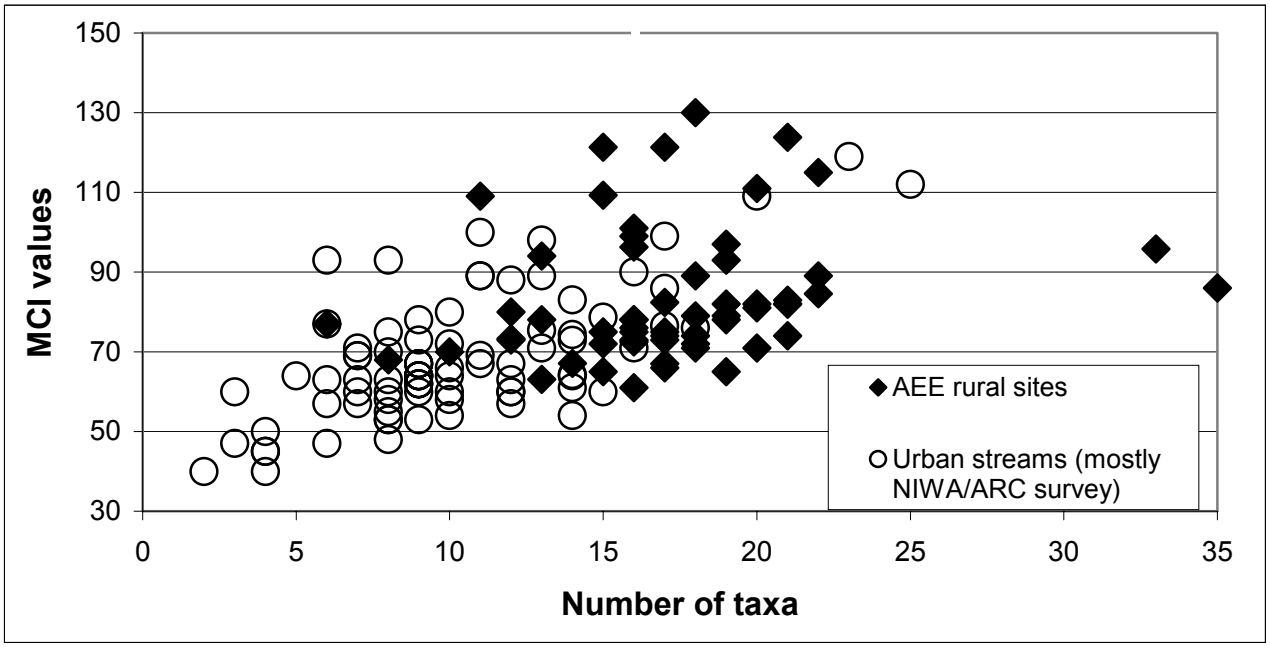


Figure 1: Macroinvertebrate Community Index (MCI) values and number of macroinvertebrate taxa, comparing Auckland rural (Landcare Research/HGCL) and Auckland urban (NIWA/ARC) datasets.

The data in Tables 1 to 3 show the Landcare Research/HGCL rural dataset is characterised by generally higher numbers of macroinvertebrate taxa (higher taxonomic richness), higher numbers of EPT taxa and higher MCI values than the NIWA/ARC urban stream dataset (Fig.1). Essentially these results indicate that the condition of aquatic communities in the Auckland rural stream sites sampled by Landcare

Research/HGCL is generally superior to the condition of aquatic communities at the Auckland urban sites sampled by NIWA/ARC.

Figure 1 shows that several of the urban sites produced MCI values over 90 (some over 100), and experience has shown that such values are quite high (indicating "good" habitat conditions) for lowland streams. These were sites in which a number of the "sensitive" taxa listed in Table 3 occurred. In high quality habitats some of these sensitive taxa also tend to be common (not just represented by occasional individuals). The Author has observed that in high-quality rural and urban sites, two or more of these sensitive taxa tend to be common or abundant. This is a simplistic but potentially useful rapid indicator that could be used in field assessments of the state of urban streams.

As urban stream databases continue to grow, water managers should be able to understand better the relationships between land use, water/habitat quality and aquatic ecosystems. If the public or local authorities wish to enhance stream biodiversity or community "health", they need to know whether changes are needed to improve urban stream physical habitat, water quality, or both. Methods of making such improvements are being developed, with on-going research into low-impact urban designs and more effective methods of reducing stormwater contaminant levels including land-based stormwater treatment systems such as treatment walls.

4. CONCLUSIONS

Auckland lowland stream invertebrate communities are generally dominated by "tolerant" species. Weed-associated groups are often most common, particularly snails, oligochaete worms, damselflies, midges and amphipods. Auckland lowland stream invertebrate communities naturally tend to lack such common riffle-dwelling taxa as *Deleatidium* mayflies, *Olinga* caddisflies, elmid beetles, and *Archichauliodes* dobsonflies that are common in faster flowing streams in other regions. The ability to assess the effects of urban development and stormwater discharges on stream communities can be limited where background habitat factors are reducing the life-supporting capacity of a stream.

Urban stream macroinvertebrate communities tend to have lower taxonomic richness, lower numbers of EPT taxa and lower MCI values than rural streams. The "sensitive" (indicator) taxa most likely to occur in high quality Auckland lowland streams include *Polyplectropus* caddisflies, *Psilochorema* caddisflies, *Zephlebia* mayflies, *Neozephlebia* mayflies, *Acroperla* stoneflies, ptilodactylid beetles, hydrophilid beetles, and *Paranephrops* crayfish. Auckland lowland stream samples containing good numbers of two or more of these groups are likely to have come from sites characterised by good water quality.

ACKNOWLEDGEMENTS

The author is grateful to Allan Leahy, Harrison Grierson Consultants (HGCL) for permission to use HGCL data; John Maxted, Auckland Regional Council, for providing the NIWA/ARC data; NIWA/ARC for providing access to the National Freshwater Fish Database; and John Herald, Bob Lee and Anne Austin, Landcare Research, for reviewing the draft manuscript.

REFERENCES

Allibone, R.; Horrox, J; Parkyn, S. 2001: Stream classification and instream objectives for Auckland's urban streams. National Institute of Water and Atmospheric Research. Prepared for the Auckland Regional Council, Environmental Research, 21 Pitt Street, Auckland. 79 p.

Stark, J D, 1998: SQMCI: a biotic index for freshwater macroinvertebrate coded-abundance data. New Zealand Journal of Marine and Freshwater Research, Vol 32: 55-66.

Winterbourn, M J; Gregson, K L D; Dolphin, C H, 2000: Guide to the Aquatic Insects of New Zealand, 3rd Edition. Entomological Society of NZ.

Appendix A

Images of the most common Auckland lowland stream macroinvertebrates (in order of taxa listed in Table 1 in text). Images captured using the Landcare Research Automontage facility.

Oligochaete worms

***Potamopyrgus* snail**

***Cura* flatworm**

Mite

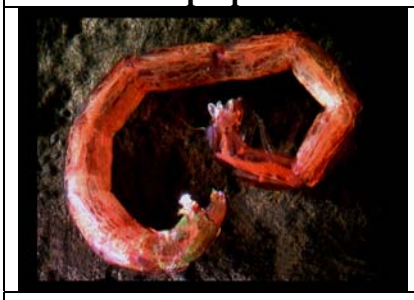
Orthoclad midge

Ostracod

***Paraleptamphopus* amphipod**

***Xanthocnemis* damselfly**

***Physa* snail**



***Chironomus* midge**

Appendix B

Images of "sensitive" (potential indicator) macroinvertebrate taxa found in Auckland lowland streams (in order of taxa listed in Table 3 in text). Images captured using the Landcare Research Automontage facility.

		
***Paralimnophila* cranefly**	***Polyplectropus* caddisfly**	***Acroperla* stonefly**
		
Hydrophilid beetle	***Zephlebia* mayfly**	***Paranephrops* crayfish**
		
Psilochorema caddisfly	**Neozephlebia mayfly**	**Ptilodactylid beetle**