Streams in the Lower North Island – regional patterns in benthic invertebrate communities and the influence of landuse.

A thesis presented in fulfilment of the requirements for the degree of Masters of Science in Ecology at Massey University, Palmerston North, New Zealand.

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ABSTRACT

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Ten streams from five different ecoregions (Mount Taranaki, Volcanic Plateau, Central Mountains, Eastern Lowlands and the Manawatu Plains) were sampled for benthic invertebrates in May 1995. Invertebrate communities were examined to determine if ecoregions or landuse were better indicators of community structure.
Six bimonthly samples were also taken between March 1995 and January 1996 from two sites on an urban stream (Mangaone stream) to examine the effects of urbanisation in comparison to streams in the Manawatu Plains. The impact of a nearby refuse facility on the Mangaone stream was also examined.

Streams invertebrate communities in the modified Eastern Lowlands and Manawatu Plains were composed of mainly Diptera and Molluscan species. They also showed significantly lower MCI, QMCI and EPT scores than the Central Mountains, Mount Taranaki and Volcanic Plateau streams. Ephemeroptera, Plecoptera and Trichoptera dominated invertebrate communities in the Central Mountain, Mount Taranaki and Volcanic Plateau. Within these two groupings of modified versus unmodified ecoregions individual ecoregions could not be clearly separated. Broad landuse categories were identified as the best discriminator of the benthic invertebrate communities rather than the 5 ecoregions. A greater range of environmental conditions in benthic invertebrate communities of the South Island could explain why ecoregions are more closely linked with lotic community structure in these systems.

Urbanisation of the Mangaone stream had significantly altered the stream invertebrate communities from those in the Manawatu Plains. Streams in the Manawatu Plains were dominated by *Potamopyrgus antipodarum* and *Oxyethira albiceps* in contrast to the Mangaone stream sites that were dominated by oligochaetes and chironomids.

Differences in invertebrate abundance between the two Mangaone stream sites were attributed to smaller and less stable substrate particles at the downstream site.

CHAPTER ONE

General Introduction

GENERAL INTRODUCTION

Aquatic invertebrates are commonly found in river systems and are recognised as indicators of water quality (Stark, 1993). Habitat also plays an important part in the structuring and functioning of aquatic invertebrate communities (Petersen, 1992). Research has shown that macroinvertebrate communities respond to a range of small, medium and large-scale environmental variables (Quinn & Hickey, 1990). Large-scale development of land for agriculture and horticulture has a significant effect on the assemblage of macroinvertebrates found in streams and rivers (Collier, 1995). Urbanisation also has a significant effect on the structure and functioning of aquatic communities (Klein, 1979; Lenat & Crawford, 1994). Catchment landuse therefore plays an important role in determining the potential macroinvertebrate communities (Harding & Winterbourn, 1995; Wang et. al.,1997).

The ability to measure impairment of a stream is important for protection of the aquatic resource. There is increasing demand on regulatory authorities to set measurable limits on water use and abstraction based on indicators such as stream invertebrates. 'Reference' or 'nonimpaired' condition needs to be defined for stream invertebrate communities so that the deviation from this condition can be measured. Stream classification has been used extensively in the States with the formation of ecoregions (Omernick, 1987), Britain with its use of a multivariate prediction tool ((River Invertebrate Prediction and Classification System) RIVPACS) (Wright, 1995), and more recently in Australia with AUSRIVAS (Australian River Assessment System)(Simpson et. al., 1996). Ecoregions have been constructed using large-scale influences on stream habitat such as geology and climate. Streams within these ecoregions are expected to have similar assemblages of macroinvertebrates. RIVPACS on the other hand predicts the assemblage of invertebrates at a site using a number of environmental features and classifies streams using multivariate analysis. Both of these techniques are used to identify reference condition and hence measure the level of impairment.

New Zealand in comparison to the States and Britain is a geographically diverse country and has a relatively short history of anthropogenic disturbance. The applicability of classification systems such as ecoregions in New Zealand are still being tested. Classification of New Zealand streams has been carried out in the past using stream invertebrates (Biggs et. al., 1990) and ecoregions (Harding, 1994). Harding (1994) showed a separation of South Island stream invertebrate communities into ecoregions. North Island streams however, were not examined in his study. Chapter 2 examines invertebrate communities in 5 North Island ecoregions proposed by Harding to investigate whether ecoregion or land use was the dominant factor for shaping stream invertebrate communities. Two pairs of ecoregions were chosen to have similar vegetation and land use, the remaining ecoregion represented a combination of the two vegetation types.

Urban streams have not been extensively studied in New Zealand, so, in Chapter 3 stream invertebrate communities in an urban stream were examined for differences in water quality and community structure to streams in the surrounding Manawatu Plains' pastoral ecoregion.

REFERENCES

Biggs, B. J. F., Duncan, M.J., Jowett, I.G., Quinn, J.M., Hickey, C.W., Davies-Colley, R.J., Close, M.E. 1990: Ecological characterisation, classification, and modelling of New Zealand rivers: an introduction and synthesis. *New Zealand Journal of Marine and Freshwater Research* **24**: 277-304.

Collier, K. J. 1995: Environmental factors affecting the taxonomic composition of aquatic macroinvertebrate communities in lowland waterways of Northland, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **29**: 453-465.

Harding, J. 1994: Lotic ecoregions of New Zealand. Unpublished PhD Thesis University of Canterbury, Christchurch.

Harding, J. S., Winterbourn, M.J. 1995: Effects of contrasting landuse on physico-chemical conditions and benthic assemblages of streams in a Canterbury (South Island, New Zealand) river system. *New Zealand Journal of Marine and Freshwater Research.* **29**: 479-492.

Klein, R.D. 1979. Urbanization and Stream Quality Impairment. *Water Resources Bulletin* **15**(4): 948-963.

Lenat, D.R., Crawford, J.K. 1994. Effects of land use on water quality and aquatic biota of three North Carolina Piedmont streams. *Hydrobiologia* **294**: 185-199.

Omernick, J. M. 1987: Ecoregions of the Conterminous United States. *Annals of the Association of American Geographers* **77**(1): 118-125.

Pedersen, R.C. 1992. The RCE: a Riparian, Channel, and Environmental Inventory for small streams in the agricultural landscape. *Freshwater Biology* **27**: 295-306.

Quinn, J. M., Hickey, C.W. 1990: Characterisation and Classification of Benthic Invertebrate communities in 88 New Zealand rivers in relation to environmental factors. *New Zealand Journal of Marine and Freshwater Research* **24**: 387-409.

Simpson, J., Norris, R., Barmuta, L., Blackman, P. 1996. AusRivAS – Australian National River Health Programme User Manual. CRC for Freshwater Ecology, University of Canberra, P.O. Box 1 Belconnen ACT 2616, University of Tasmania, GPO Box 252-05 Hobart 7001

Stark, J.D. 1993. Performance of the Macroinvertebrate Community Index: effects of sampling method, sample replication, water depth, current velocity, and substratum on index values. *New Zealand Journal of Marine and Freshwater Research* **27**: 463-478.

Wang, L., Lyons, J., Kanehl, P., Gatti, R. 1997. "Influences of Watershed Land use on Habitat Quality and Biotic Integrity in Wisconsin Streams." *Fisheries* **22**(6): 6-12.

Wright, J.F. 1995. Development and use of a system for predicting the macroinvertebrate fauna in flowing waters. *Australian Journal of Ecology* **20**: 181-197.

CHAPTER 2

Can ecoregions predict stream benthic invertebrate communities of the lower North Island?

ABSTRACT

Ten streams from each of the five ecoregions (Mount Taranaki, Volcanic Plateau, Central Mountains, Eastern Lowlands and the Manawatu Plains) were sampled for benthic invertebrates in May 1995. Benthic faunas were distinguished more clearly based on land use than ecoregions. Streams in the anthropogenically modified Eastern Lowland and Manawatu Plains ecoregions had benthic invertebrate communities composed of mainly Diptera and Molluscan species. They also had significantly lower MCI, QMCI and EPT water quality scores and higher conductivity and instability scores than the Central Mountain, Mount Taranaki and Volcanic Plateau sites. The Central Mountains, Mount Taranaki and Volcanic Plateau stream benthic invertebrate communities were dominated by Ephemeroptera, Plecoptera and Trichoptera. Within these two broad groupings the individual ecoregions could not be clearly separated. Thus broad landuse categories were the best discriminator of the benthic invertebrate communities rather than the geomorphologic and climatic factors of the 5 ecoregions. Wider variety of landuses and greater range of environmental conditions in benthic invertebrate communities of the South Island could explain why ecoregions are more closely linked with lotic community structure in these systems.

INTRODUCTION

The relationship between a river and its surrounding environment has been a strong theme of interest with aquatic biologists since it was highlighted by Hynes (1975) in the classic "A stream and its valley". Ecoregions are defined following Omernick (1987) as regions of relative homogeneity in ecological systems or in relationships between organisms and their environments. Ecoregions may thus provide regional trends in benthic assemblage structure and may allow "reference sites" to be selected for biomonitoring. Consequently, the classification of benthic invertebrate assemblages into ecoregions has become a topic of increasing interest in New Zealand (Biggs et. al., 1990; Harding, 1994) and elsewhere (Poff & Ward, 1989; Hughes & Larsen, 1988) because of the potential to predict what aquatic invertebrates should occur at a site if it were not impacted. Ecoregions have been used extensively in the United States (Plafkin et. al., 1989) for the monitoring and protection of freshwater resources.

There are several approaches that can be used in the construction of ecoregions. Biggs et al. (1990) and Franklyn (1997) sampled invertebrate and environmental data of a large number of streams throughout New Zealand and the Hawkes Bay, respectively. They analysed their data for discrete groupings, which they characterised as ecoregions. Alternatively ecoregions can be established *a priori* using classification of vegetative, geological and meteorological data and then examined for differences in macroinvertebrate community structure. Several classifications have been attempted in New Zealand along these lines (Toebes, 1969; Beables, 1982) although Harding (1994) was the first to address this for stream systems. He used vegetative cover, bedrock geology, soils, relief, rainfall normal and Meteorological Service Climatic regions to establish twenty-five ecoregions throughout New Zealand (13 in the North Island and 12 in the South Island). Examination of lotic invertebrate communities in ten of the ecoregions of the South Island were found to support his classification system (Harding, 1994). Although development of ecoregions includes vegetation and dominant land use some ecoregions, while being distinct, have similar vegetation and land use. In this thesis I investigate whether ecoregions or land use has a stronger effect on lotic invertebrate community structure. I investigate invertebrate communities in 5 (Mount Taranaki, Central Mountains, Volcanic Plateau, Eastern Lowlands and the Manawatu Plains) of the 13 ecoregions established for the North Island two pairs of which have similar vegetation.

STUDY SITES

Ten sites on first to third order streams were sampled from each of five ecoregions in the lower half of the North Island (Fig. 1)(Plate 1). To evaluate whether ecoregion or land use form was the dominant controlling factor of benthic community structure 2 pairs of ecoregions were chosen to have similar vegetation and land use. The Mount Taranaki (TK) and Central Mountains (CM) ecoregions are characterised by high elevation and steep topography and Podocarp-broadleaf-beech forest. The Manawatu Plains (MN) and the Eastern Lowlands (EL) ecoregions by rolling hills and high producing pasture. Finally the Volcanic Plateau (VP) represents a combination of the two with alpine scrub and tussock the dominant vegetation but with the southern and south western side of Mount Ruapehu covered in podocarp forest with pockets of pasture. Where possible, streams were sampled only from the characteristic vegetation type of each ecoregion.

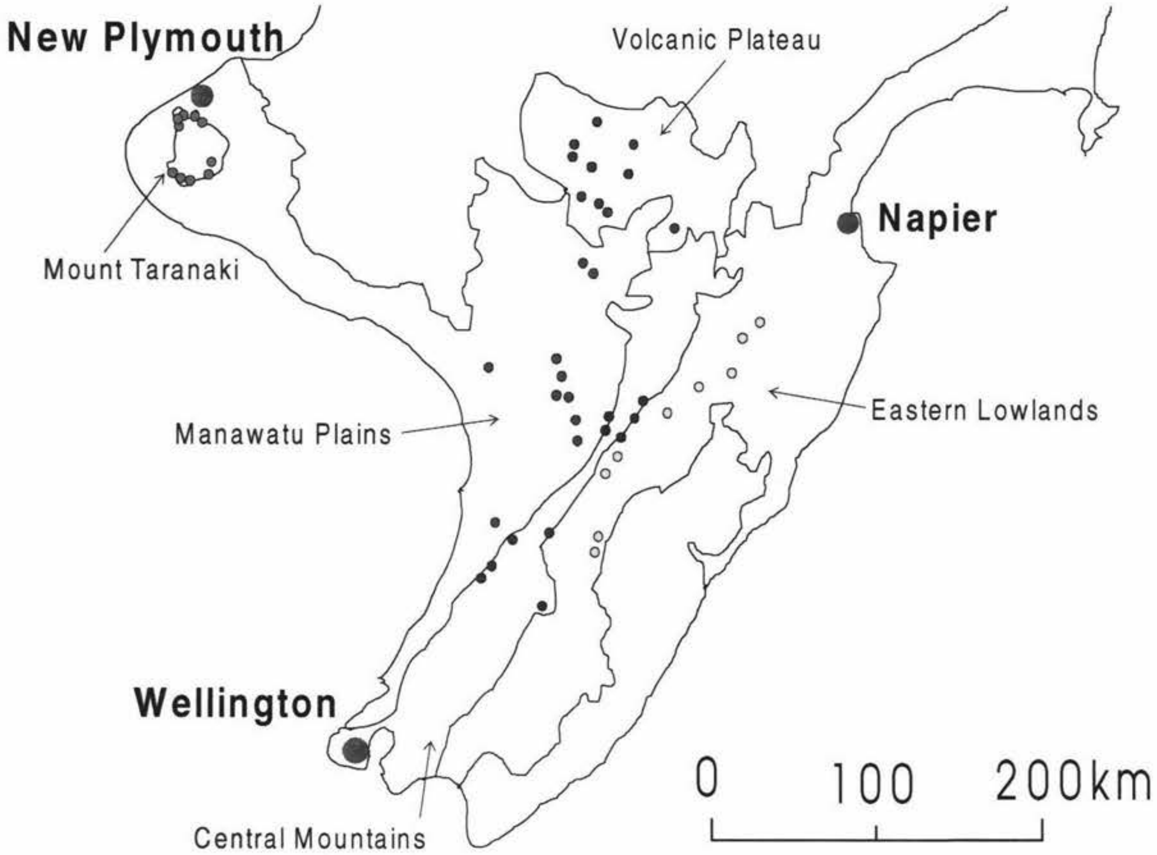


Figure 1 : Lower North Island stream sites surveyed within five ecoregions in May 1995.

(A)

(B)

Plate 1A – Central Mountains unmodified stream (Kiriwhakapapa stream) in native forest, B – Manawatu Plains modified pastoral stream (Travistock Road stream).

METHODS

Invertebrates were collected from riffles at each of the study sites (see Appendix 1) in May 1995. Invertebrates were collected in three replicate $0.1 m^2$, $250 \mu m$ mesh Surber samples. Samples were preserved in 70% alcohol in the field and sorted by eye in a white tray. Identification was conducted with a dissection microscope (40x) to species level (where possible) using McFarlane (1951), Winterbourn (1972) and Winterbourn and Gregson (1989), or to morphospecies when more accurate identification was not possible.

Environmental Measures

Concurrent with each invertebrate collection - depth, current velocity, width, conductivity (using an Orion 122 conductivity meter) and temperature were measured. Water samples (100 mL) were also collected and kept cool for later analysis of pH using a Solstat pH/MV meter. Riparian vegetation and streambed substrate composition were visually assessed and substrate percentages converted to a single substrate index following Jowett and Richardson (1990). Channel stability was assessed using the Pfankuch stability index (Pfankuch, 1975). This is determined by visually scoring the upper banks, lower banks and the streambed using a preweighted system (author's weighting) of 15 variables. These include slope, mass wasting, debris jam potential and vegetative bank protection in the upper banks. Channel capacity, bank rock content, sediment traps, cutting and deposition in the lower banks and rock angularity, brightness, substrate packing, percentage stable materials, scouring, deposition and clinging aquatic vegetation in the stream bed component. Scores for each category are then summed for an overall measure of stability between 52 and 152; with higher scores indicative of lower channel stability.

Four small stones (maximum diameter 50 mm) were collected at the same time as the invertebrate samples for the measurement of algal biomass. Periphyton pigments were extracted by immersing the collected stones in a measured volume of 90% acetone overnight at 5°C. Absorbencies were measured at 720, 665, 430 and 410 nm and converted to pigment concentration following Moss (1967a,b). Surface area of the stones was assessed with aluminium foil of known weight per unit area and used to standardise the pigment concentrations by area.

Organic matter collected in Surber samples was divided into 'Fine Particulate Organic Matter' (FPOM<1mm) and 'Coarse Particulate Organic Matter' (CPOM>1mm). Samples were dried for 7 days at 70°C to constant weight.

Statistical Analysis

To assess whether the ecoregions differed in the physicochemical and invertebrate data collected, a One Way Analysis of Variance (ANOVA) was performed using Data Desk (1992). Post hoc Scheffe tests were performed to determine where differences occurred when indicated by the ANOVA.

The Macroinvertebrate Community Index (MCI) (Stark, 1985) and its quantitative analogue were calculated by assigning predetermined sensitivity values to individual species between one and ten (ten = most sensitive taxa), and summed across all taxa at a site.

The MCI is given by:

$$\text{MCI} = \left(\sum(\text{MCI score})/\text{number of scoring taxa}\right)\times 20$$

And the quantitative MCI by:

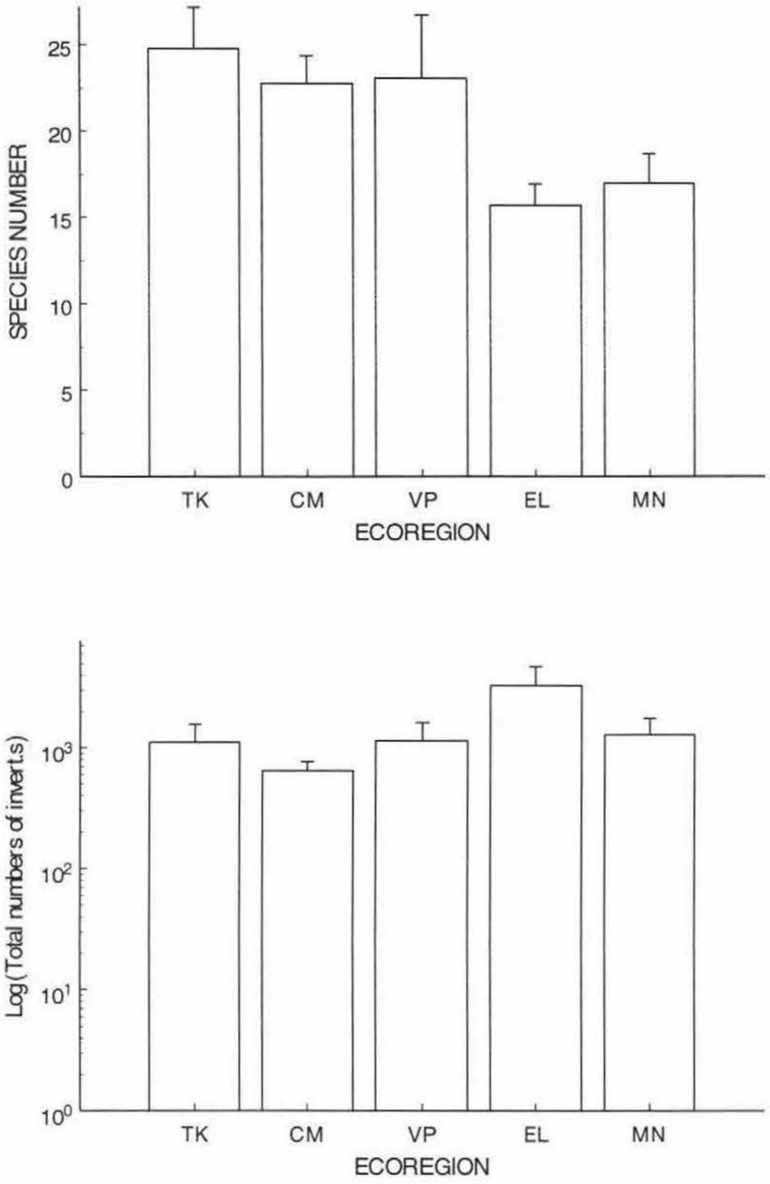
$$QMCI = (\sum(\text{species MCI score} \times \text{species abundance})/(\text{total invertebrates}))$$

Ordination of invertebrate abundance and presence/absence data was conducted using Detrended Correspondence Analysis (DECORANA (Hill, 1979a)). Environmental variables were correlated with the DECORANA axes from this analysis using Spearman Rank correlation with SAS (1995). Classification using Two Way Indicator Species Analysis (TWINSPAN (Hill, 1979b)) and CLUSTER analysis was also used to examine site groupings with both invertebrate abundance and presence/absence data. CLUSTER analysis was performed with the Sorenson distance measure and the group average clustering algorithm on invertebrate abundance, presence/absence and environmental data. All multivariate analysis was conducted using PC-ORD (McCune, 1991).

RESULTS

Invertebrate Composition

A total of 117 species were collected from streams in the five ecoregions (Appendix 1); most species were Trichoptera (35) followed by Diptera (24), Plecoptera (14) and Ephemeroptera (12). Species number (Fig. 2a) varied widely across the regions with a maximum of 36 (Auroa Stream) and a minimum of 4 (Desert Road Stream) per site. Central Mountain and Mount Taranaki sites had significantly higher species number than Eastern Lowland and Manawatu Plains' sites ($F_{4,45}$=3.12, P=0.02). Volcanic Plateau sites were highly variable in species number and were not statistically different from the other regions. No significant difference was found between the total number of individuals (Fig. 2b) in streams in the different ecoregions ($F_{4,45}$=1.51, P=0.22).



(a)

(b)

Figure 2a: Mean (± 1 S.E.) number of invertebrate species, b – total numbers of invertebrates collected in 3 replicate Surber samples from 10 streams in each of the 5 ecoregions in May 1995. TK=Mount Taranaki, VP=Volcanic Plateau, CM=Central Mountains, EL=Eastern Lowlands, MN=Manawatu Plains.

Physicochemical Measures

A summary of the measured variables from each ecoregion is presented in Table 1. Conductivity varied widely between regions from a minimum of 12μS/cm (Mangetepopo Stream) to a maximum of 298μS/cm (Manutahi Stream) however it was significantly higher in the pastoral ecoregions (EL, MN) than in the forested ecoregions (CM, TK, VP)($F_{4,45}$=23.24, P=<0.001).

Canopy cover was higher in the Volcanic Plateau than the Eastern Lowlands or the Manawatu Plains' sites ($F=_{4,45}6.51$, P<0.001) however, the Mount Taranaki sites were only higher than the Eastern Lowlands. Native forest and scrub dominated canopy cover in the forested ecoregions whereas exotic species such as willow dominated the canopy cover in the pastoral ecoregions. However several streams in the pastoral ecoregions, the Mangaonuku, Waituna West and Tutaenui Streams, all had unusually high canopy cover (≥50%) because of well established and protected (fencing from stock) riparian margins. Low canopy cover in some streams in the forested ecoregions was caused by landforms that did not allow riparian vegetation to become well established e.g. streams running through wide shingle channels devoid of vegetation such as the Coppermine Stream.

Streams in the Volcanic Plateau, Eastern Lowlands and Manawatu Plains were dominated by smaller particle sizes: small cobbles and gravel (averaged >20% and >30% respectively). Large cobbles and gravel (average ≥28%) dominated substrate composition in the Central Mountains, whereas large cobbles and small cobbles dominated (average ≥30%) the streams in the Mount Taranaki region. Bedrock and boulders were rarely encountered, averaging ≤20% of the available substrate for all regions surveyed. The Manawatu Plains and Eastern Lowlands had significantly lower substrate index scores and higher Pfankuch index scores compared to the Central Mountains and Mount Taranaki sites ($F_{4,45}$=8.08, P<0.001 and $F_{4,45}$=8.08, P<0.001).

Ecoregion	Pfankuch Stability	%Canopy Cover	Average Depth(m)	Width (m)	Velocity (m/sec)	Conductivity (µs/cm)	Substrate Index	Temperature (°C)
Central Mountains	53-113	0-100	0.06-0.28	1.1-4.5	0.4-0.88	59-162	4.4-5.95	8.9-12.9
Mount Taranaki	57-107	5-100	0.05-0.66	1.5-4.0	0.27-0.66	39-90	5.2-6.1	7.2-10.2
Volcanic Plateau	57-86	0-100	0.04-0.21	0.9-3.6	0.36-0.88	12-154	3.9-7.0	3.0-11.6
Eastern Lowlands	86-118	0-60	0.12-0.25	1.2-3.3	0.45-0.9	97-232	3.8-5.75	9.7-16.3
Manawatu Plains	82-124	0-80	0.06-0.28	1.0-3.5	1.3-0.66	118-298	3.7-5.4	10.0-14.6
F-values between regions	10.36	2.68	1.00	2.68	2.27	16.6	8.08	8.4

Table 1: Range and F-tests for physicochemical measures made at 10 streams in each of the 5 ecoregions in May 1995 (see Appendix 1).

Periphyton Biomass and Particulate Organics

Pigment concentrations (Fig. 3) were highest in the Eastern Lowlands' sites ($F_{4,45}$=18.16, P<0.001). Interestingly, periphyton differences could not be attributed to differences in riparian vegetation with both pastoral ecoregions significantly different from each other.

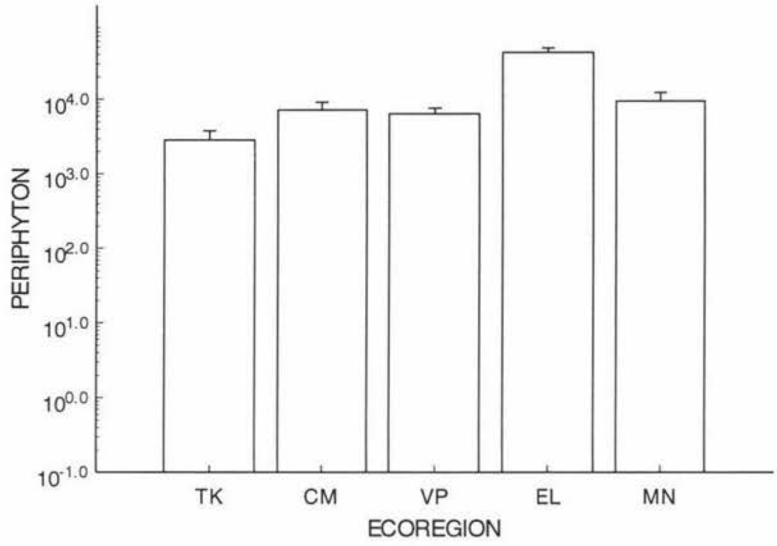


Figure 3: Total algal pigment concentrations ± 1 S.E. (phaeophyton and chlorophyll A) for five stones collected in ten streams in each of the five ecoregions in May 1995. TK=Mount Taranaki, VP=Volcanic Plateau, CM=Central Mountains, EL=Eastern Lowlands, MN=Manawatu Plains.

FPOM and CPOM (Fig. 4) biomass levels were significantly different between regions ($F_{4,145}$=7.43, P<0.001 and $F_{4,145}$=5.57, P<0.001, respectively). The Volcanic Plateau and Central Mountain sites had significantly higher FPOM than the Mount Taranaki and Manawatu Plains' sites. Mount Taranaki sites and Volcanic Plateau sites had higher

CPOM than the Eastern Lowland and Manawatu Plains' sites, Central Mountain sites had the lowest CPOM.

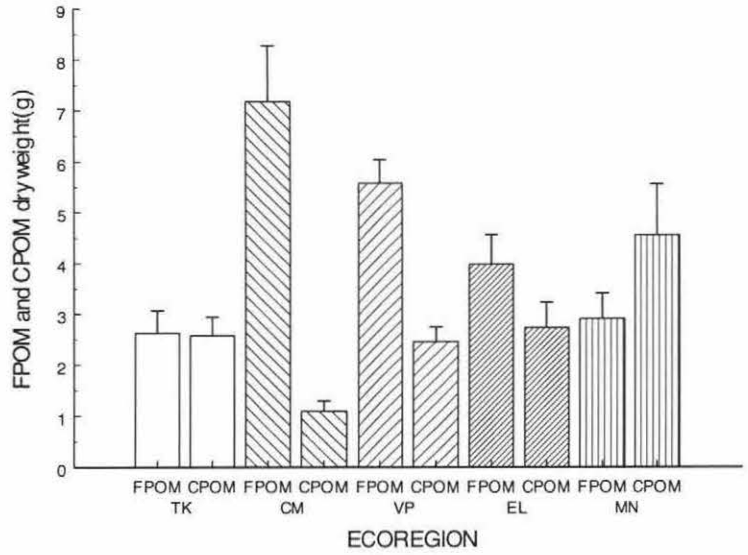


Figure 4: FPOM and CPOM ± 1 S.E. for ten streams in each of the five ecoregions collected in May 1995. TK=Mount Taranaki, VP=Volcanic Plateau, CM=Central Mountains, EL=Eastern Lowlands, MN=Manawatu Plains.

Multivariate Analysis

The CLUSTER analysis of the invertebrate data (Fig. 5) split the sites broadly into four main groups, two groups of sites from the forested ecoregions (CM, TK, VP) and the remaining two groups from the pastoral ecoregions (MN, EL). The 'Left of Ford' stream (VP9) was an exception to these groupings and was located in the pastoral group; this is a Volcanic Plateau stream running through predominantly pasture. The Mangaone, Bunny (MN7 + 8), Ruapehu, Desert Road (VP1 + 4) and Oanui (TK9), all of which had few species and total invertebrates compared to other sites were the sites found in the two outgroups. The cluster analysis of presence/absence and environmental data produced similar results (not shown).

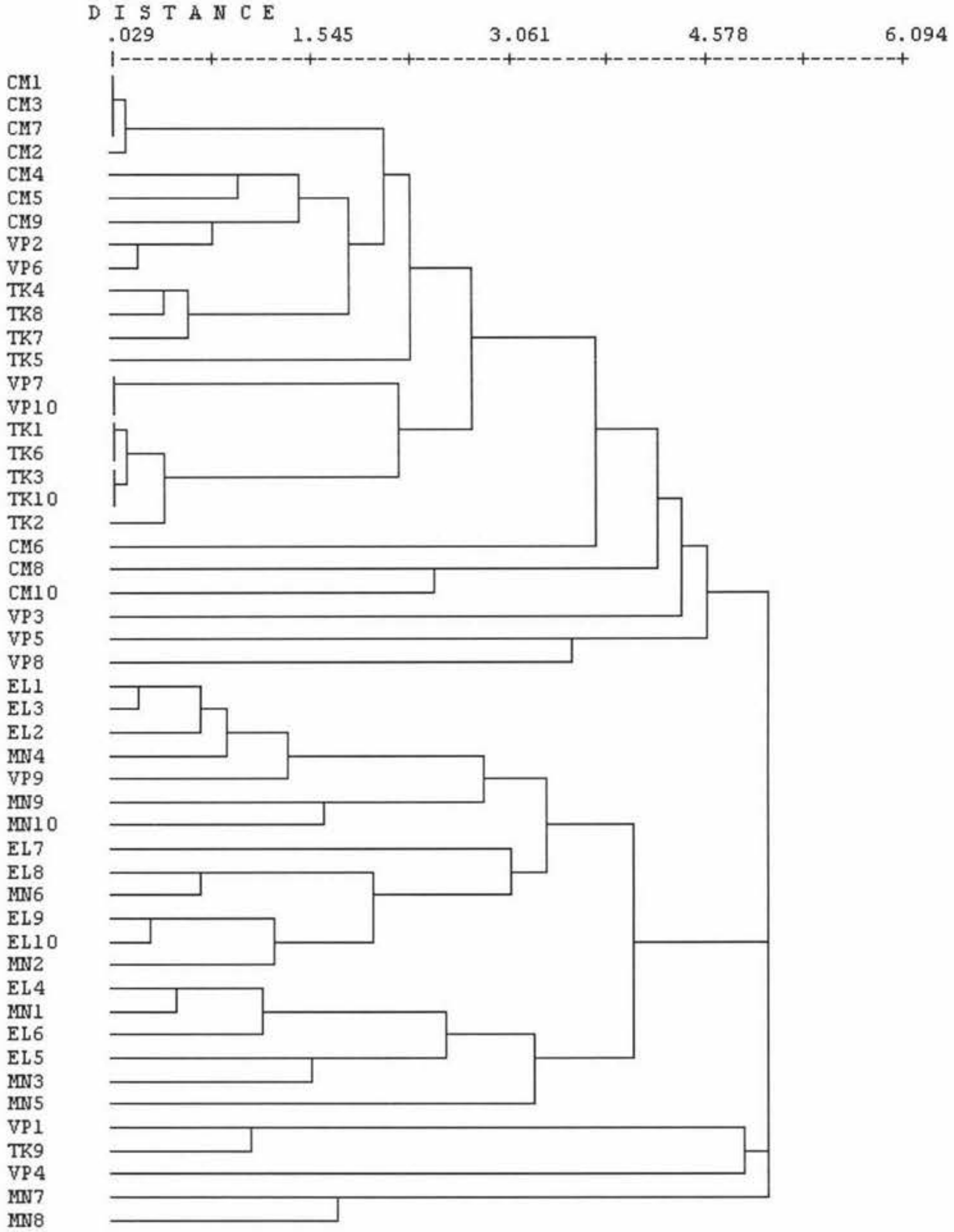


Figure 5: Cluster analysis of invertebrate abundance collected in 3 replicate Surber samples from 10 streams in each of the 5 ecoregions. MN=Manawatu Plains, EL=Eastern Lowlands, CM=Central Mountains, TK=Mount Taranaki Forest and VP=Volcanic Plateau, refer Appendix 2 for site numbers.

Similarly the DECORANA of invertebrate abundance data (Fig. 6) split the sites into two broad groupings - forested ecoregions (Mount Taranaki, Volcanic Plateau and Central Mountains) and pastoral ecoregions (Eastern Lowlands and Manawatu Plains). DECORANA of presence/absence data (not shown) produced similar groupings of the invertebrate data.

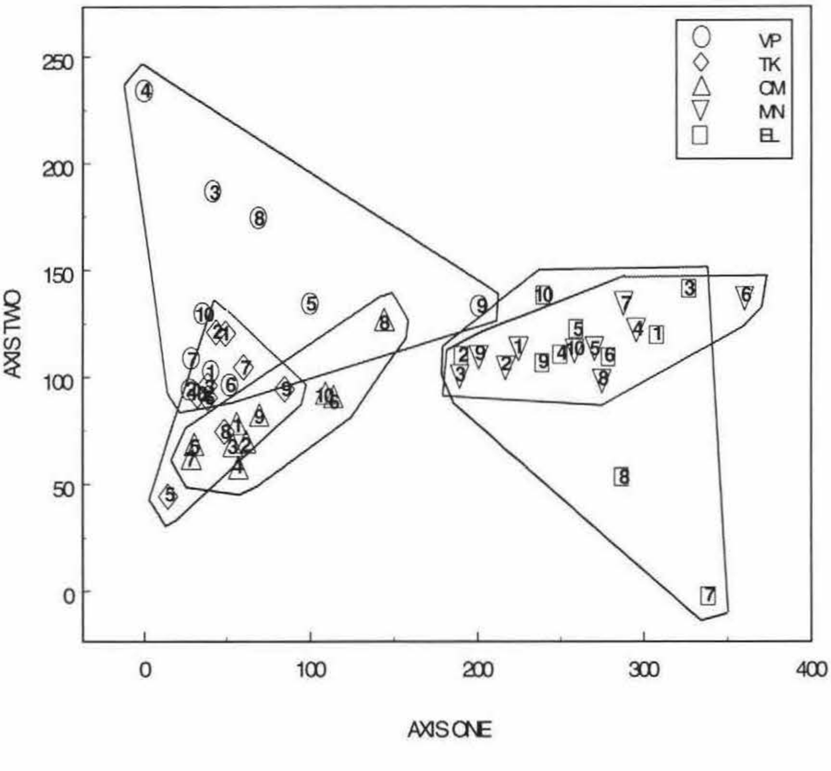


Figure 6: DECORANA of invertebrate abundance data collected in 3 replicate Surber samples from 10 streams in each of the 5 ecoregions in May 1995. TK=Mount Taranaki, VP=Volcanic Plateau, CM=Central Mountains, EL=Eastern Lowlands, MN=Manawatu Plains.

DECORANA axis one correlated positively with variables associated with highly impacted streams (Table 2): percentage pasture, conductivity and temperature. Negative correlations were found with stability, cover, substrate size and native forest.

	AXIS ONE	AXIS TWO
STABILITY	0.66***	0.18
SUBSTRATE	-0.48***	-0.29*
NATIVE FOREST	-0.64***	-0.53***
EXOTIC FOREST	0.24	0.07
SCRUB	-0.21	0.26
PASTURE	0.82***	0.30*
TUSSOCK	-0.18	0.33*
COVER	-0.65***	-0.22
DEPTH	0.03	-0.13
WIDTH	-0.23	-0.48***
VELOCITY	0.43**	0.18
CONDUCTIVITY	0.78***	0.16
TEMPERATURE	0.53***	-0.03
pH	0.14	0.05
BOTTOM	0.60***	-0.04
FPOM	-0.17	0.11
CPOM	0.28*	0.28
FPOM-CPOM	-0.32*	-0.14

Table 2 - Pearson Correlation Coefficients of environmental variables with axes one and two of a DECORANA of stream macroinvertebrates from ten streams in five ecoregions collected in May 1995. * Significant at the 95% level, ** 99% and *** significant at the 99.9% level.

The first division of the TWINSPAN of presence/absence data (Fig. 7) also showed a similar broad grouping of the forested and pastoral ecoregions. Lower divisions in the two pasture ecoregions split individual sites within both ecoregions while further divisions in the forested group split most of the Central Mountain sites from the Mount Taranaki and Volcanic Plateau sites, with some exceptions.

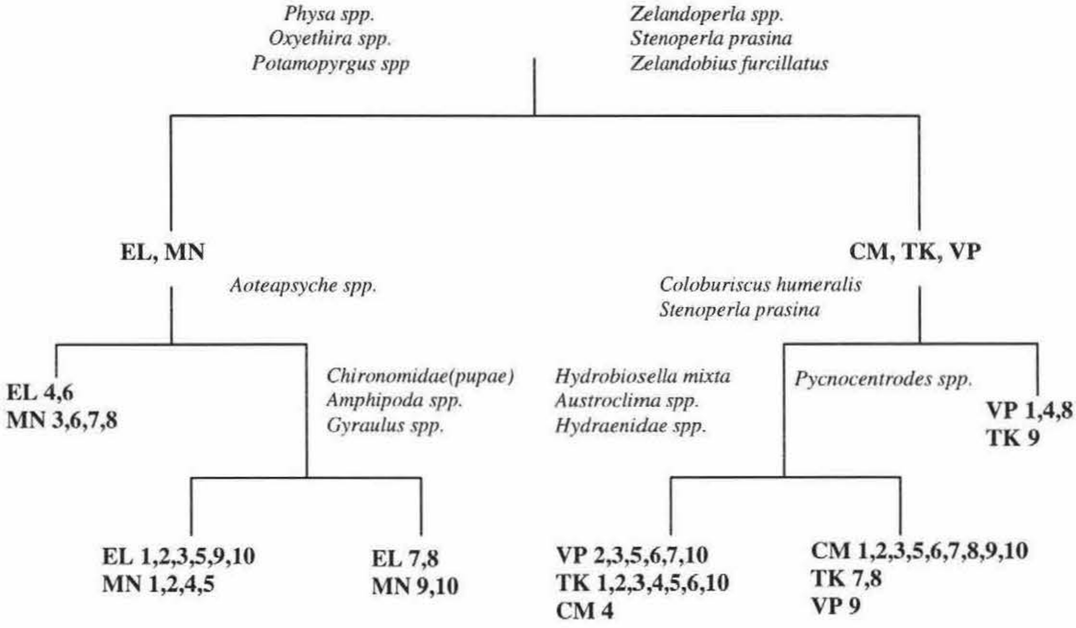


Figure 7: TWINSPAN of invertebrate presence/absence data collected in 3 replicate Surber samples from 10 streams in each of the 5 ecoregions in May 1995. TK=Mount Taranaki, VP=Volcanic Plateau, CM=Central Mountains, EL=Eastern Lowlands, MN=Manawatu Plains.

Water Quality Indices

MCI, QMCI and EPT scores (Fig. 8a,b,c) for Central Mountains, Mount Taranaki and Volcanic Plateau were all significantly higher then Eastern Lowland and Manawatu Plains' sites (($F_{4,45}$=48.53, $P<0.001$)($F_{4,45}$=20.30, $P<0.001$)($F_{4,45}$=9.94, $P<0.001$) for MCI, QMCI and EPT respectively).

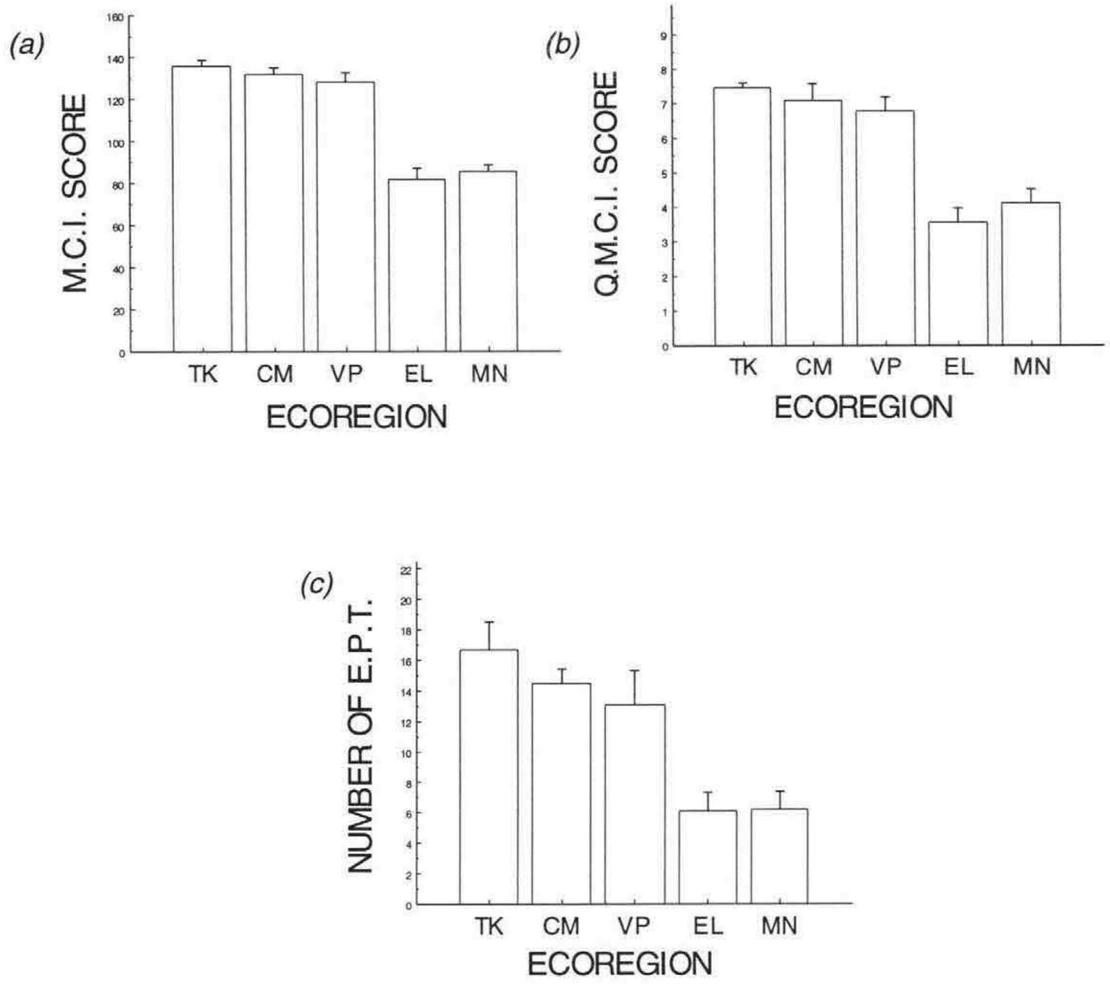


Figure 8a: Macroinvertebrate Community Index (MCI), b – Quantitative Macroinvertebrate Community Index (QMCI), c – Number of Ephemeroptera, Plecoptera and Trichoptera (E.P.T.) calculated from invertebrates in 3 replicate Surber samples from 10 streams in each of the 5 ecoregions in May 1995. TK=Mount Taranaki, CM=Central Mountains, VP=Volcanic Plateau, EL=Eastern Lowlands, MN=Manawatu Plains.

DISCUSSION

The forested ecoregions: Mount Taranaki, Volcanic Plateau and Central Mountain sites all had a higher number of mayflies, stoneflies and caddisflies than the Eastern Lowlands and Manawatu plains' sites. This shift in benthic invertebrate composition from E.P.T. to Diptera and Mollusca between unmodified and modified streams is a common phenomenon in New Zealand (Winterbourn et. al., 1981; Lenat & Crawford, 1994). Land conversion for agricultural use has a large impact on invertebrate community structure, leading to a community dominated by more pollution tolerant Diptera and Mollusca species (Wilcock, 1986; Collier, 1995; Harding & Winterbourn, 1995; Quinn et. al., 1997a). This trend was reflected in the Eastern Lowland and Manawatu Plains' sites which showed consistently low MCI, E.P.T. and QMCI scores indicative of moderate to severe enrichment (Stark, 1985). This strong influence of pastoral landuse on benthic invertebrates was highlighted in the "Left of Ford site" sampled in predominantly pasture in the Volcanic Plateau ecoregion, which shared community characteristics of the pastoral streams rather than the surrounding alpine scrub/tussock ecoregion. The results from this study suggest the distinction between streams in modified and unmodified areas was the dominant factor in the shaping of the invertebrate communities.

The Central Mountains and Mount Taranaki ecoregions were the two most closely related in terms of landusage - podocarp-broadleaf-beech forest, however, the Volcanic Plateau sites all showed similar species composition and richness to the two forested ecoregions. Clearly landusage influences affect invertebrate communities more strongly than any ecoregion influences because of the contrast in water quality and sediment inputs (Quinn et. al., 1990; Wang et. al. 1997). Streams in the forested regions have higher water quality and lower sediment runoff, supporting communities of more sensitive invertebrate taxa, whereas lowland pastoral streams have lower water quality and higher sediment inputs and support more pollution tolerant taxa.

The aim of this work was to examine the validity of the Harding ecoregions in the lower half of the North Island. Harding (1994) found good separation of ten ecoregions in the South Island based on the macroinvertebrate communities surveyed in small headwater streams. Landusage was seen as a lesser discriminant of the ecoregions and cover was used to describe subregions of the main ecoregions.
Other studies have shown the importance of landuse in the functioning of stream invertebrate communities (Glova and Sagar, 1994; Lenat & Crawford, 1994; Lester et. al., 1994; Quinn et. al., 1997a,b; Allan et. al., 1997; Townsend et. al., 1997). My results suggest that broad landuse categories are the best discriminator of the benthic invertebrate communities in these regions. Two main groupings were apparent - the Mount Taranaki, Volcanic Plateau and Central Mountain sites and the Eastern Lowlands and Manawatu Plains. The first group was located in elevated mountainous areas with native bush/forest and alpine tussock/scrub as the main vegetation types, while the latter were on the plains with high producing pasture as the primary vegetation type. The broad distinction in these invertebrate communities is between forested/alpine scrub and pastoral landuse. Harding's results indicated that geomorphology and climate were the important factors shaping invertebrate communities in the South Island streams while Friberg and Winterbourn (1997) in a more restricted geographical study of South Island streams found similar effects. Southern North Island benthic invertebrate communities appear to be more strongly influenced by landuse than geomorphologic and climatic factors. South Island streams are relatively pristine compared to the well developed lowland streams in this study, making landuse a far more important influence on stream invertebrate communities in the lower North Island. Reference sites chosen on the basis of ecoregions in the lower

North Island are therefore less likely to be a relevant indicator of the ‘best attainable’ invertebrate communities in streams. Reference sites should therefore be chosen from sites of similar landuse for a more accurate indication of stream condition.

REFERENCES

Allan, J.D., Erickson, D.L., Fay, J. 1997. The influence of land use on stream integrity across multiple spatial scales. *Freshwater Biology* **37**: 149-161.

Beable, M. E., McKerchar, A.I. 1982. Regional flood estimation in New Zealand. *Water and Soil Technical Publication 20*, National Water and Soil Conservation Organisation, Wellington.

Biggs, B. J. F., Duncan, M.J., Jowett, I.G., Quinn, J.M., Hickey, C.W., Davies-Colley, R.J., Close, M.E. 1990. Ecological characterisation, classification, and modelling of New Zealand rivers: an introduction and synthesis. *New Zealand Journal of Marine and Freshwater Research* **24**: 277-304.

Collier, K. J. 1995. Environmental factors affecting the taxonomic composition of aquatic macroinvertebrate communities in lowland waterways of Northland, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **29**: 453-465.

Data Desk, Data Description Inc., 1992. P.O. Box 4555, Ithaca, New York 14852. Data Desk Statistics Guide Ch. 2.

Franklyn, G. 1997. Characterisation of Hawkes Bay rivers based on biotic communities. Unpublished Msc Thesis, Massey University, Palmerston North.

Friberg, N., Winterbourn, M.J. 1997. Effects of native and exotic forest on benthic stream biota in New Zealand: a colonisation study. *Marine and Freshwater Research* **48**: 267-275.

Glova, G. J., Sagar, P.M. 1994. Comparison of fish and macroinvertebrate standing stocks in relation to riparian willows (Salix spp.) in three New Zealand streams. *New Zealand Journal of Marine and Freshwater Research.* **28**: 255-266.

Harding, J.S. 1994. Lotic ecoregions of New Zealand. Unpublished PhD Thesis University of Canterbury, Christchurch.

Harding, J.S., Winterbourn, M.J. 1995. Effects of contrasting landuse on physico-chemical conditions and benthic assemblages of streams in a Canterbury (South Island, New Zealand) river system. *New Zealand Journal of Marine and Freshwater Research.* **29**: 479-492.

Hill, M. O. 1979a. DECORANA - A FORTRAN program for detrended correspondence analysis and reciprocal averaging. *Ecology and Systematics, Cornell University, Ithaca, New York.*

Hill, M. O. 1979b. TWINSPAN - A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. *Ecology and Systematics, Cornell University, Ithaca, New York.*

Hughes, R.M., Larsen, D.P. 1988. Ecoregions: an approach to surface water protection. Journal of the Water Pollution Control Federation **60**: 486-493.

Hynes, H.B.N. 1975. "The stream and its valley." Verhandlungen der Internationale Vereinigung fur Theoretische und Andewandte Limnologie **19**: 1-15

Jowett, I. G., Richardson, J 1990. Microhabitat preferences of benthic invertebrates In a New Zealand river and the development of in-stream flow-habitat models for *Deleatidium spp. New Zealand Journal of Marine and Freshwater Research* **24**:19-30.

Lenat, D.R., Crawford, J.K. 1994. Effects of land use on water quality and aquatic biota of three North Carolina Piedmont streams. *Hydrobiologia* **294**: 185-199.

Lester, P. J., Mitchell, S.F., Scott, D. 1994. Effects of Riparian willow trees (Salix fragilis) on macroinvertebrate densities in two small Central Otago, New Zealand streams. *New Zealand Journal of Marine and Freshwater Research* **28**: 267-276.

McCune, B. 1991. Multivariate analysis on the PC-ORD system. Indianapolis, Indiana, Butler University.

McFarlane, A. G. 1951. Caddis fly larvae (Trichoptera) of the family Rhacophilidae. *Records of the Canterbury Museum* **5**: 267-289.

Moss, B. 1967a. A spectrophotometric method for the estimation of percentage degradation of chlorophylls to phaeo-pigments in extracts of algae. *Limnology and Oceanography* **12**: 335-340.

Moss, B. 1967b. A note on the estimation of chlorophyll a in freshwater algal communities. *Limnology and Oceanography* **12**: 340-342.

Omernick, J. M. 1987. Ecoregions of the Conterminous United States. *Annals of the Association of American Geographers* **77**(1): 118-125.

Pfankuch, D. J. 1975. Stream Reach Inventory and Channel Stability Evaluation. USDA Forest Service, Region 1, Missoula, Montana.

Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K., Hughes, R.M. 1989. Rapid Bioassessment Protocols for use in Streams and Rivers: Benthic Macroinvertebrates and Fish. United States Environmental Protection Agency Assessment and Watershed Protection Division. Washington D.C..

Poff, N.L., Ward, J.V. 1989. Implications of stream flow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. *Canadian Journal of Fisheries and Aquatic Sciences* **46**: 1805-1817.

Quinn, J. M., Hickey, C.W. 1990. Characterisation and Classification of Benthic Invertebrate communities in 88 New Zealand rivers in relation to environmental factors. *New Zealand Journal of Marine and Freshwater Research* **24**: 387-409.

Quinn, J.M., Cooper, A.B., Davies-Colley, R.J., Rutherford, J.C., Williamson, R.B. 1997a. Land use effects on habitat, water quality, periphyton, and benthic invertebrates in Waikato, New Zealand, hill country streams. *New Zealand Journal of Marine and Freshwater Research* **31**: 579-597.

Quinn, J.M., Cooper, A.B., Stroud, M.J., Burrell, G.P. 1997b. Shade effects on stream periphyton and invertebrates: an experiment in streamside channels. *New Zealand Journal of Marine and Freshwater Research* **31**: 665-683.

SAS 1995. SAS User's Guide. Statistics. Version 6.1. SAS Institute Inc., Cary, North Carolina, USA.

Stark, J. D. 1985. A macroinvertebrate community index of water quality for stony streams. *Water and Soil Miscellaneous Publication* **87**: 53p.

Toebes, C., Palmer, B.R. 1969. Hydrological regions of New Zealand. *Water and Soil Division, Miscellaneous Hydrological Publication 4, Wellington.*

Townsend, C.R., Arbuckle, C.J., 1997. The relationship between land use and physicochemistry, food resources and macroinvertebrate communities in tributaries of the Taieri River, New Zealand: a hierarchically scaled approach. *Freshwater Biology* **37**:177-191.

Wang, L., Lyons, J., Kanehl, P., Gatti, R. 1997. "Influences of Watershed Land use on Habitat Quality and Biotic Integrity in Wisconsin Streams." *Fisheries* **22**(6): 6-12.

Wilcock, R. J. 1986. Agricultural runoff: A source of water pollution in New Zealand. *New Zealand Agricultural Science* **20**: 98-103.

Winterbourn, M. J. 1972. A guide to the freshwater Mollusca of New Zealand. *Tuatara* **20**: 141-159.

Winterbourn, M. J., Rounick, J.S., Cowie, B. 1981. Are New Zealand stream ecosystems really different? *New Zealand Journal of Marine and Freshwater Research* **15**: 321-328.

Winterbourn, M. J., Gregson, K.L.D. 1989. *Guide to the Aquatic Insects of New Zealand.* Bulletin of the Entomological Society of New Zealand.

CHAPTER 3

The invertebrate communities of an urban stream.

ABSTRACT

Macroinvertebrate communities in two sites, one above and one below a refuse facility, of the urban Mangaone stream (Palmerston North) and ten pastoral streams in the surrounding pastoral Manawatu were examined for differences in water quality and community structure. The impact of a nearby refuse facility on the Mangaone stream was also examined.

Results indicated that urbanization had significantly altered the invertebrate communities from those of streams in surrounding pasture. Urban sites had significantly lower MCI and QMCI scores than the Manawatu Plains' sites and were dominated by oligochaetes and chironomids. *Potamopyrgus antipodarum* and *Oxyethira albiceps* in contrast were the numerically dominant species of the Manawatu Plains' streams. These observed differences could potentially be attributed to stormwater runoff, increased sediment transport and poorer water quality often found in urban streams. Differences in benthic invertebrate communities between the two Mangaone stream sites are probably attributable to more unstable conditions at the lower site rather than the effects of the nearby Palmerston North Refuse Facility.

INTRODUCTION

Urban streams are a common feature in New Zealand. Streams such as the Mangaone in Palmerston North often originate in the agricultural land surrounding urban areas. Agricultural land use in New Zealand strongly influences the benthic invertebrate communities that live within these streams (Quinn and Hickey, 1990a; Scott et. al., 1994; Collier, 1995; Wilcock et. al., 1995). The assemblage of tolerant benthic invertebrate communities found in agricultural catchments have been attributed to increased nutrient input (Cooper & Thomsen, 1988), temperature and flow variability (Harding and Winterbourn, 1995).

The effects of urbanization on streams have been studied overseas (Klein, 1979; Kibler et. al., 1981; Jones & Clark, 1987; Lenat & Crawford, 1994; Wang et. al., 1997) yet have received little attention in New Zealand (Williamson, 1985; Williamson, 1986; Wilding, 1996). Urbanization of streams overseas has been shown to exhibit similar effects on the stream environment as agricultural development (Lenat & Crawford, 1994). They also show increased levels of toxic substances such as heavy metals (Klein, 1979) and increased runoff because of the large amount of impervious surfaces in the catchment (Jones & Clark, 1987). This study was undertaken to examine the effects of urbanization on benthic invertebrate communities. Two sites of the urban Mangaone stream are compared with ten streams from the surrounding agricultural region (Manawatu Plains). The effects of an adjacent refuse facility on the Mangaone stream was also examined.

STUDY SITES

The Mangaone stream originates in farmland in the Manawatu, and runs through the city of Palmerston North in its lower reaches collecting residential stormwater. Bank stability has been artificially increased by large earth banks to reduce flood events that previously occurred in residential areas alongside the stream. Just prior to its entry into the Manawatu River the Mangaone stream runs along side the Palmerston North Refuse Facility. Two sites were examined, one above (Racecourse site) and one below the refuse site (Downstream site).

Ten streams from the Manawatu Plains (MN) (see Chapter one) were used as reference sites for comparison with the Mangaone. This region is characterised by lowland plains with a predominantly rolling (<10° slopes) or flat topography. All of the ten sites were located in high producing pasture - predominantly dairy farming in the Manawatu. The streams chosen for the study were second and third order streams.

METHODS

Invertebrates were collected in 4 (0.1 m^2) 250 μm mesh Surber samples from riffles at the two Mangaone sites at bimonthly intervals between March 1995 and January 1996 (Appendix 3). Three Surber samples from 10 sites in the Manawatu Plains were also collected in a similar way in May 1995. Samples were preserved in 70% alcohol in the field, sorted in a white tray by eye then identified using the keys of Winterbourn and Gregson (1989), Winterbourn (1973) and McFarlane (1951), to the lowest possible taxonomic level using a dissecting microscope (40x magnification).

Environmental Measures

Concurrent with the invertebrate sampling in the Manawatu Plains and Mangaone stream sites the following environmental measures were also recorded: width (n=3), depth and water velocity (current meter) at midstream sampling points; conductivity and temperature (using an Orion model 122 conductivity meter); riparian vegetation, substrate composition and Pfankuch Stability Scores (Pfankuch, 1975) were visually assessed.

Statistical Analyses

The Macroinvertebrate Community Index (MCI) (Stark, 1985) and its quantitative analogue were calculated for an indication of the water quality at the sites. Given respectively as:

$\text{MCI} = (\sum(\text{MCI taxa score})/\text{number of scoring taxa})\times 20$

And $\text{QMCI} = (\sum(\text{MCI taxa score}\times\text{species abundance})/(\text{total invertebrates}))$

Analysis of variance (ANOVA) was used to investigate for significant differences between invertebrate data from the Mangaone stream and the Manawatu Plains' sites using Data Desk 4 (1992). Scheffe post hoc tests were used to determine differences within the ANOVA design.

Detrended correspondence analysis (DECORANA) (Hill, 1979b) with the statistical package PC-ORD (McCune, 1991) was also carried out on the invertebrate data. Correlation of environmental variables with the two main axes of the DECORANA was performed using the Spearman Rank correlation procedure of SAS (SAS, 1995). Substrate classes were combined into a single substrate index following Quinn and Hickey (1990b). Two way indicator species analysis (TWINSPAN) (Hill, 1979a) was also used to examine the groups of sites according to both invertebrate abundance and presence/absence data. Six pseudospecies cut levels were used in the analysis of the abundance data - 1, 5, 10, 50, 100, 500. Bray-Curtis distance group average cluster analysis was also used to classify both invertebrate abundance and presence/absence data using the package PC-ORD (McCune, 1991).

RESULTS

Environmental Measures

Environmental parameters measured at the study sites are presented in Table 1. Manawatu streams were all unstable ranging in Pfankuch stability scores from 82 (Pukenaua stream) to 124 (Bunny stream). Cover was generally sparse for these sites, only the Tutaenui stream had a significant proportion (>50%) of cover, because of a fenced riparian margin. Depth measures for Manawatu streams ranged from 0.06 – 0.28 m and width ranged from 1.0 – 3.5 m. Velocity ranged between 0.55 – 1.30 m/s and conductivity between 118 – 298 μS/cm. Gravel dominated the substrate for 8 out of the 10 Manawatu Plains' sites, large cobbles and boulders dominated the remaining two sites (Manutahi stream and Haynes creek). The Mangaone urban stream in contrast had generally higher conductivity scores (225 – 364 μS/cm) and was generally wider (2.5 – 8.0 m) and deeper (0.12 m to 0.50 m) than the Manawatu Plains' streams. The Mangaone stream was similar to the Manawatu Plains in velocity (0.33 m/s to 1.10 m/s), and dominance of the gravel substrate.

SITE	STREAM	Map Reference	Pfankuch stability	%Cover	Depth (m)	Width (m)	Velocity (m/sec)	Conductivity uS/cm	Temperature °C
D	Mangaone	Sht 8:728088	120	0	0.12-0.50	2.5-8.0	0.33-1.1	209-361	8.4-23.6
R	Mangaone	Sht 8:728089	100	0	0.12-0.34	3.5-7.0	0.27-1.00	225-364	8.0-23.6
MN 1	Mangapipi	Sht 6:735135	89	5	0.06	1.5	1.10	124	11
MN 2	Waituna West	Sht 6:736126	106	50	0.19	3	0.83	118	10.7
MN 3	MacKay rd.	Sht 6:732116	101	5	0.25	2.5	1.20	237	11.3
MN 4	Travistock rd.	Sht 8:708065	102	0	0.08	3	0.88	236	14.6
MN 5	Manutahi	Sht 6:746166	83	2	0.16	1	0.55	298	10
MN 6	Haynes creek	Sht 6:735116	107	0	0.25	3.5	1.30	200	11.5
MN 7	Mangaone trib.	Sht 6: 736106	101	0	0.28	3	1.00	188	11.3
MN 8	Bunny stream	Sht 8: 742098	124	10	0.12	2.5	0.67	269	10.4
MN 9	Tutaenui	Sht 6: 715132	105	80	0.08	1	0.66	232	10.6
MN 10	Pukenaua	Sht 6: 750165	82	20	0.14	1.4	0.66	262	10

Table 1: Mean Physicochemical measures for two sites on the Mangaone stream('D' – Downstream site, 'R' – Racecourse site) recorded between February 1995 to January 1996 and ten sites in the Manawatu Plains (MN) collected in May 1995 (Appendix 2).

Benthic Invertebrate Community Composition

A total of 67 taxa were recorded in the 11 surveyed streams (Appendix 1, 3); most were Trichoptera (18 taxa), followed by Diptera (11), Ephemeroptera (7) and Mollusca (6) were also common (Fig. 1).

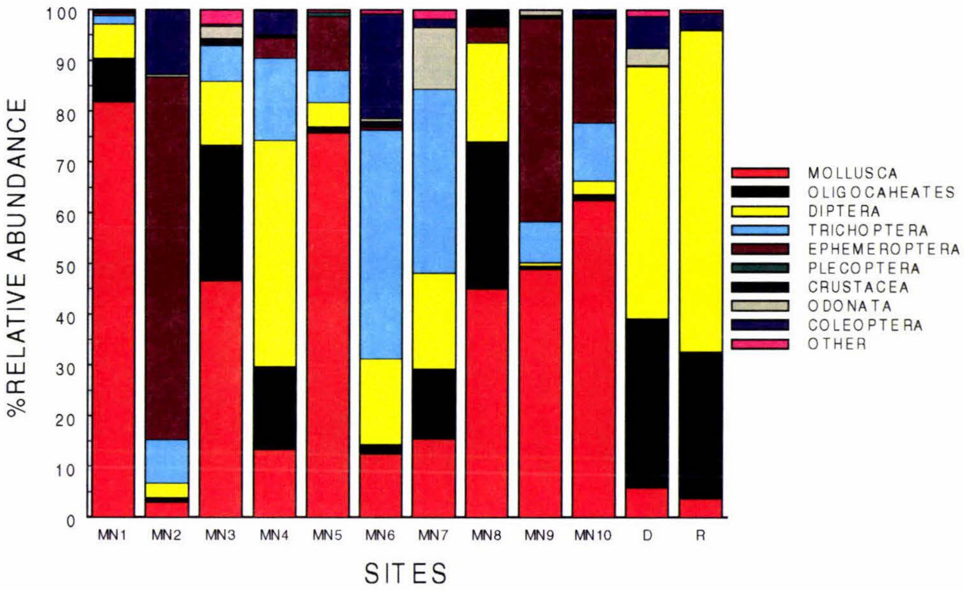


Figure 1: Mean Relative Abundance of macroinvertebrates collected at two sites on the Mangaone stream ('D' – Downstream site, 'R' – Racecourse site) between February 1995 and January 1996 (sample averages) and at ten sites in the Manawatu Plains (MN) in May 1995.

The lowest number of species was recorded at the Mangaone Downstream site (5 species) (Fig. 2a) and the highest number at the Pukenaua site (27 species) (Fig. 2a). The Mangaone Downstream site had significantly lower numbers of species compared to Manawatu Plains' sites ($F_{2,35}$=5.48, P<0.01); the Mangaone Racecourse site was not significantly different from the other sites. Oligochaetes and chironomids dominated Mangaone urban stream sites and consequently scored the lowest MCI and QMCI scores in the study (Fig. 3a,b).

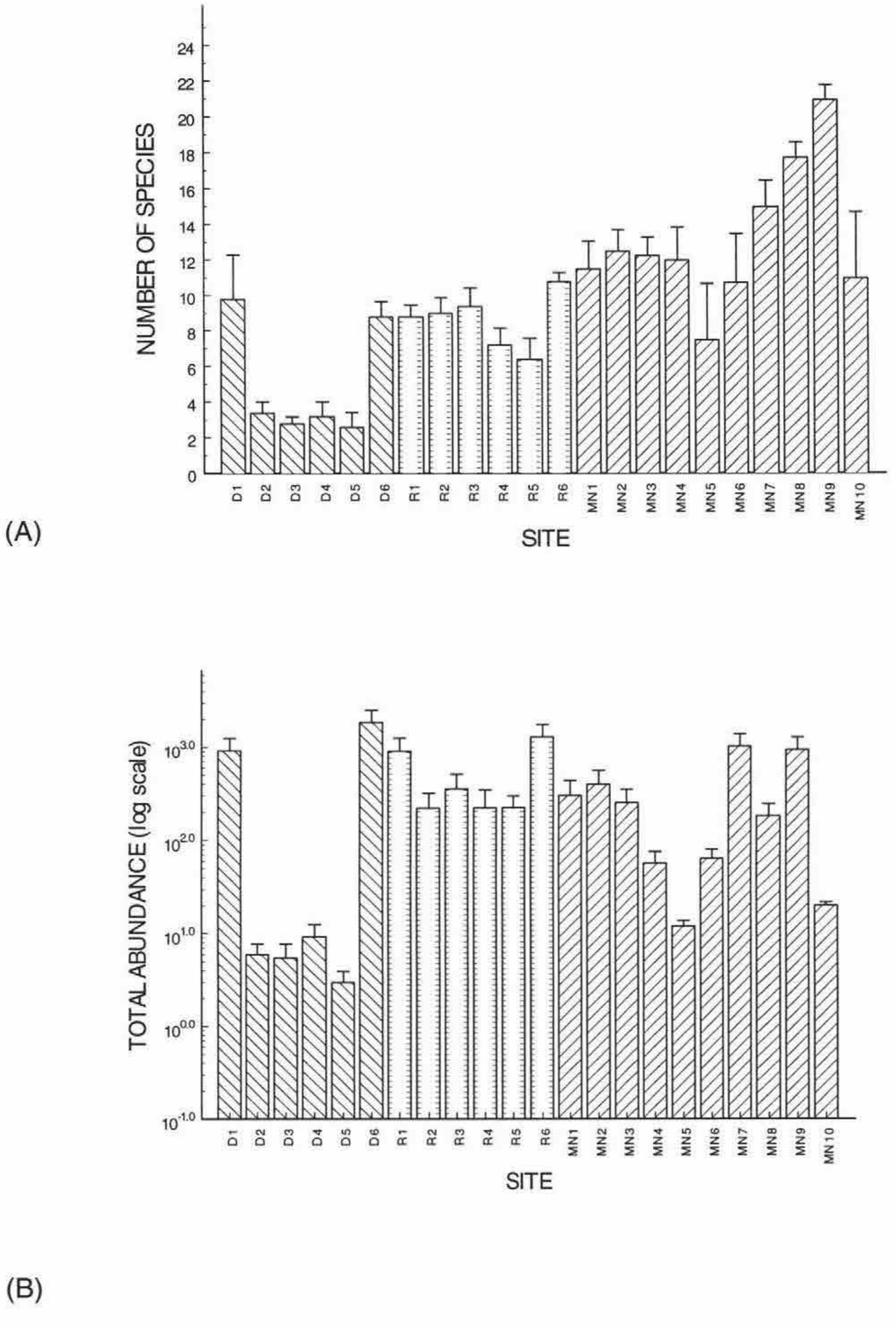


Figure 2: Mean (± 1 S.E.) Species number (A) and abundance (B) per 0.1 m^2 for samples collected at two sites on the Mangaone stream ('D' – Downstream site, 'R' – Racecourse site) between February 1995 to January 1996 and ten sites in the Manawatu Plains (MN) collected in May 1995.

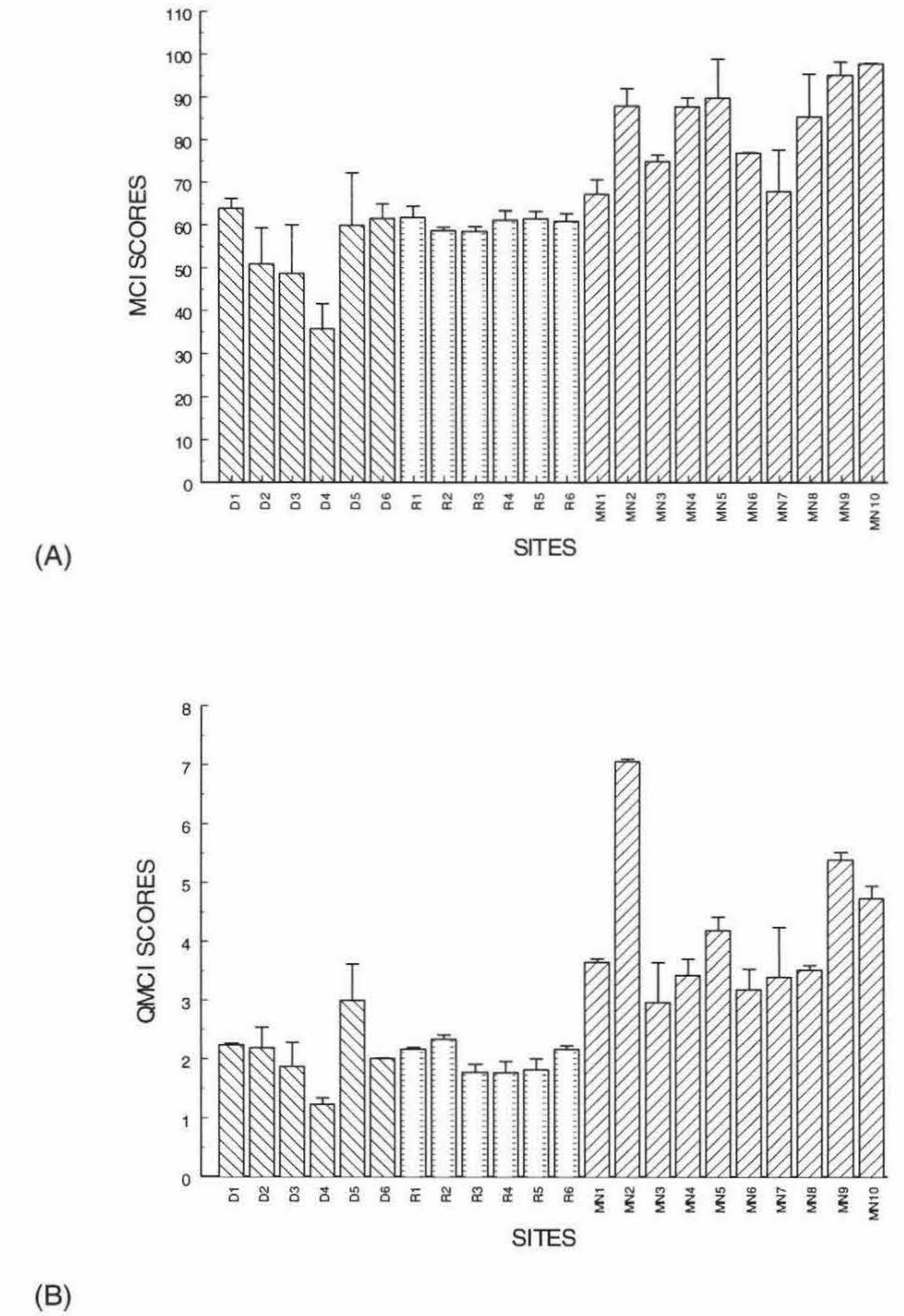


Figure 3: Macroinvertebrate Community Scores (MCI)(A) and Quantitative M.C.I scores (B) for invertebrate data for two sites on the Mangaone stream ('D' – Downstream site, 'R' – Racecourse site) collected between February 1995 to January 1996 and ten sites in the Manawatu Plains (MN) collected in May 1995.

The Mangaone Downstream site had the greatest range of total invertebrates (Fig. 2b) from 1 in October to 2862 per sample in January, whereas the Upstream site maintained relatively consistent numbers throughout the study. Total invertebrates at the other Manawatu Plains' sites ranged from 10 at the Bunny Stream to 1629 per sample at the Tutaenui stream. The Downstream site of the Mangaone had significantly lower numbers of invertebrates ($F_{2,35}$=10.70, $P<0.001$)(Fig. 2b) than the Upstream and Mangaone sites which could not be separated. *Potamopyrgus antipodarum* was the numerically dominant species at 5 sites with *Oxyethira albiceps* dominant at two sites.

MCI scores for all of the sites were in the category of moderately to grossly polluted (Stark, 1985) with ranges for the Manawatu Plains' sites of between 67 - 98 and the Mangaone of 58 - 61. Mangaone stream MCI and QMCI scores were significantly lower than the Manawatu Plains' sites ($F_{2,35}$=23.58, $P<0.01$ and $F_{2,35}$=7.28, $P<0.01$). CLUSTER analysis of invertebrate abundance data (Fig. 4) shows three main groupings of sites, two groups including Mangaone stream samples and Mangaone (MN7) and Bunny stream sites (MN8), another with the remaining sites.

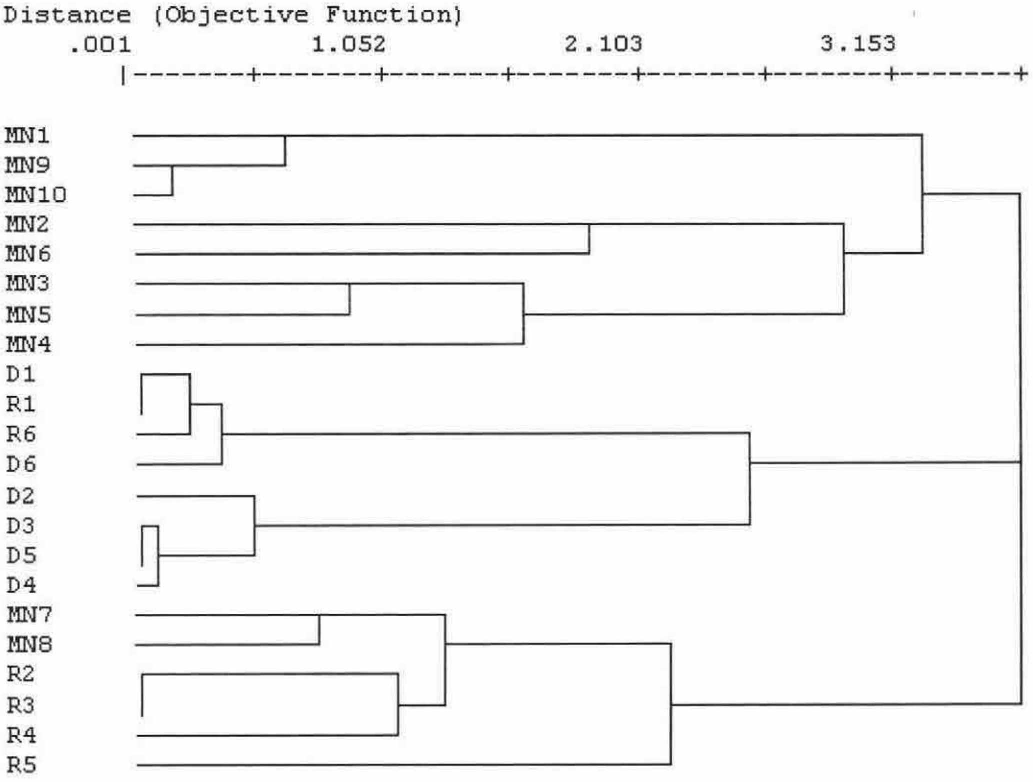


Figure 4: CLUSTER analysis of invertebrate abundance data of two sites on the Mangaone stream between February 1995 to January 1996 and ten sites in the Manawatu Plains in May 1995. Refer to Table 1 for site codes.

TWINSPAN of abundance data also split the Mangaone replicates from most of the other Manawatu sites but also included the Mangapipi and Waituna West streams (Fig. 5) based on the presence of *Austrosimulium*, *Oxyethira albiceps* and *Aoteapsyche colonica* at most Manawatu sites.

Figure 5: TWINSPAN of invertebrate abundance data for the Mangaone stream collected between February 1995 to January 1996 and ten sites in the Manawatu Plains (MN) collected in May 1995. For site codes refer to Table 1.

DECORANA of abundance data showed even clearer cut separation of the Mangaone and Manawatu Plains' sites (Fig. 6).

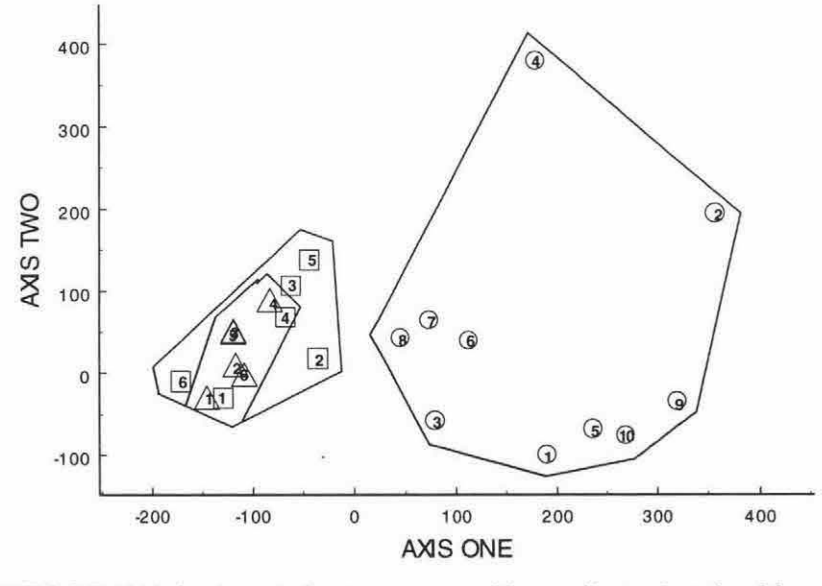


Figure 6: DECORANA for invertebrate communities collected at the Mangaone stream between February 1995 to January 1996 and ten sites in the Manawatu Plains (MN) in May 1995. Downstream site = ❑, Racecourse site = Δ, numbers depict sampling occasion (Appendix 3). Manawatu Plains' sites = o, numbers depict specific site (Appendix 2).

Conductivity and width were negatively correlated with axis one of this analysis, and percentage cover and percentage exotic woodland were positively correlated (Table 2).

VARIABLE	AXIS ONE	AXIS TWO
%PASTURE	-0.74*	-0.28
%EXOTIC WOODLAND	0.74*	0.28
%SCRUB	0.36	0.08
DEPTH	-0.33	-0.25
WIDTH	-0.52*	-0.33
VELOCITY	0.29	-0.24
CONDUCTIVITY	-0.64*	0.12
TEMPERATURE	-0.37	0.20
STABILITY	0.14	-0.39
COMBINED SUBSTRATE INDEX	0.00	0.44

Table 2: Spearman Rank Correlation Coefficients between environmental variables and axes one and two of a DECORANA ($P<0.05$).*

DISCUSSION

The aquatic faunas of both the urban and pastoral streams show a high proportion of pollution tolerant taxa in all of the streams examined. Chironomids, oligochaetes and molluscs dominated the composition of the samples and are those most often associated with highly modified catchments (Lenat and Crawford, 1994; Collier, 1995) and high nutrient inputs (Cooper and Thomsen, 1988).

Multivariate analysis showed a separation between the Mangaone and Manawatu Plains' invertebrate community composition. Manawatu Plains' sites with higher QMCI scores had a higher proportion of mayflies (Waituna West, Tutaenui and Pukenaua streams) while the other sites had a greater proportion of molluscs and trichopteran larvae. The Mangaone stream in contrast showed dominance of chironomids and oligochaetes. Other studies have also found increases in abundance of Diptera (Jones & Clark, 1987) and oligochaetes (Pitt & Bozeman, 1983) with urbanization. MCI and QMCI scores indicated significantly lower water quality in the Mangaone stream compared to that of the other Manawatu Plains' sites.

Urban streams studied overseas indicate that as urbanization increases, stormwater runoff and the amount of toxic substances in streams also increase (Klein, 1979), both of which can have adverse effects on aquatic life (Garie and McIntosh, 1986). The extreme nature of stormwater runoff from urban areas can be sufficient to restrict the benthic assemblage to only those fauna adapted to extreme bed instability (Pedersen & Perkins, 1986). Increased sediment transport in urban streams (Scott et. al., 1986) also has a detrimental effect on stream invertebrate fauna (Rosenburg & Wiens, 1978). These factors combined could account for the significant differences observed in the benthic invertebrate communities in the Mangaone stream when compared to the other Manawatu Plains' sites. Other studies examining the differences between forested, urban and agricultural streams (Lenat & Crawford, 1994), and longitudinal studies of streams flowing into urban areas (Whiting & Clifford, 1983; Pratt et. al., 1981), also found significant changes in benthic invertebrate communities to more pollution tolerant taxa.

The Mangaone Downstream site showed a similar number of species, yet had significantly lower total invertebrate abundance than the Racecourse site. Stream substrate disturbance during floods was higher in the Downstream site because of the predominantly finer gravel substrate and poor substrate packing compared to the cobble substrate of the upstream site. Other studies have also shown an increase in invertebrate abundance with substrate size up to cobble size (Ward 1975; Jowett & Richardson, 1990; Quinn & Hickey, 1990b). Scouring of the banks was also obvious in the Downstream site. The highly unstable nature of the Downstream site was reflected in low numbers of taxa and invertebrates sampled during the winter when floods were common. Although the Downstream site was highly unstable the benthic invertebrate composition was similar to the Racecourse site, this was shown in the multivariate ordinations and classifications of the benthic invertebrate data. Water quality indices also did not show a significant difference between the Mangaone stream sites. It is therefore likely that the lower stability of the bed particles of the Downstream site allowed greater mobility of the substrate during flood events (Ashworth & Ferguson, 1989), that caused the observed decrease in total invertebrates from the Racecourse site rather than the impact of the nearby refuse facility. Other studies have shown that stable habitats are able to support more productive invertebrate communities (Way et. al., 1995), and lesser reductions in population density following a disturbance (Reice, 1985).

In summary, urbanisation had a significant effect on stream invertebrate communities in the Mangaone stream, distinguishing them from the surrounding Manawatu Plains' sites. These effects are most likely from a combination of stormwater runoff, elevated suspended sediment transport and poorer water quality. Differences between the urban sites could be attributed to smaller, and less stable substrate particles at the Downstream site.

REFERENCES

Ashworth, K.R., Ferguson, R.I. 1989. Size-selective entrainment of bed loads in gravel bed streams. *Water Resources Research* **25**: 627-634.

Collier, K.J., 1995. Environmental factors affecting the taxonomic composition of aquatic macroinvertebrate communities in lowland waterways of Northland, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **29**: 453-465.

Cooper , A.B., Thomsen, C.E. 1988. Nitrogen and phosphorus in streamwaters from adjacent pasture, pine, and native forest catchments. *New Zealand Journal of Marine and Freshwater Research* **22**: 279-291.

Data Desk, Data Description Inc., 1992. P.O. Box 4555, Ithaca, New York 14852. Data Desk Statistics Guide Ch. 2.

Garie, H.L., McIntosh, A. 1986. Distribution of benthic macroinvertebrates in a stream exposed to urban runoff. *Water Resources Bulletin* **22**: 447-455.

Harding, J.S., Winterbourn, M.J. 1995. Effects of contrasting land use on physico -chemical conditions and benthic assemblages of streams in a Canterbury (South Island, New Zealand) river system. *New Zealand Journal of Marine and Freshwater Research* **29**: 479-492.

Hill, M. O. 1979a. TWINSPAN - A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. *Ecology and Systematics, Cornell University, Ithaca, New York.*

Hill, M. O. 1979b. DECORANA - A FORTRAN program for detrended correspondance analysis and reciprocal averaging. *Ecology and Systematics, Cornell University, Ithaca, New York.*

Jones, R.C., Clark, C.C. 1987. Impact of Watershed Urbanization on Stream Insect Communities. *Water Resources Bulletin* **23**(6): 1047-1055.

Jowett, I.G., Richardson, J. 1990. Microhabitat preferences of benthic invertebrates in a New Zealand river and the development of in-stream flow-habitat models for Deleatidium spp. *New Zealand Journal of Marine and Freshwater Research* ***24**: 19-30.*

Kibler, D.F., Froelich, D.C., Aron, G. 1981. Analyzing Urbanization Impacts on Pennsylvania Flood Peaks. *Water Resources Bulletin* **17**:270-274.

Klein, R.D. 1979. Urbanization and Stream Quality Impairment. *Water Resources Bulletin* **15**(4): 948-963.

Lenat, D.R., Crawford, J.K. 1994. Effects of land use on water quality and aquatic biota of three North Carolina Piedmont streams. *Hydrobiologia* **294**: 185-199.

McCune, B. 1991. Multivariate analysis on the PC-ORD system. Indianapolis, Indiana, Butler University.

McFarlane, A. G. 1951. Caddis fly larvae (Trichoptera) of the family Rhacophilidae. *Records of the Canterbury Museum* **5**: 267-289.

Pedersen, E.R., Perkins, M.A. 1986. The use of benthic invertebrate data for evaluating impacts of urban runoff. *Hydrobiologia* **139**: 13-22.

Pfankuch, D. J. 1975. Stream Reach Inventory and Channel Stability Evaluation. USDA Forest Service, Region 1, Missoula, Montana.

Pitt, R., Bozeman, M. 1983. Sources of Urban Runoff Pollution and its Effects on an Urban Creek. United States Environmental Protection Agency, EPA-600/S2-82-090.

Pratt, J.M., Coler, R.A., Godfrey, P.J. 1981. Ecological effects of urban stormwater runoff on benthic macroinvertebrates inhabiting the Green River, Massachusetts. *Hydrobiologia* **83**: 29-42.

Quinn, J.M., Hickey, C.W. 1990a. Characterisation and classification of benthic invertebrate communities in 88 rivers in relation to environmental factors. *New Zealand Journal of Marine and Freshwater Research* **24**: 387-409.

Quinn, J. M., Hickey, C.W. 1990b. Magnitude of effects of substrate particle size, recent flooding and catchment development on Benthic Invertebrates in 88 New Zealand rivers. *New Zealand Journal of Marine and Freshwater Research* **24**: 411-427.

Reice, S.R. 1985. Experimental disturbance and the maintenance of species diversity in a stream community. *Oecologia (Berlin)* **67**: 90-97.

Rosenburg, D.M., Wiens, A.P. 1978. Effects of sedimentation on macrobenthic invertebrates in a North Canadian river. *Water Resources* **12**: 753-763.

SAS 1995. SAS User's Guide: Statistics. Version 6.1. SAS Institute Inc., Cary, North Carolina, USA.

Scott, D., White, J.W., Rhodes, D.S. 1994. Invertebrate fauna of three streams in relation to land use in Southland, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **28:** 277-290.

Scott, J.B., Steward, C.R., Stober, Q.J. 1986. Effects of Urban Development on Fish Population Dynamics in Kelsey Creek, Washington. *Transactions of the American Fisheries Society* **115**: 555-567.

Stark, J. D. 1985. A macroinvertebrate community index of water quality for stony streams. *Water and Soil Miscellaneous Publication* **87**: 53p.

Wang, L., Lyons, J., Kanehl, P., Gatti, R. 1997. Influences of Watershed Land use on Habitat Quality and Biotic Integrity in Wisconsin Streams. *Fisheries* **22**(6): 6-12.

Ward, J.A. 1975. Bottom fauna-substrate relationships in a North Colorado trout stream: 1945 and 1974. *Ecology* **56**: 1429-1434.

Way, C.M., Burky, A.J., Binham, C.R., Miller, A.C. 1995. Substrate roughness, velocity refuges, and macroinvertebrate abundance on artificial substrates in the lower Mississippi River. *Journal of the North American Benthological Society* **14(4)**: 510-518.

Whiting, E.R., Clifford, H.F. 1983. Invertebrates and urban runoff in a small northern stream, Edmonton, Alberta, Canada. *Hydrobiologia* **102**: 73-80.

Wilcock, R.J., McBride, G.B., Nagels, J.w., Northcott, G.L. 1995. Water quality in a polluted lowland stream with chronically depressed oxygen: causes and effects. *New Zealand Journal of Marine and Freshwater Research* **29**: 277-288.

Wilding, T.K. 1996. Effects of urban development on small stream ecosystems of Auckland and the influence of riparian vegetation. Unpublished MSc Thesis. The University of Auckland, New Zealand.

Williamson, R.B. 1985. Urban Stormwater Quality I. Hillcrest, Hamilton, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **19**: 413-427.

Williamson, R.B. 1986. Urban Stormwater Quality II. Comparison of three New Zealand Catchments. *New Zealand Journal of Marine and Freshwater Research* **20**: 315-328.

Winterbourn, M. J. 1973. A guide to the freshwater Mollusca of New Zealand. *Tuatara* **20**: 141-159.

Winterbourn, M. J., Gregson, K.L.D. 1989. *Guide to the Aquatic Insects of New Zealand.* Bulletin of the Entomological Society of New Zealand.

CHAPTER 4

General Conclusions.

GENERAL CONCLUSIONS

Stream invertebrate communities in the lower North Island are strongly influenced by catchment landuse. Streams in developed pastoral land consist of more pollution tolerant taxa as indicated by lower EPT and MCI scores. As a result both developed ecoregions: Manawatu Plains and Eastern Lowlands, were not distinguishable from one another based on their invertebrate fauna. Stream invertebrate communities in undeveloped ecoregions: Mount Taranaki, Volcanic Plateau and Central Mountains were also unable to be easily separated in the analyses. The strong influence of catchment development was highlighted in a Volcanic Plateau (Left of Ford) site that was located in a pastoral area within the unmodified ecoregion. Invertebrate communities at this site conformed to those in the other 2 developed ecoregions (Manawatu Plains, Eastern Lowlands). This shift in invertebrate composition between modified and unmodified sites is a common phenomenon in New Zealand streams (Winterbourn et. al., 1981). In previous study both in New Zealand and overseas, catchment landuse has been identified as a significant influence on invertebrate communities (Quinn & Hickey, 1990; Collier et. al., 1997; Quinn et. al., 1997).

Ecoregions in this study encompassed areas with a variety of landusage – ranging from relatively unmodified streams in forest/bush to pastoral streams. These landuse types were a better discriminator of the invertebrate data rather than the ecoregions.

The invertebrate communities in the urban Mangaone stream could be separated from the other surrounding pastoral sites in the Manawatu Plains. These communities were dominated by oligochaetes and chironomids and showed lower water quality scores than streams in the Manawatu Plains. Overseas study has also shown significant differences in invertebrate communities between urban and pastoral streams (Pedersen & Perkins,1986; Lenat & Crawford, 1994). The differences in invertebrate abundance between the two urban sites were attributed to differences in substrate composition and stability. Clearly, more research is needed on New Zealand's urban streams to examine invertebrate communities and define reference condition.

This study suggests that the comparability of stream invertebrate communities between streams in the lower North Island is going to be strongly influenced by catchment modification. The selection of reference sites should therefore be chosen from streams of similar landuse, for a more accurate indication of stream condition.
Trials of other classification systems such as RIVPACS, which take into account smaller scale influences on stream communities, should also be attempted so that we may be able to more accurately classify our streams and rivers.

REFERENCES

Collier, K.J., Smith, B.J., Baillie, B.R. 1997. Summer light-trap catches of adult Trichoptera in hill-country catchments of contrasting land use, Waikato, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **31**: 623-634.

Lenat, D.R., Crawford, J.K. 1994. Effects of land use on water quality and aquatic biota of three North Carolina Piedmont streams. *Hydrobiologia* **294**: 185-199.

Petersen, E.R., Perkins, M.A. 1986. The use of benthic invertebrate data for evaluating impacts of urban runoff. *Hydrobiologia* **139**: 13-22.

Quinn, J. M., Hickey, C.W. 1990. Characterisation and Classification of Benthic Invertebrate communities in 88 New Zealand rivers in relation to environmental factors. *New Zealand Journal of Marine and Freshwater Research* **24**: 387-409.

Quinn, J.M., Cooper, A.B., Davies-Colley, R.J., Rutherford, J.C., Williamson, R.B. 1997. Land use effects on habitat, water quality, periphyton, and benthic invertebrates in Waikato, New Zealand, hill country streams. *New Zealand Journal of Marine and Freshwater Research* **31**: 579-597.

Winterbourn, M. J., Rounick, J.S., Cowie, B. 1981. Are New Zealand stream ecosystems really different? *New Zealand Journal of Marine and Freshwater Research* **15**: 321-328.

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APPENDICES

APPENDIX 1

Mean invertebrate abundance from four replicate Surber samples taken from 10 streams in 5 ecoregions in May 1995. TK=Mount Taranaki, VP=Volcanic Plateau, CM=Central Mountains, EL=Eastern Lowlands, MN=Manawatu Plains.

	TK1	TK2	TK3	TK4	TK5	TK6	TK7	TK8	TK9	TK10
A. australense	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Acroperla spiniger	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Acroperla travicuata	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Austroperla cyrene	6.3	1.3	3.3	0.3	0.7	6.0	0.0	0.0	0.0	1.0
Alloecentrella magnicornis	0.7	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Amelotopsis	1.0	0.3	0.3	0.0	0.3	0.7	0.0	0.0	0.0	0.0
Aphrophila	4.3	3.0	0.7	2.0	0.0	4.3	2.0	0.0	0.3	0.3
Archicauliodes	13.0	0.0	8.7	2.0	0.3	5.3	0.0	0.3	0.0	8.0
Austroclima	32.3	8.7	12.7	0.3	0.0	5.0	0.0	0.0	0.0	7.0
Baraeoptera	0.7	0.0	0.0	2.0	0.0	20.0	2.0	2.7	0.0	0.0
Berosus	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae A	1.3	2.3	1.3	0.0	0.0	0.0	0.0	1.7	0.0	0.0
Chironomidae B	0.0	0.0	0.0	0.0	14.7	0.0	0.0	0.0	0.0	11.7
Chironomidae C	0.0	0.3	0.0	19.0	0.7	1.7	8.3	0.3	0.0	0.0
Chironomidae E	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Chironomidae (pupae)	0.0	0.0	0.0	0.7	0.0	0.3	0.3	0.0	0.3	0.7
Coleoptera	0.0	1.0	0.7	0.0	0.0	2.7	0.3	0.0	0.0	1.0
Coloburiscus	94.7	4.0	28.0	14.0	0.0	21.3	0.3	2.3	0.0	32.3
Confluens	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Costachorema brachyptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Deleatidium	114.7	6.7	111.3	182.3	216.0	84.3	39.3	119.7	7.0	83.0
Elmidae	24.7	22.0	5.3	10.3	43.0	19.7	18.7	33.3	0.3	9.0
Empididae	0.3	0.7	1.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Eriopterini	0.0	0.0	0.3	0.0	10.3	1.7	0.0	0.3	2.0	1.0
Ferrissia dohrnialis	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gyraulus	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Hydrobiosis clavigera	0.0	0.0	0.0	0.7	0.3	0.3	0.3	1.0	0.0	0.0
Hydrochorema crassicaudatum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Hydrobiosis frater	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Hydrobiosella mixta	1.7	2.3	2.0	0.7	0.7	2.3	0.0	0.0	0.0	6.0
Hydrobiosis perumbripennis	2.3	0.3	0.0	1.3	0.0	1.7	1.0	0.7	4.0	1.7
Hydrophilidae	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Ichthybotus	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Limnophora	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Megaleptoperla diminuta	0.0	0.0	0.7	0.3	0.3	6.7	1.0	0.0	0.0	0.0
Muscidae	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Neozephlebia	5.7	2.0	8.7	0.7	0.0	6.7	0.7	0.3	0.0	10.7
Nesameletus	1.7	0.7	5.0	5.3	2.0	1.3	0.0	9.0	0.0	2.7
Oligochaetes	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Olinga	0.3	0.0	0.0	0.0	0.0	3.0	0.0	0.7	0.0	0.0
Oniscigaster wakefieldi	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Orchymontia	1.0	0.0	1.0	0.0	0.7	1.7	0.0	0.3	0.0	0.0
Orthopsyche	18.7	32.0	8.0	1.3	0.3	14.7	1.7	1.0	0.0	16.0
Paralimnophila skusei-	0.0	1.3	0.0	0.0	0.3	0.7	0.0	0.0	0.0	0.0
Potamopyrgus	1.7	1.3	0.7	0.0	0.0	1.7	0.0	0.0	0.0	0.0
Psilochorema	2.0	0.3	0.7	0.7	0.0	6.7	0.0	0.0	0.0	0.3

	TK1	TK2	TK3	TK4	TK5	TK6	TK7	TK8	TK9	TK10
Psychodidae	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Ptilodactylidae	6.3	13.3	0.7	0.0	0.0	3.3	0.0	0.0	0.0	12.3
Pycnocentrella eruensis	0.0	0.0	1.3	0.0	0.3	0.3	0.0	0.0	0.0	0.0
Pycnocentrodes	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Scirtidae	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Spaniocercoides philpotti	0.0	0.0	0.7	0.0	1.7	0.0	0.0	0.3	0.0	0.7
Stenoperla prasina	1.0	4.3	4.3	2.0	4.3	2.7	0.3	1.0	0.0	0.7
Triplectides dolichos	0.0	0.0	0.0	0.0	0.0	1.7	0.7	0.0	0.0	0.0
Unknown three	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown two	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Zephlebia borealis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Zephlebia dentata	6.0	7.7	1.0	0.3	0.0	3.7	0.0	0.0	0.0	1.0
Zelandoperla spp	3.7	0.7	2.0	5.3	10.3	5.7	3.0	2.3	3.7	1.7
Zelolessica cheira	10.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zelandobius furcillatus	5.3	7.0	15.7	20.7	121.7	4.3	2.0	4.0	0.0	8.3

	CM1	CM2	CM3	CM4	CM5	CM6	CM7	CM8	CM9	CM10
A. australense	0.0	0.0	0.0	0.0	0.0	18.0	0.0	3.7	0.0	0.0
Acanthophlebia	0.0	0.0	0.0	7.7	0.0	0.0	0.7	0.0	0.0	0.0
Acroperla spiniger	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Austroperla cyrene	3.0	0.0	0.0	6.3	16.3	0.0	6.0	0.3	0.7	0.0
Aoteapsyche	24.7	12.0	7.7	0.7	0.0	70.3	2.0	0.3	1.0	1.0
Aphrophila	0.3	0.0	0.0	0.0	0.0	5.0	0.3	0.0	0.3	0.7
Archicauliodes	1.3	0.0	1.0	13.0	0.7	38.7	1.3	0.0	1.3	0.0
Baraeoptera	45.7	5.0	21.0	0.0	1.3	16.0	4.3	0.3	1.3	5.0
Ceratopogonidae	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae A	0.3	1.0	2.3	2.7	1.0	1.3	0.3	86.7	0.3	6.7
Chironomidae B	0.0	0.0	0.3	0.7	0.0	0.0	5.0	0.0	0.0	0.0
Chironomidae C	0.0	0.0	0.0	0.0	0.3	0.3	2.3	27.3	4.0	2.7
Chironomidae (pupae)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0	1.7
Coloburiscus	86.7	2.3	17.7	6.3	17.3	55.3	21.3	0.0	4.7	0.3
Deleatidium	194.3	131.0	128.0	46.0	68.3	153.7	236.3	28.0	94.3	150.3
Diptera unknown five	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Diptera unknown one	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Diptera unknown two	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Dolicopodidae	0.0	0.0	0.0	0.0	0.0	3.3	0.7	0.0	0.0	0.0
Elmidae	4.0	7.3	7.3	11.3	5.0	92.7	7.7	0.0	35.7	2.7
Empididae	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Eriopterini	0.3	0.0	0.3	1.0	1.7	6.7	0.3	0.0	0.7	0.3
Halticoperla vividans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.0
Hydrobiosis clavigera	0.3	2.7	2.3	0.0	1.3	0.3	5.0	0.0	0.0	0.0
Helicopsyche	2.7	3.3	31.3	0.0	0.0	51.7	12.7	0.0	0.0	0.0
Hydrobiosella mixta	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrobiosis perumbripennis	0.7	0.7	0.3	0.0	0.0	2.0	0.3	0.3	0.7	0.0
Hudsonema amabalis	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Hydrobiosella spp	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Hydrobiosis spp	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ichthybotus	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Megaleptoperla diminuta	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	1.3
Neozephlebia	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0
Nesameletus	0.3	0.3	6.3	2.7	0.0	0.0	11.7	0.0	1.3	0.0
Neurochorema	0.0	0.0	0.0	0.0	0.0	9.7	0.0	0.0	0.0	0.0
Oligochaetes	0.0	0.0	0.0	6.0	2.0	0.0	0.3	1.3	4.3	1.0
Olinga	23.3	1.3	18.3	0.0	2.0	14.7	14.0	3.7	1.0	0.3
Oniscigaster wakefieldi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Orchymontia	0.3	0.0	0.0	0.7	2.3	29.7	0.0	0.0	0.0	0.0
Orthopsyche	0.0	0.0	0.0	2.7	2.3	0.0	4.0	0.0	0.7	0.0
Pycnocentria evecta	0.0	0.0	0.0	0.0	0.0	28.7	0.0	0.0	0.0	0.0
Philopotamidae	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	CM1	CM2	CM3	CM4	CM5	CM6	CM7	CM8	CM9	CM10
Polycentropodidae	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Potamopyrgus	0.0	0.0	0.0	0.0	0.0	5.7	0.0	0.0	0.0	0.0
Psilochorema	0.7	1.3	1.0	1.3	1.3	0.3	0.3	0.0	2.0	0.3
Psychodidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Ptilodactylidae	1.0	0.0	0.0	3.0	0.3	0.3	0.3	0.0	0.0	0.0
Pycnocentrodes	4.3	0.0	0.7	0.0	0.0	1081.3	0.0	0.3	0.3	4.7
Scirtidae	0.0	0.0	0.0	0.0	1.7	2.7	0.0	0.0	0.0	0.0
Spaniocerca zelandica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Stenoperla prasina	3.3	3.7	2.7	2.7	4.3	0.3	2.3	1.0	7.0	0.3
Tabanidae	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Zelandobius confusus	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Zephlebia dentata	0.3	0.0	0.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0
Zelandobius spp	0.0	0.0	0.0	1.0	0.3	0.0	0.0	0.0	0.3	2.0
Zelandoperla spp	12.7	20.7	11.0	2.3	2.7	1.0	5.7	1.0	15.0	3.7
Zelolessica cheira	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zelandobius furcillatus	0.3	0.0	0.3	16.0	2.3	1.7	0.3	3.7	0.0	0.0
Zelandobius illiesi	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0

	VP1	VP2	VP3	VP4	VP5	VP6	VP7	VP8	VP9	VP10
A. australense	0.0	1.7	3.0	0.0	0.0	0.0	0.0	1.7	88.3	0.3
Acroperla spiniger	0.0	0.0	1.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Austroperla cyrene	0.0	25.3	2.3	0.0	0.0	7.3	2.3	0.0	0.0	0.0
Alloecentrella magnicornis	0.0	0.0	1.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Amphipoda	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aoteapsyche	0.0	0.0	0.0	0.0	0.0	23.3	0.0	0.0	33.0	0.3
Aphrophila	0.0	1.3	6.3	0.0	0.0	6.0	9.7	0.0	0.0	10.0
Archicauliodes	0.0	3.0	0.0	0.0	0.3	2.0	0.0	0.0	1.7	0.0
Austroclima	0.0	0.7	27.7	0.0	4.3	0.3	0.0	6.0	0.3	0.0
Baraeoptera	0.0	2.7	2.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0
Chironomidae A	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.0
Chironomidae B	0.0	4.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.7
Chironomidae C	0.3	10.0	24.0	0.0	0.0	6.7	79.0	10.3	16.0	5.7
Chironomidae D	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae E	0.0	0.0	1.0	0.0	0.0	0.7	11.0	0.7	2.0	15.3
Chironomidae F	0.0	0.0	9.7	0.0	0.0	0.0	0.7	0.7	44.3	3.3
Chironomidae (pupae)	0.0	0.0	0.3	0.0	0.0	0.0	1.7	0.3	0.7	0.0
Coleoptera	0.0	4.7	0.3	0.0	0.0	0.3	3.7	0.0	0.0	1.7
Coloburiscus	0.0	9.0	5.0	0.0	2.0	3.7	14.3	0.0	0.7	4.3
Costachorema psaraeoptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7
Deleatidium	3.3	145.0	19.3	2.0	67.3	151.3	93.7	14.0	172.0	107.0
Elmidae	0.0	29.0	0.3	0.3	2.3	32.0	10.3	3.0	8.0	7.3
Empididae	0.0	6.0	1.0	0.0	0.0	3.7	0.3	2.3	0.3	0.0
Eriopterini	0.0	1.3	0.0	0.0	0.0	5.7	0.7	1.7	0.0	0.7
Hydrobiosis clavigera	0.0	1.3	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
Hydrochorema crassicaudatum	0.0	0.7	2.0	0.0	0.0	0.3	0.7	0.3	0.0	0.3
Helicopsyche	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Hydrobiosella mixta	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	4.0
Hydrobiosis perumbripennis	0.3	12.0	12.7	0.0	0.0	2.0	1.3	0.0	8.0	1.0
Hydrobiosis spatulata	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
Hudsonema amabalis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0
Hydrobiosis spp	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.3	0.0	0.0
Limonia	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.7	0.0	0.0
Megaleptoperla diminuta	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0
Megaleptoperla grandis	0.0	1.7	0.7	0.0	0.0	1.3	0.3	0.0	0.0	0.0
Neozephlebia	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	7.7	0.0
Nesameletus	0.0	1.3	0.0	0.0	1.0	2.7	0.0	0.0	0.0	0.0
Neurochorema	0.0	0.0	4.3	0.0	2.0	2.0	0.0	0.0	0.0	0.0
Oeconesus spp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Oligochaetes	0.0	0.3	2.0	0.0	0.7	1.0	0.0	0.0	70.7	0.0
Olinga	0.0	3.3	767.3	0.0	0.0	0.3	0.3	0.3	0.3	0.0
Oniscigaster wakefieldi	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0
Orchymontia	0.0	21.3	0.0	0.0	0.0	2.0	13.0	0.0	0.0	11.3

	VP1	VP2	VP3	VP4	VP5	VP6	VP7	VP8	VP9	VP10
Orthopsyche	0.0	1.7	21.3	0.0	0.0	1.0	8.7	0.0	0.0	11.7
Ostracoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	114.0	0.0
Oxyethira	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0
Paralimnophila skusei	0.0	0.0	0.0	0.0	0.7	0.7	1.0	0.0	1.0	0.0
Pycnocentria evecta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.3	0.0
Pycnocentria funerea	0.0	0.0	140.3	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Polyplectropus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0
Potamopyrgus	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	499.3	0.0
Psilochorema	0.0	1.0	0.0	0.0	1.0	7.3	4.0	0.0	0.7	0.0
Ptilodactylidae	0.0	10.7	1.3	0.0	0.3	1.0	4.7	0.0	16.3	1.3
Pycnocentrella eruensis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Pycnocentrodes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	226.3	0.0
Scirtidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Spaniocercoides philpotti	0.0	0.0	0.0	0.0	0.0	0.3	1.3	0.0	0.0	0.0
Stenoperla prasina	0.0	7.3	0.0	0.0	0.0	2.7	2.0	0.0	0.0	1.3
Stratiomyidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Tabanidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0
Triplectides dolichos	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
Unknown five	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Unknown four	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Zephlebia dentata	0.0	0.7	0.0	0.0	0.3	0.0	0.0	0.0	27.3	0.0
Zelandobius spp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zelandoperla spp	4.7	20.0	31.3	0.0	0.0	7.7	2.3	1.3	0.3	0.7
Zelolessica cheira	0.0	0.3	12.3	0.3	0.0	0.0	0.0	2.3	0.0	0.0
Zelandobius furcillatus	0.0	28.3	57.3	0.0	0.3	4.7	20.0	2.0	0.0	5.3

	EL1	EL2	EL3	EL4	EL5	EL6	EL7	EL8	EL9	EL10
A. australense	167.3	18.7	0.7	410.7	1.7	23.3	93.0	0.0	3.0	27.3
Amphipoda	0.0	0.0	0.7	0.0	0.0	0.0	154.0	0.0	0.0	0.0
Aoteapsyche	323.7	19.0	42.3	0.0	0.3	0.0	2.3	1.0	3.0	3.7
Aphrophila	0.0	1.7	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Archicauliodes	0.0	1.7	1.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Austroclima	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae A	13.7	15.3	44.3	80.3	7.7	4.0	644.7	195.3	24.7	443.7
Chironomidae B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae C	13.3	1.3	0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.0
Chironomidae E	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.3	0.0
Chironomidae F	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0
Chironomidae (pupae)	0.0	0.0	0.0	0.0	0.0	0.0	2.7	1.3	0.3	0.0
Coloburiscus	0.0	0.0	6.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Damsel/dragonfly	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Deleatidium	112.7	76.7	194.7	0.0	0.0	0.3	0.0	2.3	15.0	23.0
Elmidae	233.7	51.3	439.7	0.0	1.7	0.0	1.3	12.0	18.0	5.0
Eriopterini	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ferrissia dohrnialis	13.7	21.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gyraulus	0.0	0.0	0.0	2.0	0.0	0.3	0.0	8.7	0.0	0.0
Hirudinea	0.0	0.0	0.0	0.0	0.0	8.3	0.0	0.0	0.0	0.0
Hydrobiosis perumbripennis	7.3	2.0	4.0	6.0	0.3	0.0	0.3	5.7	5.3	6.7
Hydrobiosis spatulata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hudsonema amabalis	0.3	29.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Megaleptoperla diminuta	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Neozephlebia	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Neurochorema	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oligochaetes	7.0	118.7	14.3	256.0	11.7	60.7	8.3	108.3	1.3	8.0
Olinga	5.3	0.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ostracoda	0.0	0.0	0.0	0.0	0.0	5.7	0.0	1.3	0.0	0.0
Oxyethira	0.0	0.0	0.7	0.7	0.7	1.3	6.7	0.0	0.3	13.7
Paracalliope	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Paralimnophila skusei	0.0	0.0	0.0	0.7	0.3	0.0	0.0	0.0	0.0	0.0
Pycnocentria evecta	0.7	63.0	26.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Physa	24.0	0.0	4.0	3.0	0.7	133.3	0.3	18.3	0.3	5.0

	EL1	EL2	EL3	EL4	EL5	EL6	EL7	EL8	EL9	EL10
Potamopyrgus	463.3	104.3	16.7	114.0	8.7	4815.3	13.7	6.0	1.7	5.3
Psilochorema	0.0	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Pycnocentrodes	73.0	1.0	165.3	0.0	0.0	0.0	0.0	0.7	1.7	0.3
Sphaerium novaezelandiae	0.0	0.0	0.0	0.0	0.0	54.7	0.0	0.0	0.0	0.0
Stratiomyidae	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.3	0.0
Tabanidae	1.0	0.0	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown one	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Zephlebia dentata	8.3	25.3	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zelandobius spp	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zelandobius furcillatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Oxyethira pupae	3.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flatworm	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.3	0.0	0.3

	MN1	MN2	MN3	MN4	MN5	MN6	MN7	MN8	MN9	MN10
A. australense	1.7	10.0	0.7	135.0	2.7	3.0	0.0	0.0	9.0	8.3
Amphipoda	0.0	0.0	1.0	2.3	0.0	0.3	0.0	0.0	8.7	1.0
Anisoptera	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Antiporus	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Aoteapsyche	0.3	28.7	0.0	35.0	1.7	0.0	0.0	0.0	90.3	21.0
Archicauliodes	0.7	2.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0	0.0
Austroclima	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	84.3
Berosus	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae A	33.3	1.0	3.7	11.7	0.3	30.7	1.7	0.3	0.0	14.3
Chironomidae C	0.3	0.0	0.0	0.3	0.7	2.3	0.0	0.0	0.0	8.7
Chironomidae D	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Chironomidae (pupae)	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.7
Deleatidium	0.0	283.0	0.0	2.3	0.0	1.3	0.0	0.3	182.0	0.3
Elmidae	0.7	49.0	0.0	15.3	0.0	48.0	0.0	0.0	0.0	10.3
Empididae	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Eriopterini	0.0	0.0	0.0	0.0	0.0	0.3	1.7	1.7	0.0	1.3
Ferrissia dohrnialis	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gyraulus	0.0	0.0	0.0	0.0	0.0	3.3	1.3	3.7	1.7	0.0
Helicopsyche	0.0	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hirudinea	1.0	0.0	0.3	0.0	0.0	0.3	0.3	0.0	0.0	0.0
Hydrobiosella mixta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrobiosis perumbripennis	7.3	2.0	0.3	1.7	1.0	4.7	0.0	0.0	0.0	14.0
Hudsonema amabalis	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Hydrobiosis umbripennis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Hydrobiosis spp	0.0	0.0	0.0	0.7	0.0	0.0	0.7	0.0	0.0	0.0
Hydrophilidae	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Hydroptilidae spp	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Hygraula nitens	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Latia neratoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.3	0.0
Limnophora	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3
Lymnaea columella	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Megaleptoperla diminuta	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0
Neozephlebia	0.0	0.0	0.0	0.0	6.3	0.0	0.0	0.0	29.3	94.7
Neurochorema	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Oeconesus spp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
Oligochaetes	45.3	4.0	19.0	54.3	1.0	4.3	2.7	3.0	9.3	15.0
Olinga	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Ostracoda	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.3	0.0	8.7
Oxyethira	0.3	0.3	1.0	1.0	2.0	101.0	6.0	0.0	4.0	56.7
Pycnocentria evecta	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Physa	30.7	0.0	10.0	0.0	7.7	7.3	1.3	1.0	14.7	6.7
Polyplectropus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	4.7
Potamopyrgus	393.7	11.3	23.0	44.3	52.0	18.3	0.3	0.0	627.0	762.0
Psilochorema	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	11.0	0.7
Pycnocentrella eruensis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.3
Pycnocentrodes	0.0	0.7	0.0	15.3	0.0	0.0	0.0	0.0	0.0	0.0

	MN1	MN2	MN3	MN4	MN5	MN6	MN7	MN8	MN9	MN10
Sigara	0.0	0.0	1.7	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Sphaerium novaezelandiae	2.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	5.0
Staphylinidae	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stratiomyidae	0.3	0.0	1.7	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Veliidae	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xanthocnemus	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0
Zephlebia dentata	2.7	0.0	0.0	10.7	0.0	0.0	0.0	0.0	332.0	75.0
Zelandobius furcillatus	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zephlebia versicolor	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Zygoptera spp	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0
Flatworm	1.0	0.3	0.3	0.0	0.0	1.3	0.0	0.0	0.0	0.0

APPENDIX 2

Mean physico-chemical measures made at 10 streams in 5 ecoregions in May 1995. TK=Mount Taranaki, VP=Volcanic Plateau, CM=Central Mountains, EL=Eastern Lowlands, MN=Manawatu Plains.

SITE	STREAM	GRID REFERENCE		Pfankuch stability	%Canopy Cover	Average Depth(m)	Width(m)	Velocity(m/sec)	Conductivity (uS/cm)	Substrate Index	Temperature (C)
CM 1	Otaki	sht8	698045	53	40	0.27	4.5	0.662	92	5.2	12.9
CM 2	Waiti	sht8	713060	80	100	0.163	3.2	0.554	76	5.45	12
CM 3	Waikawa	sht8	702050	66	20	0.25	3.9	0.554	86	5.9	11
CM 4	Mangaroa	sht8	728062	75	80	0.12	1.1	0.446	59	5.95	12.8
CM 5	Kiriwhakapapa	sht8	725041	83	90	0.24	3.7	0.879	66	5.7	11.5
CM 6	Ohinetapu	sht6	756112	74	10	0.1	2	0.5	162	5.1	11
CM 7	Matanganui	sht6	762110	69	5	0.06	2	0.5	77	5.3	9.5
CM 8	Tamaki	sht6	767117	109	10	0.14	2.2	1.4	71	4.4	9.2
CM 9	Coppermine	sht6	756102	74	0	0.28	4.2	0.4	82	5.2	8.9
CM 10	Manapuaka	sht6	752106	113	5	0.22	2.6	0.76	73	4.4	9.5
TK 1	Timaru(tributary)	sht 6	595222	67	70	0.13	3.4	0.662	80	5.65	10.2
TK 2	Oakura	sht 6	598225	65	95	0.13	1.5	0.359	52	5.4	9.7
TK 3	Mangorei	sht 6	602222	75	80	0.22	3.4	0.532	39	6.1	9.2
TK 4	Timaru	sht 6	595220	66	10	0.25	3.3	0.554	43	5.9	8.8
TK 5	East Egmont	sht 6	606210	57	20	0.05	1.6	0.27	39	5.3	7.2
TK 6	Auroa	sht 6	595203	70	80	0.24	3.5	0.446	90	5.3	7.6
TK 7	Cold Water	sht 6	597202	91	80	0.28	2.7	0.446	88	5.45	8
TK 8	Mormona	sht 6	598205	76	60	0.17	4	0.532	46	5.6	10
TK 9	Oanui	sht 6	592206	83	5	0.18	4	0.662	90	5.4	9.7
TK 10	Paopaohaonui	sht 6	598224	107	100	0.662	1.7	0.446	51	5.2	10.2
VP 1	Ruapehu	sht 6	730218	83	90	0.14	2	0.662	153	4.2	9.5
VP 2	Waiharuru	sht 6	735198	77	70	0.09	3	0.36	80	4.5	5.1
VP 3	Waiharuru(tributary)	sht 6	734198	76	10	0.21	3.6	0.77	114	3.9	6.1

SITE	STREAM	GRID REFERENCE		Pfankuch stability	%Canopy Cover	Average Depth(m)	Width(m)	Velocity(m/sec)	Conductivity (uS/cm)	Substrate Index	Temperature (C)
VP 4	Desert rd.	sht 6	745216	57	90	0.14	1.2	0.662	22	4.1	10.7
VP 5	Mangetepopo	sht 6	735235	78	80	0.19	1.75	0.879	12	4.1	11.6
VP 6	Ohakunemountainrd.	sht 6	722202	83	80	0.04	1.5	0.4	48	4.2	3
VP 7	Mangahuia	sht 6	748225	81	45	0.16	2	0.4	34	5.6	6.4
VP 8	Wharepu	sht 6	725225	86	100	0.14	0.9	0.359	46	4.9	7.8
VP 9	Left of ford	sht 6	771177	62	0	0.14	0.9	0.662	154	7	9.8
VP 10	Whakapapa culvert	sht 6	724223	70	80	0.1	1.5	0.25	33	5.6	6.9
EL 1	Tapuata	sht 7	773108	114	0	0.25	0.8	0.71	124	4.3	9.7
EL 2	Ohuha	sht 8	744051	105	0	0.14	1.6	0.532	176	3.8	14.9
EL 3	Balance	sht 8	746084	104	0	0.15	3.3	0.9	202	4.1	12.5
EL 4	Parangahou	sht 7	792123	104	0	0.15	1.3	0.76	232	4	9.8
EL 5	Te punga	sht 8	744050	113	0	0.12	1.6	0.446	128	3.8	14
EL 6	Butler rd	sht 7	807145	113	0	0.12	1.5	0.48	184	4.1	10.3
EL 7	Pinfold rd	sht 8	756096	90	0	0.17	1.2	0.532	138	5.75	16.3
EL 8	Mangaonuku	sht 7	808155	86	60	0.18	2.5	0.9	97	4.3	12.3
EL 9	Matamau	sht 7	780115	118	0	0.12	1.9	0.83	118	4.3	9.9
EL 10	Ongaonga	sht 7	802137	99	0	0.16	3.3	0.77	146	4.6	12
MN 1	Mangapipi	sht 6	735135	89	5	0.06	1.5	1.1	124	4.2	11
MN 2	Waituna West	sht 6	736126	106	50	0.19	3	0.83	118	3.9	10.7
MN 3	MacKay rd.	sht 6	732116	101	5	0.25	2.5	1.2	237	3.7	11.3
MN 4	Travistock rd.	sht 8	708065	102	0	0.08	3	0.879	236	3.7	14.6
MN 5	Manutahi	sht 6	746166	83	2	0.16	1	0.554	298	5.4	10
MN 6	Haynes creek	sht 6	735116	107	0	0.25	3.5	1.3	200	4.35	11.5
MN 7	Mangaone	sht 6	736106	101	0	0.28	3	1	188	4.1	11.3
MN 8	Bunny	sht 8	742098	124	10	0.12	2.5	0.67	269	4	10.4
MN 9	Tutaenui	sht 6	715132	105	80	0.08	1	0.662	232	4.8	10.6
MN 10	Pukenaua	sht 6	750165	82	20	0.14	1.4	0.662	262	5.2	10

APPENDIX 3

Mean invertebrate abundance from four replicate Surber samples at bimonthly intervals for 12 months in 1995 from two sites on the urban Mangaone stream (D=Downstream site, R=Racecourse site)

	R1	**R2**	**R3**	**R4**	**R5**	**R6**	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**
A. australense	0	0	0.25	0	0	0	0	0	0.25	0	0.25	7.5
Amphipoda	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Anisops	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Aoteapsyche	0.3	0.0	0.0	0.0	0.0	0.5	17.5	0.0	0.0	0.0	0.0	0.0
Berosus	0.5	0.3	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.3
Chironomidae A	1073.5	138.5	75.3	3.5	34.5	648.5	1093.5	2.0	0.5	1.3	1.0	1844.0
Chironomidae B	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae C	0.0	108.5	160.5	65.3	108.3	499.3	0.0	0.0	0.0	0.3	0.0	614.0
Chironomidae D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Chironomidae (pupae)	3.3	16.5	9.5	0.5	0.0	30.5	15.5	0.8	0.3	0.0	0.0	102.5
Costachorema brachyptera	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elmidae	11.0	22.0	14.3	27.0	0.0	37.5	18.0	0.5	0.5	0.0	0.5	0.5
Gyraulus	0.5	0.0	0.0	0.0	0.0	0.5	2.3	0.0	0.0	0.0	0.0	0.0
Hirudinea	11.0	8.0	2.3	0.5	0.0	1.0	0.8	0.3	0.0	0.3	0.0	0.0
Hydrobiosis perumbripennis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Limnophora	2.0	1.0	0.8	0.0	0.0	41.8	0.8	0.0	0.0	0.0	0.0	1.5
Lymnaea columella	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0
Oligochaete	9.5	42.5	205.5	283.5	118.0	245.8	10.0	3.8	3.8	13.3	0.3	0.3
Ostracoda	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Oxyethira	0.0	0.0	0.0	0.5	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.3
Physa	7.3	5.3	0.8	0.0	0.0	35.8	52.3	0.0	0.0	0.3	0.0	1.3
Potamopyrgus	71.3	21.8	2.3	2.8	4.5	146.5	69.0	1.8	0.0	0.8	0.0	4.3
Sigara	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.3	0.0	0.0	1.0
Staphylinidae	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Xanthocnemis	0.0	0.0	0.5	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Oxyethira (pupae)	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flatworm	0.0	0.5	2.5	0.5	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0