METHODS OF ASSESSMENT OF MACROINVERTEBRATE BIODIVERSITY IN NEW ZEALAND STREAMS

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ABSTRACT

In this study different sampling methodology and strategy was explored to develop an efficient inventory protocol for assessing biodiversity of stream macroinvertebrates in New Zealand. In a preliminary study 3 benthic invertebrate sampling techniques (Surber, kicknet and individual stone sampling) were compared to examine which maximised collected biodiversity per unit effort. Kicknet samples collected a higher number of taxa than either Surber or individual stone samples. Three-minute kicknets collected significantly more taxa than the other techniques, although 30-second kicknets collected the most taxa per unit effort. Detrended correspondence analysis of sampling techniques showed groupings of 30-second and 1-minute kicknets, 5 or more Surber samples, or individual stones samples collected the best representation of the community.

Three strategies of sample collection using kicknet samples were investigated in 54 streams, in 3 conservation regions in the South Island, to see which collected greater taxa richness per unit effort. These strategies examined taxa accumulation in three samples in a) the same stream, b) different streams within one region, c) different streams in each of the 3 regions. Collected taxa richness was higher when sampling effort was spread over more habitats and a larger area i.e., strategy b and c.

Environmental characteristics measured at each stream, were assessed to examine links between community structure and habitat characteristics. Community structure was most strongly linked with altitude, canopy cover, moss cover, stream width, and temperature. Five groups of communities were identified ranging from small high altitude streams with moss and high canopy cover, to larger more open low altitude streams. These groups had a common core of invertebrate taxa that differed in density and relative abundance. To test for the presence of indicator taxa of biodiversity, individual taxa densities were correlated with total taxa richness. Several taxa e.g., *Archichauliodes diversus* and *Coloburiscus humeralis* showed positive linkages with taxa richness, but none were particularly strong suggesting indicator taxa might not be appropriate for the measurement of invertebrate biodiversity in New Zealand streams.

EXPLANATION OF TEXT

This thesis is a combination of three individual papers. This has resulted in some replication of introductions, methods and site descriptions in Chapters 2 and 3.

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"When one tugs at a single thing in nature, he finds it attached to the rest of the world"

John Muir, 1911

1

GENERAL INTRODUCTION

"Biological diversity, or biodiversity for short describes the variety of all biological life – plants, animals, fungi and micro-organisms – the genes they contain and the ecosystems on land or in water where they live. It is the diversity of life on earth" New Zealand Biodiversity Strategy 2000.

It has been said that biodiversity is "the key to the maintenance of the world as we know it" (Wilson 1992). In the past decade since the term "Biodiversity" was introduced (Wilson 1988), it has grown as one of the central themes in both applied and theoretical ecology and become one of the principal goals of conservation internationally. As a result, the focus of conservation and ecological research has shifted from single species studies and given a more holistic approach to the conservation of the world's biological resources (Pearson and Cassola 1992; Wilson 1992; Colwell and Coddington 1994; Harper and Hawksworth 1994; Pearson 1994; Williams and Gaston 1994; Suter 1998; Department of Conservation 2000).

Species inventories are being used more frequently to document biodiversity patterns and determine parameters controlling those patterns, in order to protect and manage areas of biological diversity (Stohlgren et al. 1995; Keating et al. 1998; Vinson and Hawkins 1998). These inventories and surveys use large proportions of conservation budgets, and demand for such surveys is still increasing. Limitations to funding and resources mean that designing cost effective inventories remains an important challenge for ecologists and resource managers (Colwell and Coddington 1994; Harper and Hawksworth 1994; Pearson 1994; Williams and Gaston 1994; Keating et al. 1998). This highlights the importance of allocating sampling effort in the most cost effective manner possible while considering sampling methodology to ensure collection of maximum taxa in biodiversity inventories

(Colwell and Coddington 1994; Pearson 1994; Keating et al. 1998; MacNally and Fleishman 2002)

The New Zealand Biodiversity Strategy (Department of Conservation 2000) was published in response to the decline of New Zealand's indigenous biodiversity. It fulfils, in part, commitments New Zealand made under The International Convention on Biological Diversity in 1992 (UNEP 1992). The purpose of the Strategy is to establish a strategic framework for action, to conserve and sustainably manage New Zealand's biodiversity (Department of Conservation 2000). Key areas highlighted by the strategy include increasing knowledge of our indigenous biodiversity and identifying key threats, as well as developing performance standards and codes of practice for monitoring biodiversity (Department of Conservation 2000) To gain much of this information and to protect and manage areas of biological diversity it is necessary to conduct biological inventories of many habitats and areas throughout New Zealand.

New Zealand's isolated nature and variety of habitats has given rise to a unique and highly endemic invertebrate fauna (Boothroyd 2000), within which there is a vital need to establish biodiversity patterns. It has been suggested that it is logical to use the most diverse group of organisms for planning in conservation and management of biodiversity, yet this has not happened (Colwell and Coddington 1994). Many areas of New Zealand have not been surveyed for invertebrates, many invertebrates are undescribed and for those that are described we have little information about their distribution, habitat preferences, ecology and possible threats to their long-term survival. The abundance and variety of streams and freshwater habitats within New Zealand has lead to a highly speciated and distinctive freshwater fauna, of which our knowledge of the distribution and taxonomy is equally limited (Collier 1992; Boothroyd 2000; Collier et al. 2000). Existing survey and monitoring programmes are generally not sufficient to define freshwater biodiversity or to identify changes in freshwater species composition and abundance or habitat condition (Boothroyd 2000; Department of Conservation 2000). To design cost effective inventories for stream macroinvertebrates, the allocation of sampling effort in the most efficient manner possible and a sampling methodology which collects greatest biodiversity per unit effort is required (Colwell and Coddington 1994; Vinson and Hawkins 1998).

In this study of the assessment of macroinvertebrate biodiversity within New Zealand streams, three approaches are used. Taxa richness is used as the measure of biodiversity in this study, as it is a commonly used measure of biodiversity (Vinson and Hawkins 1998; Gaston 2000). In a preliminary study conducted in Te Urewera National Park, 3 common sampling techniques (Surber, kicknet and individual stone sampling) are compared to investigate which collects the highest biodiversity per unit effort. In the second stage of this study (Chapter Two), a sampling protocol for assessing macroinvertebrate biodiversity is examined in 3 conservation parks, Abel Tasman National Park, Kahurangi National Park and Mt Richmond Forest Park, in the Nelson region of the South Island. Three methods of sample collection at several scales are investigated with regard to taxa richness collection. Chapter Three analyses stream invertebrate community assemblages to determine if there are differences between the three regions and if so which environmental characteristics are most closely linked to community structure. The occurrence of potential biodiversity indicator taxa within these communities is also assessed. The overall aim of the study is to develop a cost effective and efficient sampling protocol within which resource and conservation managers can assess the freshwater biodiversity of a region and focus conservation effort on appropriate areas.

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2

A COMPARISON OF SAMPLING METHODS FOR MAXIMISING THE COLLECTION OF STREAM MACROINVERTEBRATE BIODIVERSITY

ABSTRACT

Three commonly applied benthic invertebrate sampling techniques (Surber samples, kicknet samples and individual stone samples) were compared to examine which maximises collected biodiversity per unit effort. This study was conducted in a small forest stream of Te Urewera National Park, New Zealand, as part of a preliminary study to develop a biodiversity protocol for stream macroinvertebrates. Kicknet samples collected a higher number of taxa than either Surber or individual stone samples. The 3-minute kicknet collected significantly more taxa than the other techniques, although the 30-second kicknet collected the most taxa per unit effort. Detrended correspondence analysis of sampling techniques showed groupings of 30-second and 1-minute kicknets, 5 or more Surber samples, or individual stones samples collected the best representation of the benthic community. It is concluded that approximately 3-5 short time period kicknets are most useful in collecting representative taxa in biodiversity inventories.

Keywords: biodiversity, individual stone sampling, kicknet, sampling techniques, stream macroinvertebrates, Surber sampler, taxa richness, Te Urewera National Park.

INTRODUCTION

Biodiversity has become a popular phrase in ecology and resource management over recent years, switching the focus away from single species studies to a more holistic approach to conservation. Protecting and preserving this biodiversity has become one of the principal goals of conservation internationally (Wilson 1992; Colwell and Coddington 1994; Harper and Hawksworth 1994; Williams and Gaston 1994; Suter 1998; Department of Conservation 2000). To protect and manage areas of biological diversity, species inventories are being used more frequently, to document patterns and determine possible causes of these patterns (Stohlgren et al. 1995; Keating et al. 1998; Vinson and Hawkins 1998). These inventories and surveys use large proportions of conservation budgets with a still increasing need. Limitations to funding and resources mean that designing cost effective inventories remains an important challenge for ecologists. (Pearson 1994; Williams and Gaston 1994; Keating et al. 1998)

To design cost-effective biodiversity inventories for stream invertebrates, a sampling methodology that collects the greatest biodiversity (generally measured in terms of taxa richness) per unit effort, is required (Vinson and Hawkins 1998). A variety of techniques have been developed over the years for sampling freshwater invertebrates including Surber samples, kick net samples, box samplers artificial substrates, dredging and coring (Hughes 1975; Resh 1979). These all have certain advantages and disadvantages often with concern as to precision, practicality, sampling representative collections of the community present and being appropriate to the organism or its lifecycle stage (Resh 1979; Peckarsky 1984; Winterbourn 1985). The design of any sampling programme depends on the questions being asked (Resh 1979), thus measuring biodiversity will require different sampling strategies to water quality, productivity and population studies.

Two of the most commonly used sampling methods for collecting stream macroinvertebrates are Surber sampling and kicknet sampling (Hynes 1970; Hughes 1975; Stark 1993). The Surber is the most commonly used quantitative sampler suitable for community studies (Hughes 1975; Winterbourn 1985). The kicknet was formally described by Frost et al in 1971 (Winterbourn 1985), and is widely considered a convenient and effective qualitative method that does not rely on cumbersome or expensive equipment (Mackey et al. 1984; Reynoldson and Rosenberg 1996). It is especially good for collecting species lists (Mackey et al. 1984), and is one of the few techniques available in rivers where the substratum is large, rough and unsorted (Cowie 1985; Winterbourn 1985). Invertebrate collection by kicknet sampling is affected by its duration, kicking intensity, behaviour of fauna, mesh size and flow (Winterbourn 1985). Where as full a complement of species as possible is desired, a collection should cover a large area of the stream bottom (Winterbourn 1985).

Individual stone sampling is another technique advocated by Doeg & Lake (Doeg and Lake 1981; Wrona et al. 1986). It provides quantitative density data by taking individual stones as sampling units, a method which can be useful in New Zealand streams where beds are often irregular and rocky and Surbers can not be easily used (Winterbourn 1985; Death and Winterbourn 1995). Stones in streams can be regarded as segments of habitat. They are rapidly colonised, and are quickly and easily sampled as discrete units (Winterbourn 1985; Douglas and Lake 1994).

Not only does the sampling technique (i.e., surber or kicknet) used in freshwater studies often differ, but the number of samples/replications is also widely debated with no simple answer as to how many replicates will be required to collect the highest number of taxa or best representation of the benthic community. Again, it is dependant on the goals of the study (Resh 1979; Winterbourn 1985). The number of taxa encountered in a sample increases asymptotically as functions of both the area sampled and the number of individuals in the sample. Larger numbers of individuals per sample increase the likelihood new taxa will be encountered. (Arrhenius 1921; Preston 1948; Hart and Horwitz 1991; Soberon and Llorente 1993; Douglas and Lake 1994; Vinson and Hawkins 1996; Keating and Quinn 1998). Resh (Resh 1979), states sample number "is generally determined by experience or intuition and then modified by cost". Stark (Stark 1993), considers, as few samples as possible are desirable in view of the relatively high cost of sample processing (1-4 hrs per Surber). Most relatively pristine stream faunas include a few abundant species and a large number of less common ones meaning that as sampling effort is increased the number of taxa should increase as rare species are encountered (Winterbourn 1985; Allen 1995; Death 1996). Generally, studies show 4 – 6 samples appear to be necessary to compile a representative list of taxa, while considerable replication (12 – 20) would be preferable if a comprehensive and accurate species inventory is required (Mackey et al. 1984; Winterbourn 1985; Stark 1993; Reynoldson and Rosenberg 1996).

In this study the 3 common sampling techniques (Surber, kicknet and individual stone sampling) are compared to investigate which collects the highest biodiversity per unit effort. Biodiversity is measured as taxa richness in this study as it is a commonly used measure of biodiversity (Vinson and Hawkins 1998; Gaston 2000). The kicknet samples are tested over 3 different time periods, 30-second, 1-minute and 3-minutes. Samples are collected from riffle habitats, which are known to have higher species richness and be dominated by insect larvae (Hynes 1970; Hughes 1975; Winterbourn 1985). I investigate which technique and how many samples will be required for efficient and cost effective biodiversity inventories.

METHODS

Study area

Waiaruhe Stream, a small second order forest stream in Te Urewera National Park, was selected to compare sampling techniques as it has a high biodiversity (Death in press). Te Urewera National Park is situated in the East Coast of the North Island of New Zealand and consists of a total land area of 212 673 hectares. It was created in 1954 and is both the largest national park and the largest area of original native forest in North Island (Department of Conservation 2002).

Environmental measures

Environmental characteristics were assessed at the time of sample collection. Water quality parameters measured included conductivity (measured with an Orion 122 Conductivity meter), temperature and pH (measured with an Oakton waterproof pHtestr). Width, depth and current velocity (measured with a Marsh McBirney velocity metre) were also measured. Percent riparian vegetation composition, canopy cover and moss presence were visually assessed. Waiaruhe Stream is in completely native vegetation having about 80% overhead cover with a mean depth of 18 cm, mean width of 2.8 m and mean water velocity of $0.35 ms^{-1}$. Temperature recorded at the time of sample collection was 7.8°C with a pH of 8.4, and water conductivity of 158.8μS/cm.

Invertebrate samples

Samples were collected on October 18, 2000. Three techniques were used for collecting invertebrate samples. Ten replicate individual stone samples (each consisting of 3 stones of different size classes: maximum linear, planar dimensions <60mm, 60-90mm, 91-180mm). Stones were sampled as the collector moved progressively up stream. A 250μm mesh net was held behind each stone, which was lifted quickly into it. Ten replicate Surber samples (0.1 m^2, 250μm mesh) and three, 30-second kick net samples; four, 1-min kick net samples and one, 3-min kick net sample (250μm mesh), were collected. All samples were collected in random order from riffles along a 200m length of the stream reach. Samples were stored in 10% formalin. In the laboratory, samples were filtered through a 500μm sieve and invertebrates identified where possible to species level using available keys and counted (McFarlane 1951; Cowley 1978; Towns 1983 ; Winterbourn, and Gregson 1989). If it were not possible to identify invertebrates then they were grouped into apparent morphospecies.

Data analysis

Taxa accumulation curves were derived for each sampling technique by calculating cumulative taxon richness of samples accumulated in random order. A taxa accumulation curve (or collectors curve) is a plot of the cumulative number of species collected within an area, as a function of some measure of the effort to collect them (Colwell and Coddington 1994). Average values of taxon richness were calculated for every possible combination of successive samples. This eliminates variation arising from sampling error (Colwell and Coddington 1994). Data was checked for normality and homodescasity. Analysis of Variance (ANOVA) was used to determine if significant differences occurred between the 3 sampling techniques. Further examination of significant models was carried out using Multiple Comparison Procedures (SAS 8e, 2001).

A Detrended Correspondence Analysis (DECORANA) was performed in PC-ORD (McCune and Mefford 1999), to examine which sampling technique gave the best representation of the invertebrate community in the stream. The community was assumed to be represented by the sum of all the animals collected in all the samples.

This was investigated for individual samples, groupings of samples (i.e., 5 surber samples) and all samples of each technique (i.e., 10 surber samples).

RESULTS

The series of 10 replicate Surbers contained between 16 and 26 taxa per sample, whereas individual stone samples (i.e., 3 stone sizes) contained only 13 to 21 taxa. The three, 30-second kicknets contained 19 to 29 taxa, the four, 1-minute kicknets contained 16 to 30 taxa while the 3-minute kicknet contained 46 taxa (Appendix 1). The kicknet samples generally yielded higher minimum, maximum and average numbers of taxa with the 3-minute kicknet having a substantially higher number of taxa. (Table.2.1). When corrected for unit effort, 30-second kicknet gave the same number of taxa as the 3-minute kicknet, with the 1-minute kicknet being slightly lower. The individual stone samples gave consistently lower taxon numbers than the other methods. Statistically there was a significant difference in total taxon richness collected by the 3-minute kicknet sample and all other sample techniques ($F_{4,23} = 11.71$, $P<0.001$).

Table 2.1. Summary of minimum, maximum and average numbers of taxon collected with different sampling methods at Waiaruhe Stream, October 2000.

	Minimum	Maximum	Average
Individual stones (10)	13	21	17.7
Surbers (10)	16	26	20.1
30 second kicknet (3)	19	29	24
1 minute kicknet (4)	16	30	24
3 minuter kicknet (1)	46	46	46

The number of taxa collected increased with sampling effort (Fig.2.1). For all sampling techniques the accumulation curves had not reached asymptotes, indicating more replicates were required to collect all taxa present. By extrapolating the curves it would appear that the curves for 30-sec and 1-minute kicknets could be expected to plateau around 7-8 samples at 45 to 48 taxa, Surbers and individual stones would plateau around 15 – 16 samples at approximately 50 taxa. One 3-minute kicknet collected more taxa than most other methods of expected equal unit effort. The exception was the 30-second kicknet, which appears to collect a slightly higher level of taxa when 6 samples are collected (6 x 30 sec = 3mins). From Figure 2.1, it can be seen, that to collect an equal level of taxa to that of one, 3-minute kick net approximately five, 1-minute kicknet samples, 7 Surber samples or up to 12 individual stone samples would be required. Interestingly 30 second and 1-minute kicknet samples had similar collection rates, despite differences in unit effort.

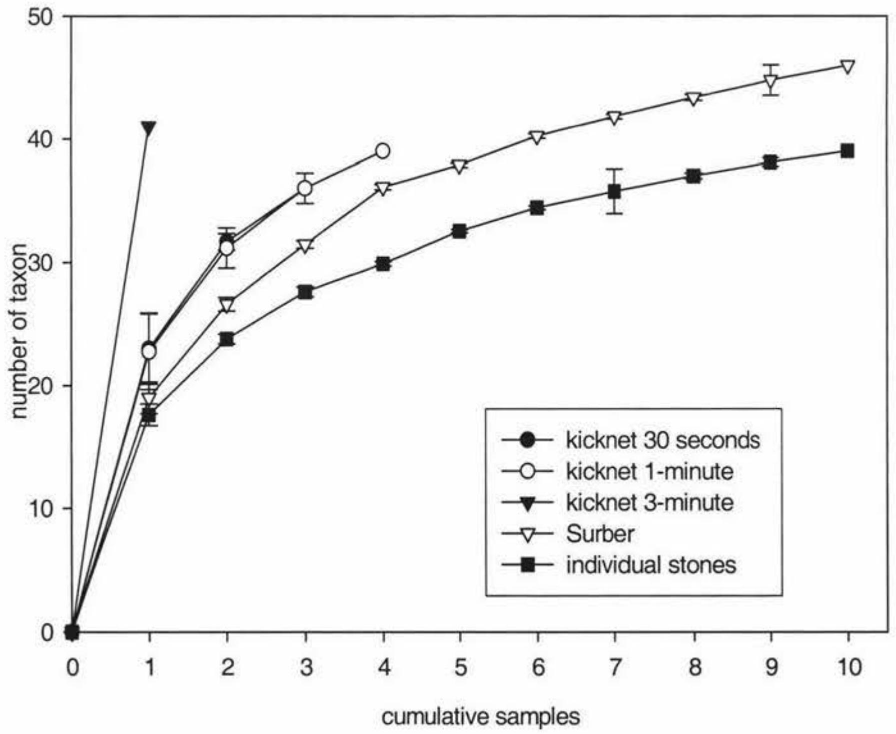

Figure 2.1. Taxa accumulation curves for samples collected at Waiaruhe Stream in October 2000

The DECORANA (Fig. 2.2), indicated that the 3-minute kicknet sample was some distance from the total community despite it having the greatest number of animals. The 30-second kicknets were closely grouped together and were similar to the total benthic community. The 1-minute kicknets were also closely grouped but not as close to the total community. Individual stones and individual Surber samples were spread out with those taken consecutively being clustered closest together. Interestingly one individual stone sample lay very close to the total community, despite generally lower taxa numbers. The closest sample to the community was that of 5 randomly chosen Surber samples grouped together. A grouping of 5 randomly chosen individual stones also laid close to the 'true' community.

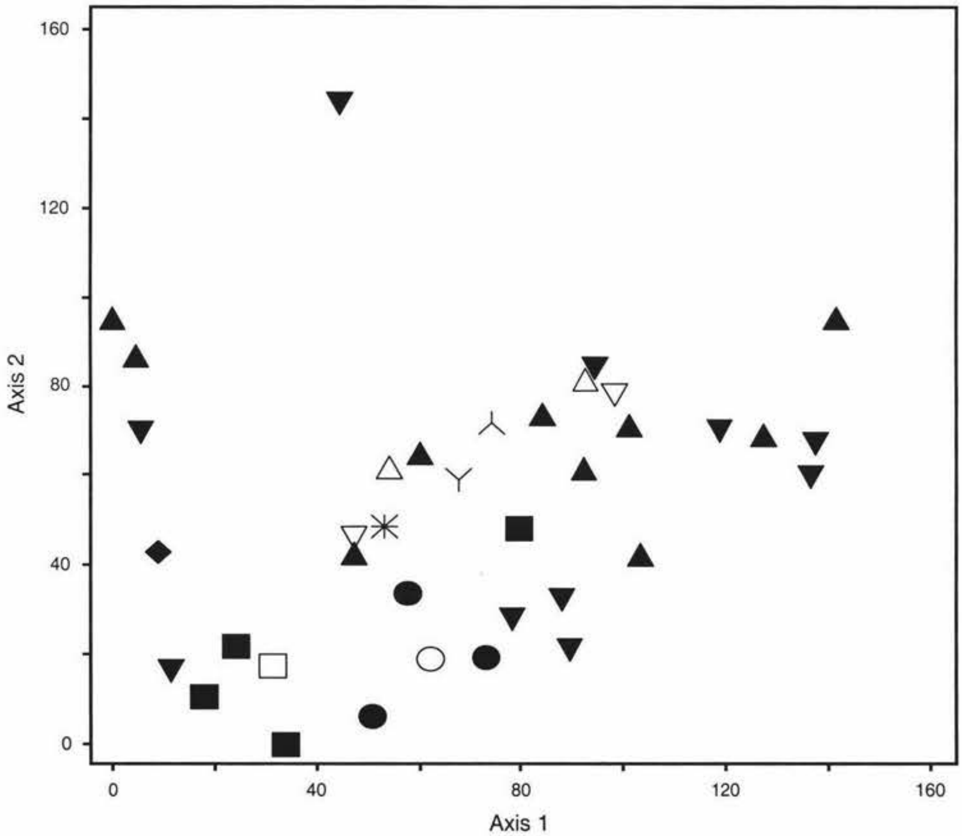

Figure 2.2. Plot of axis 1 against axis 2 of a DECORANA of stream macroinvertebrate samples collected with different techniques (Surber, kicknet and individual stones), at Waiaruhe Stream, Te Urewera National Park in October 2000. ▲ individual stone samples, △ individual stone sample group (5), ⅄ individual stone sample group (all), ▼ Surber samples, ▽ Surber group (5), Y Surber group (all), ● 30-second kicknet samples, O 30-second kicknet group (all), ■ 1-minute kicknet samples, □ 1-minute kicknet group (all), ◆ 3-minute kicknet, ✳community

DISCUSSION

In this study it was found kicknet samples of all time classes yielded more taxa than either Surber or individual stone samples. A significant difference in taxa number collected was found between all techniques but the 3-minute kicknet returned substantially higher numbers of taxa than the other sample methods. When corrected for time and unit effort, 30-second kicknets collected the highest numbers of taxa, followed by the 3-minute kicknet and the 1-minute kicknet. Individual stone sampling consistently returned the lowest taxa numbers for unit effort of sampling. This is probably due to the potential loss of mobile species (e.g., *Nesameletus* sp.) and taxa that live amongst the substrata being missed by this sampling technique as well as the lower habitat complexity of the stone surface (Doeg and Lake 1981; Winterbourn 1985; Douglas and Lake 1994).

The taxa accumulation curves showed the number of taxa collected increased with sampling effort. For all sampling techniques the accumulation curves had not reached asymptotes, indicating more replicates were required to collect all taxa present. When examining the taxa accumulation curves for the 3 techniques it is clear that substantially higher (6 or more) numbers of samples of any other technique would be required to collect the same level of taxa as that of the 3-minute kicknet, though when corrected for time this meant the 30-second kicknet collected a slightly higher level of taxa. Both 1-minute and 30-second kicknets collected very similar levels of taxa. This is probably due to the relatively small difference in the amount of streambed and habitats covered during these collection periods, highlighting the importance of habitat area sampled.

When the sampling techniques were examined with regard to community composition in the ordination, it appeared a grouping of 5 Surber samples gave the best representation of the benthic invertebrate community in the Waiaruhe Stream. It was interesting to note the 3-minute kicknet point was some distance from the total community point despite it having the highest taxa richness suggesting a different community assemblage collected over the larger habitat area. The 30-second kicknets were closely grouped together and were close to the total community. The 1-minute kicknets were also grouped and quite close to the total community. These shorter time period kicknet samples appear to show a good representation of the macroinvertebrate community. This supports the work of (Vinson and Hawkins 1996), who suggested that due to the high habitat heterogeneity of streams, collecting a series of pooled $0.1m^2$ or larger samples (i.e., the Surbers, or 30 and 1 minute kicknets) was better than a single sample (i.e., the 3-minute kicknet) from an equal area. Individual stones and individual Surber samples points are quite spread out within the axes, with those taken consecutively being clustered closest together because of the similar habitat areas sampled from.

The results found in this study support the work of Mackey et al. (Mackey et al. 1984) and Stark (Stark 1993), who both found kick net samples generally collect more taxa than Surber samples. Mackey et al. (Mackey et al. 1984), found that pondnet (kicknet) samples collected the most taxa per unit effort when times for collecting and processing were considered. Stark (Stark 1993), found that he required about 20% less kicknet samples than Surber samples to achieve similar results of taxa numbers collected in surveys. The higher level of taxa richness collected by individual kicknets no doubt reflects the greater area of streambed and therefore habitats compared to individual Surber samples (Mackey et al. 1984; Stark 1993). This relationship between the number of taxa and area is well reported, as is the greater diversity of habitat types sampled over a large area and thus greater collected taxa (Arrhenius 1921; Preston 1948; Hart and Horwitz 1991; Douglas and Lake 1994; Vinson and Hawkins 1996; Li et al. 2001).

Whilst the kicknets collected the highest taxa levels, Surbers still collected high levels of taxa and remain an effective and efficient quantitative sample technique for New Zealand stream macroinvertebrate communities. The main drawback of Surber samples is their inability to be used in large bouldered streams. Missing faster swimming species such as *Nesameletus* sp. and those living within the substrate possibly explains the lower numbers collected by individual stone samples. While individual stone sampling is fast, convenient and provides easily processed collections (Stark 1993), it is not the most efficient technique for biodiversity surveys.

In summary for the purpose of biodiversity inventories within New Zealand streams it would appear that several (3-5 depending on the study) kicknet samples of 30-second or 1-minute duration would be most effective for collecting the highest levels of biodiversity per unit effort whilst also collecting representative samples of the community present. A trade off between sorting time, sampling time and area of streambed covered by the technique would suggest approximately three, 1-minute kicknet samples as a useful guideline to be used in future studies.

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3

DEVELOPMENT OF A BIODIVERSITY SAMPLING PROTOCOL FOR NEW ZEALAND STREAM MACROINVERTEBRATES

ABSTRACT

The stream invertebrate fauna of 54 streams in 3 conservation regions in Nelson, South Island, New Zealand were sampled with three 1-minute kicknet collections to assess biodiversity measured as taxa richness. The efficacy of sampling for assessing biodiversity was examined using sample collection at 3 differing spatial scales. This involved examining taxa accumulation in 3 samples in a) 1 stream, b) different streams within 1 region, c) different streams, in each of the 3 regions. Taxa richness was higher when sampling was spread over more habitats and a larger area. It was concluded that sampling effort is most effective for taxa richness collection when spread over a medium to large scale and thus encompassing more habitats.

Keywords: Abel Tasman National Park, biodiversity, Kahurangi National Park, kicknet, Mount Richmond Forest Park, sampling protocol, taxa richness, stream macroinvertebrates.

INTRODUCTION

In recent years protecting and preserving biodiversity has become one of the principal goals of conservation internationally. (Wilson 1992; Pearson and Cassola 1992; Pearson 1994; Williams and Gaston 1994; Suter 1998; Harper and Hawksworth 1994; Department of Conservation 2000). In February of 2000, the New Zealand Biodiversity Strategy (Department of Conservation 2000), was published in response to the state of decline of New Zealand's indigenous biodiversity. It fulfils in part, commitments New Zealand made under The International Convention on Biological Diversity in 1992 (UNEP 1992). The purpose of the Strategy was to establish a strategic framework for action, to conserve and sustainably manage New Zealand's biodiversity. Key areas highlighted by the strategy include the need for increasing knowledge of our indigenous biodiversity and the key threats to it, as well as developing performance standards and codes of practice for monitoring biodiversity (Department of Conservation 2000).

To protect and manage areas of biological diversity, species inventories are being used more frequently to document patterns and determine parameters controlling those patterns (Stohlgren et al. 1995; Keating et al. 1998; Vinson and Hawkins 1998). These inventories and surveys use large proportions of conservation budgets with demand for such surveys still increasing. Limitations to funding and resources mean that designing cost effective inventories remains a difficult and important challenge for ecologists (Colwell and Coddington 1994; Pearson 1994; Williams and Gaston 1994; Keating et al. 1998). Because of these limitations and the knowledge that species discovery rates decline rapidly with increased sampling, truly complete inventories are not a reasonable goal. This highlights the importance of allocating sampling effort in the most cost effective manner possible while considering sampling methodology to ensure collection of maximum taxa in biodiversity inventories (Colwell and Coddington 1994; Pearson 1994; Keating et al. 1998; MacNally and Fleishman 2002).

Within the invertebrate fauna there is a vital need to establish what the current state of New Zealand's biodiversity is. It has been suggested that it is only logical to use the most diverse group of organisms for planning in conservation and management of biodiversity, yet this has not happened (Colwell and Coddington 1994). Invertebrates have not been collected from many areas of New Zealand, many invertebrates are undescribed and for those that are described we have little information about their distribution, habitat preferences, ecology and possible threats to their long-term survival. Our knowledge of the distribution and taxonomy of many indigenous freshwater invertebrate species is similarly limited (Collier 1992; Collier et al. 2000). Existing survey and monitoring programmes are generally not sufficient to define freshwater biodiversity or to identify changes in freshwater species composition and abundance or habitat condition (Department of Conservation 2000). A protocol is therefore required for maximising the benefit from any such biodiversity inventory, for example should more effort be put into one area or the same effort spread over a number of areas or regions to maximise the number of recorded species.

In this study a sampling protocol for assessing freshwater macroinvertebrate biodiversity is examined. For the purposes of this study, biodiversity is measured as taxa richness, an important and commonly used component of biodiversity (Vinson and Hawkins 1998; Gaston 2000; MacNally and Fleishman 2002). The method of sample collection gives greatest taxa richness per unit effort is investigated. This is achieved by assessing at which scale sampling effort should be concentrated to maximise taxa collection. That is, should sampling effort be concentrated by intensively sampling at the stream level, or should the same effort be spread over a larger spatial scale to include higher variation (i.e., catchment or region)(Kerans et al. 1992; Downes et al. 1995; Richards et al. 1997; Li et al. 2001; Sponseller et al. 2001).

METHODS

Site Selection

Three Department of Conservation managed areas in the Nelson region of the South Island were selected for this study (Figure 3.1). These were Abel Tasman National Park, Kahurangi National Park and Mount Richmond Forest Park. They were chosen as they are relatively pristine, have a high habitat diversity and a large number of reportedly rare invertebrates (Collier 1992). Fifty-four 2nd and 3rd order streams, eighteen in each region, were selected, based on their unmodified state and that they had significant native riparian margin (Appendix 2a,b,c)(Plate 1a,b,c). Samples were collected during November and December 2000.

Abel Tasman National Park

Abel Tasman National Park is New Zealand's smallest national park at 22,530 hectares, located at the top of the South Island and opened in 1942. The landscape of the park has been modified, more than other national parks and some remnants of early settlers and their impacts can still be seen. The vegetative cover varies and reflects a history of fires and land clearance, but the forests are regenerating. The park is built mostly of granite, colouring the beaches and streambeds and giving rise to characteristically infertile soils. Little is known about the park's freshwater fauna (Department of Conservation 2002b).

Kahurangi National Park

Kahurangi National Park is in the northwest corner of the South Island. It is the second largest national park in New Zealand, consisting of 452,002 hectares. It contains the greatest range of landforms, habitats and communities of plants and animals of any of the national parks in New Zealand. It is geologically complex and parts of the region are limestone or marble. The vegetation cover changes markedly from one side of the park to the other. The limestone ecosystems of the park are important because of the high diversity, endemism and rarity of species associated with them. The Park has a high diversity of aquatic and terrestrial invertebrates, which exhibit a high level of endemism. This is due to complex biogeographic processes and also because of the many specialised habitats present.

Mt Richmond Forest Park

Mt Richmond Forest Park lies between Nelson and Blenheim and consists of steep native forest covered mountain country as well as exotic pine forest. It was opened in 1977 and has an area of 184 000 ha, being the third largest forest park in the country. Three major river systems have their headwaters in the Park, the Pelorus, Waimea and Motueka. The headwaters of these enclosed catchments are mostly steep and mountainous with narrow incised valleys. The native forest areas of the Park are dominated by beech with all five species present. Podocarps are well represented though less so in lowlands and broadleaved species are also important components of the forest of the park.

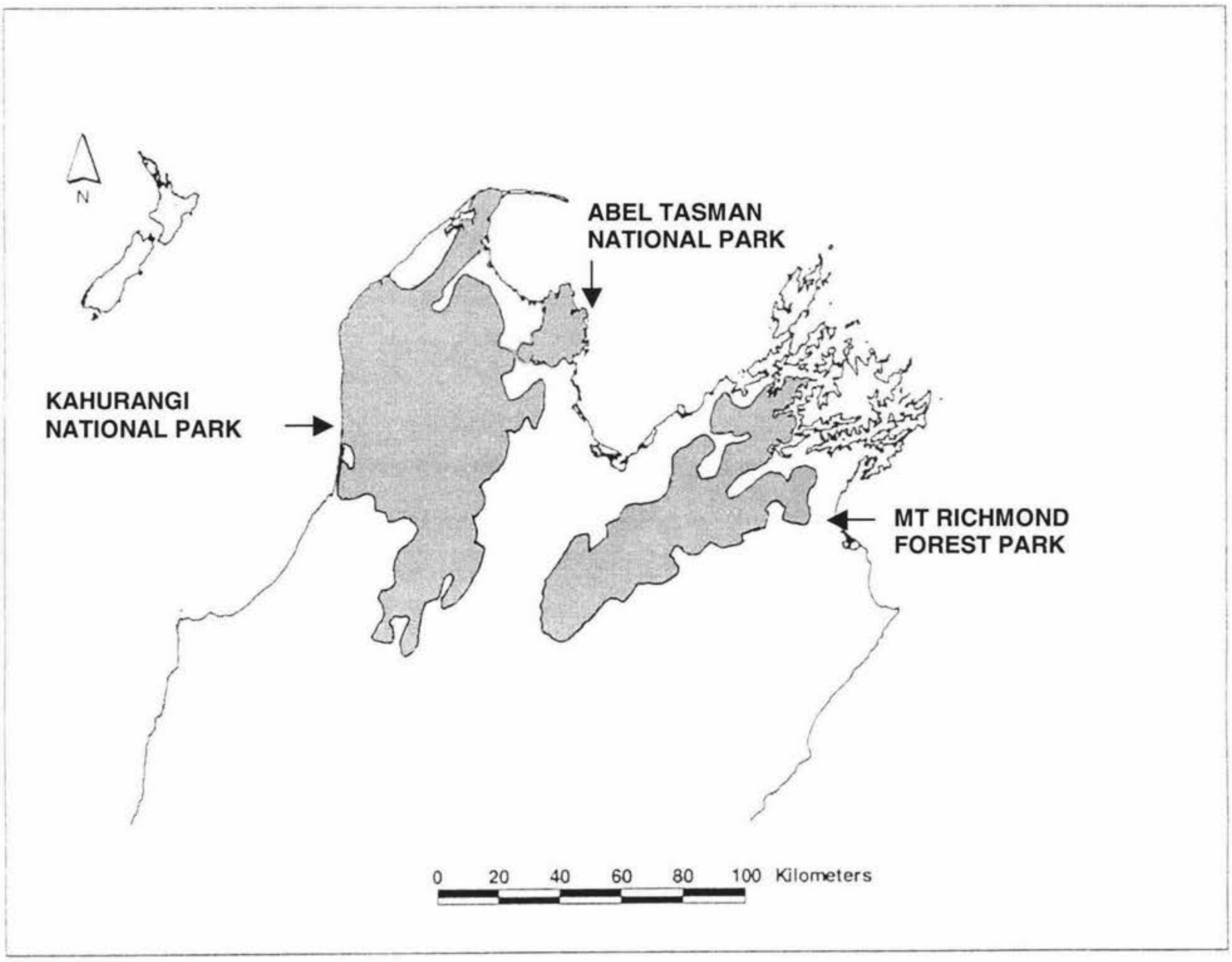

Figure 3.1. Location of Abel Tasman National Park, Kahurangi National Park and Mt Richmond Forest Park in the Nelson region of the South Island, New Zealand.

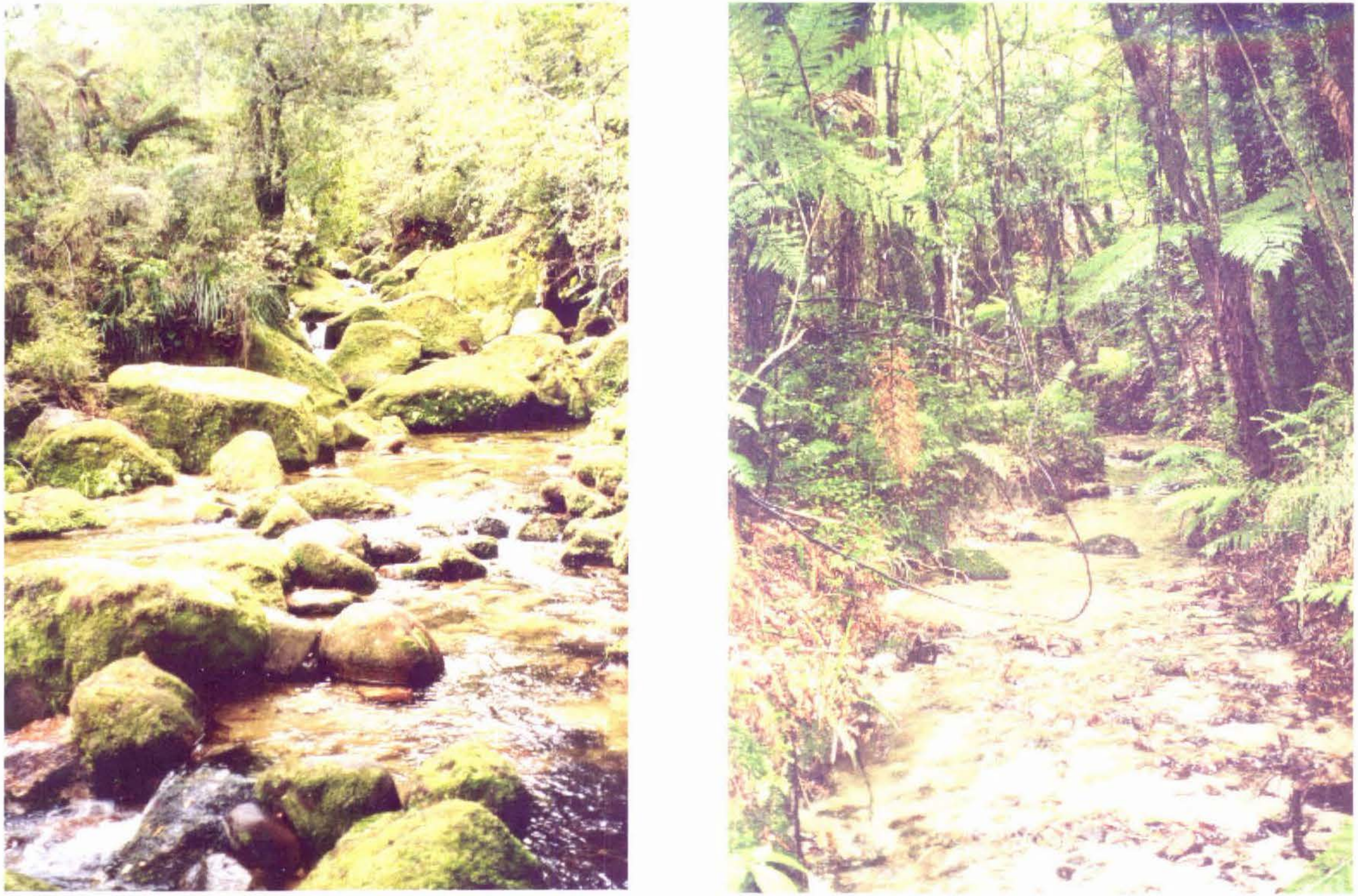

Plate 1a. Examples of Abel Tasman National Park streams. Cleopatra Pools Tributary (left), and Waiharakeke Stream (right).

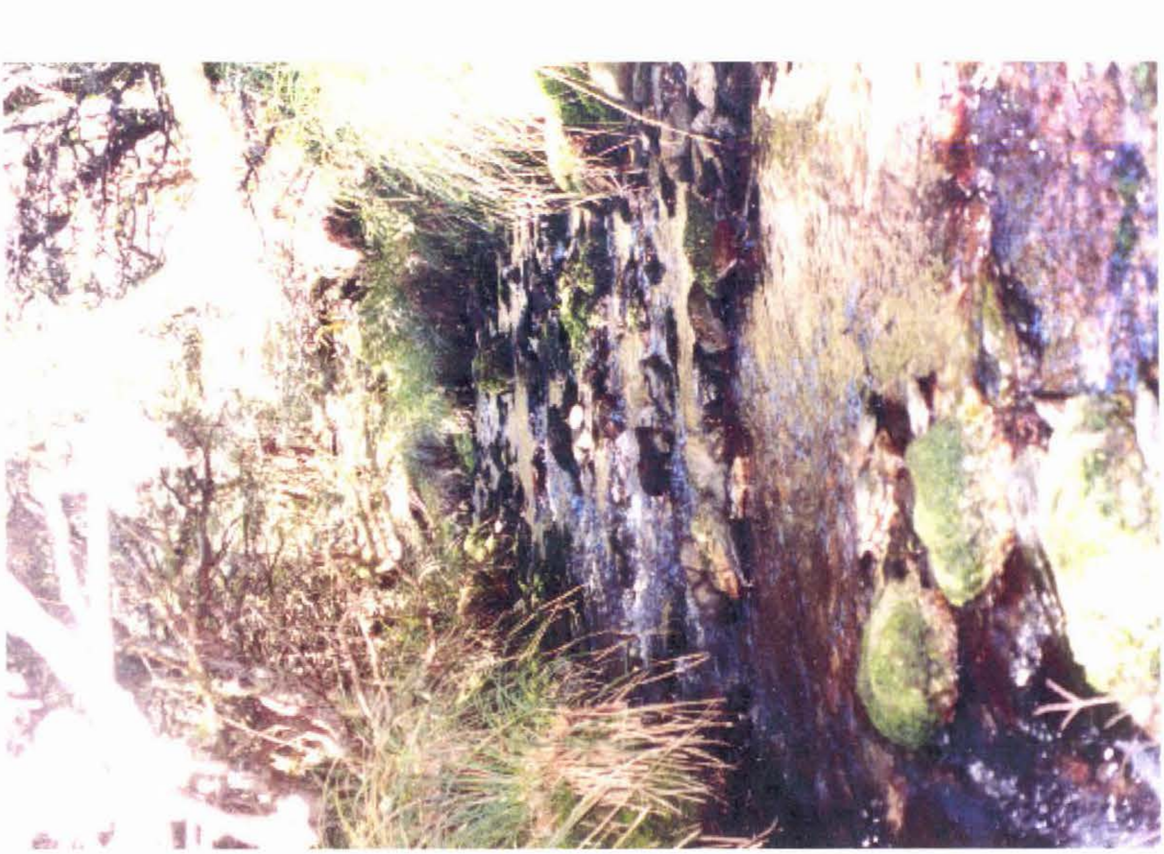

Plate 1b. Examples of Kahurangi National Park streams. Upper Flora Stream (left), and Thorns Creek (right).

Plate 1c. Examples of Mt Richmond Forest Park streams. Johnstons Creek (left), and Collins Creek (right).

Invertebrate samples

Three 1-minute kicknet samples (250µm mesh) were used to collect invertebrates from riffles at sites 20 metres apart within each of the 54 streams. Samples were collected from riffle habitats, as they are known to have higher species richness and be dominated by insect larvae (Hynes 1970; Hughes 1975; Winterbourn 1985). Samples were stored in 10% formalin. In the laboratory, samples were filtered through a 500µm sieve and the invertebrates were identified to species level where possible using available keys (McFarlane 1951; Cowley 1978; Towns 1983; Winterbourn and Gregson 1989). If it was not possible to identify to species level, invertebrates were then grouped into apparent morphospecies.

Environmental measures

Environmental characteristics of each site were measured at the time of sample collection. Water chemistry parameters measured included conductivity and temperature (measured with an Orion 122 Conductivity meter), and pH (measured with an Oakton waterproof pHtestr). Width, depth, current velocity (measured with a Marsh McBirney velocity metre) and hydraulic radius were measured above and below each of the 3 sites in a stream. Stream slope was measured over a 10 m reach using an Abney level. Percent riparian vegetation composition, canopy cover and presence of moss were visually assessed. Altitude and stream order were derived from 1:50 000 scale topographical maps (Spence 1985; DSLI 1996; Terralink 1997b; Terralink 1997a LINZ, 1999a; Terralink 1998a; LINZ 1999b; Terralink, 1998b; LINZ 2000b; LINZ 2000a). Substrate composition was assessed using a gravelometer and Wolman method (Wolman 1954). Thirty-three stones were measured at each of the 3 sites (approximately 100 per stream) and categorised into the 10 size groups as per Wolman (1954). Substrate embededness was subjectively assessed on a scale from 1-6 representing very loose to very tight. Habitat stability was assessed with the Pfankuch channel stability index (Pfankuch 1975). The Duncan's stability equation (Duncan et al. 1999) was also calculated using hydraulic radius measures taken at the 3 sites in each stream.

Data analysis

Taxa richness and total abundance were measured as the total number of taxa and individuals collected in each replicate, in each of the 54 streams. Totals and averages of these measures were calculated for each stream. The biotic indices, EPT (Ephemeroptera, Plecoptera and Trichoptera) (Lenat 1988), Berger Parker Index (Berger and Parker 1970) and Margalef's Index (Clifford and Stephenson 1975) were also calculated.

The number of rare species in each area was identified as those species only occurring in 1 of the 3 regions or those species that were represented by less than 10 individuals in the entire study. Pearson's correlations were used to identify any significant relationships between total and mean taxa richness and environmental variables.

Taxa accumulation curves were derived for each of the 54 streams for the taxa collected in 3 replicate samples. A taxa accumulation curve (or collectors curve) is a plot of the cumulative number of species collected within an area, as a function of some measure of the effort to collect them (Colwell and Coddington 1994). Average values of taxa richness were calculated for every possible combination of successive samples. This eliminates variation arising from sampling error (Colwell and Coddington 1994). Slopes were obtained for the accumulation curves by logarithmically transforming data and fitting with a linear regression. Analysis of Variance (ANOVA) in SAS (2001) was used to examine differences in the slopes of the 3 regions.

Three combinations were used to test sampling protocols for collecting biodiversity (measured as taxa richness). The combinations examined whether higher taxa richness was collected by a) 3 samples within one stream, b) 3 samples randomly selected from different streams within one region or c) 3 samples randomly selected, 1 from each of 3 streams in 3 regions. This was carried out for all replicates in all streams.

Within one region, Mt Richmond Forest Park, within region variation was also examined. The region was split into 3 sections, (North, Central and South) with 6 streams in each sub-region. The above methods were then repeated at this smaller scale, comparing the number of taxa collected from 3 samples within 1 stream, with the taxa collected from 3 samples within 3 streams in 1 sub- region and the taxa from 3 samples in 3 streams from all the sub-regions.

Analysis of Variance (ANOVA) using SAS (2001), was used to examine differences of taxa collection at the three scales.

RESULTS

The ranges of physicochemical and biological characteristics measured at the sites are presented in Table 3.1. Abel Tasman streams were generally small (< 4 m wide), steeper, streams at low altitudes with high moss cover, warmer water temperatures (9 - 13° C) and granite geology. Kahurangi streams were all high altitude (mean = 500m), stable, cold streams (5 - 11° C) with greywacke, marble and granite geology. Mt Richmond sites were intermediate with medium to large size (mean = 4 m wide) and moderate altitude streams with low levels of canopy cover. A full list of environmental characteristics recorded at all sites is given in Appendix 4.

A total of 84 525 stream macroinvertebrates comprising 121 taxa were collected from the 3 regions (Appendix 3). Of the regions, Mt Richmond Forest Park had the highest taxa richness with 100 collected taxa, followed by Kahurangi National Park (95) and Abel Tasman National Park (92). Streams in Mt Richmond Forest Park also yielded higher mean taxa richness of all replicates per stream, at 38.6 taxa (range 22-56), with streams in Kahurangi having mean taxa richness of 35.6 taxa (range 7-46) and Abel Tasman streams having mean taxa richness of 35 taxa (range 24-46) (Fig. 3.2). Kahurangi contained 12 taxa, which were not collected from the other two parks. Mt Richmond contained 7 taxa not collected from the other two parks and Abel Tasman also contained 7 taxa exclusive to it. No significant relationships were identified between any of the environmental variables and total or mean taxa richness (Table 3.2).

Table 3.1. Mean and range for environmental characteristics and biotic indices measured during November/December 2000 in Abel Tasman National Park, Kahurangi National Park and Mount Richmond Forest Park

	Abel Tasman National Park		**Kahurangi National Park**		**Mount Richmond Forest Park**	
	Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**
Altitude (m)	67	10 - 480	488	140 - 940	226	40 - 500
Stream width (m)	3.81	0.45 - 4	4.92	0.6 - 18.5	4.38	0.36 - 20.7
Water depth (cm)	20.82	6 - 55.5	24.07	6 - 61	20.4	6 - 65
Current velocity (cm s^{-1})	19.85	0.1 - 58	15.94	0.23 - 48	5.85	0.03 - 31
Conductivity (μS cm^{-1})	75.48	32.6 - 243	135.79	53.5 - 228	92.8	40.8 - 225
Temperature (°C)	11.5	9.4 - 13.2	8.4	5.4 - 11.1	10.8	6 - 15
pH	8.22	7.9 - 8.8	8.56	8.4 - 4.7	8.5	8.2 - 9.1
Native vegetation (%)	92.8	0 - 100	86.9	50 - 100	86.9	0 - 100
Canopy cover (%)	46.1	5 - 100	48.7	5 - 90	29.7	0 - 85
Moss cover (%)	43.3	0 - 90	33.1	0 - 100	11.2	0 - 80
Embededness	4	1 - 6	3.5	1 - 5	3	1 - 6
Channel slope	0.06	0.01 - 0.22	0.044	0.004 ± 0.15	0.043	0.003 - 0.12
Dominant Geology		Granite		Greywacke/ marble & granite		Greywacke/ granite
Substrate size (mm)	160	Sand -boulders	169	Sand - boulders	155	Sand - boulders
Pfankuch score bottom	25.31	15 - 40	31.5	16 - 45	28.9	18 - 54
Pfankuch score total	45.69	28 - 83	52.4	37 - 71	51.97	33 - 91
Duncan score	0.21	.0004 – 2.87	.05	0.00006 – 0.3	0.08	0.00002 - 0.64
Total taxa richness	35.1	24 - 46	35.72	7 - 46	38.5	22 - 56
EPT	0.58	0.47 - 0.69	0.53	0.14 – 0.67	0.58	0.48 – 0.68
Berger Parker Index	0.38	0.19 – 0.70	0.48	0.26 – 0.95	0.47	0.14 – 0.81
Margalef's index	5.13	3.76 – 6.62	4.74	1.23 – 6.28	5	2.75 – 6.97

Table 3.2. Bonferroni adjusted Pearson correlations between mean and total taxa richness and environmental variables at each of 54 streams sampled in Abel Tasman National Park, Kahurangi National Park and Mt Richmond Forest Park in November and December 2000. No correlations were significant at <0.05

Environmental Variable	Mean Taxa Richness	Total Taxa Richness
Altitude	0.031	0.181
Width	-0.277	-0.204
Depth	-0.127	-0.093
Velocity	-0.138	-0.181
Conductivity	0.026	0.070
Temperature	-0.002	-0.045
pH	0.012	0.067
Native vegetation	0.055	-0.047
Canopy cover	0.175	0.095
Moss presence	0.090	0.060
Embededness	-0.190	-0.187
Slope	0.048	-0.015
Granite	-0.106	-0.184
Greywacke	-0.048	0.075
Marble	-0.049	0.009
Substrate size	-0.050	0.005
Pfankuch bottom	-0.320	-0.309
Pfankuch total	-0.222	-0.199
Duncan stability score	0.046	-0.033

The number of taxa collected at each site increased with sampling (Fig. 3.3 a,b,c). The accumulation curves in only a few streams were close to reaching asymptotes, indicating considerably more replicates were required to collect all the taxa present at most of the streams. The accumulation curves show considerable variation in the rate of taxa collection between streams within each park. Analysis of variance of the slopes showed Mt Richmond Forest Park slopes were significantly lower ($F_{2,51}$= 4.30, $P < 0.01$) than the slopes of Abel Tasman National Park, but there was no difference in the slopes of Kahurangi National Park and the other two parks. The lower slopes of Mt Richmond Forest Park accumulation curves suggests an homogeneous instream habitat in contrast to a more patchy habitat found in Abel Tasman streams (Fig. 3.4)

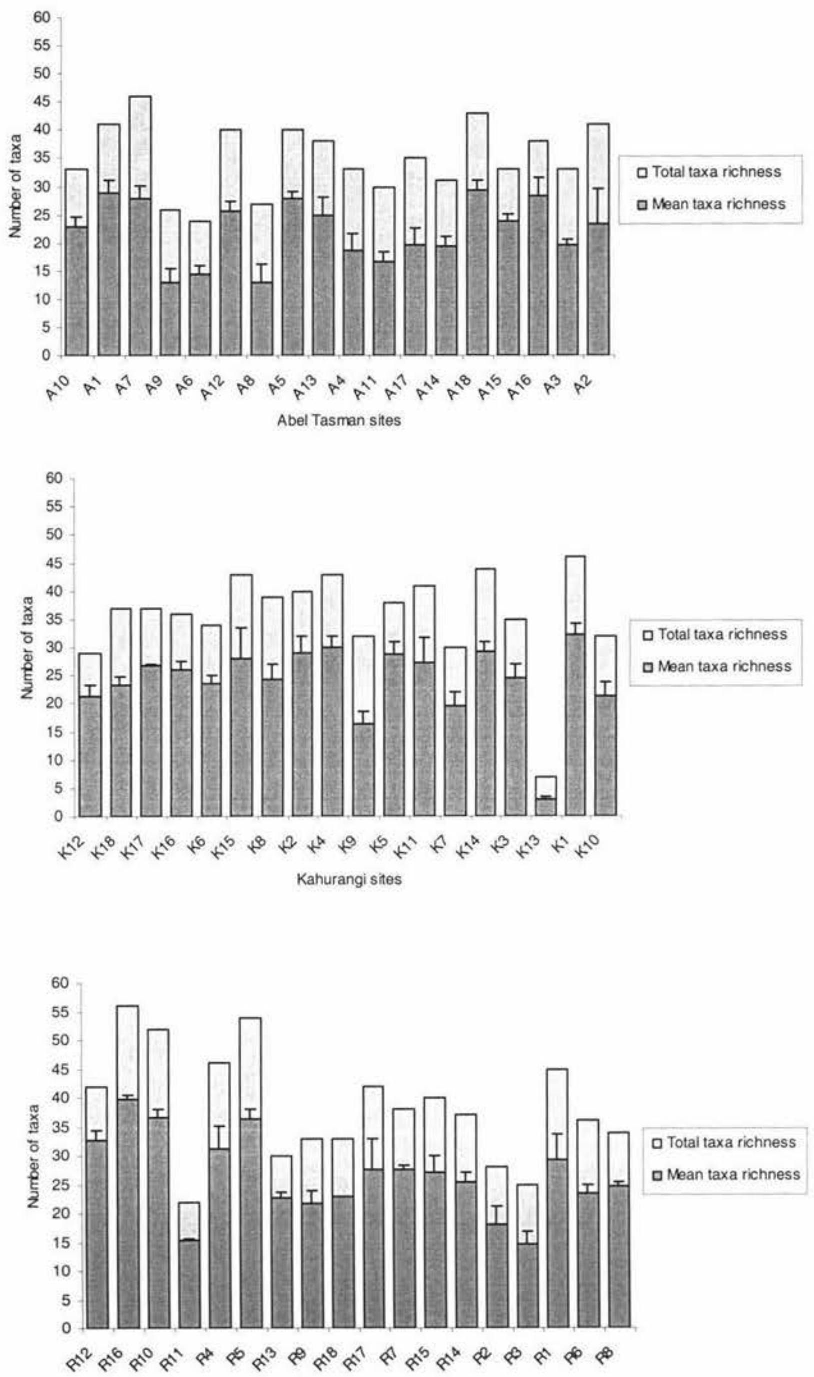

Figure 3.2. Mean (per 1-minute kicknet) and total taxa richness, collected in 54 streams in Abel Tasman National Park, Kahurangi National Park and Mt Richmond Forest Park in November and December 2000. Sites are plotted in order of increasing stability based on the Duncan stability score. Site references for each area (i.e, A1- A18), represent streams as listed in Appendix 2a-c.

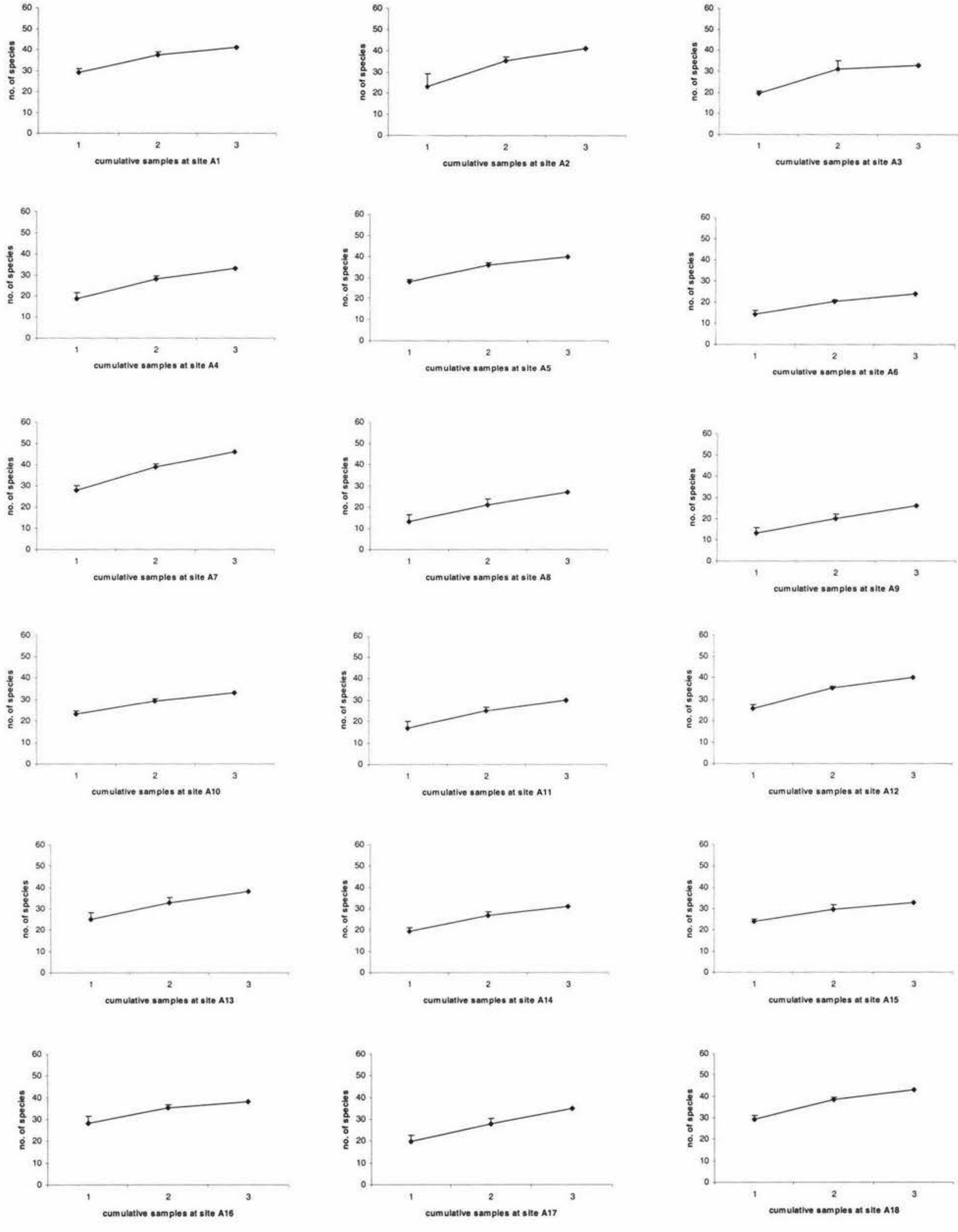

Figure 3.3a. Species accumulation curves for three replicate kicknet samples collected during November and December 2000, at each of the 18 streams (represented by A1-A18) in Abel Tasman National Park.

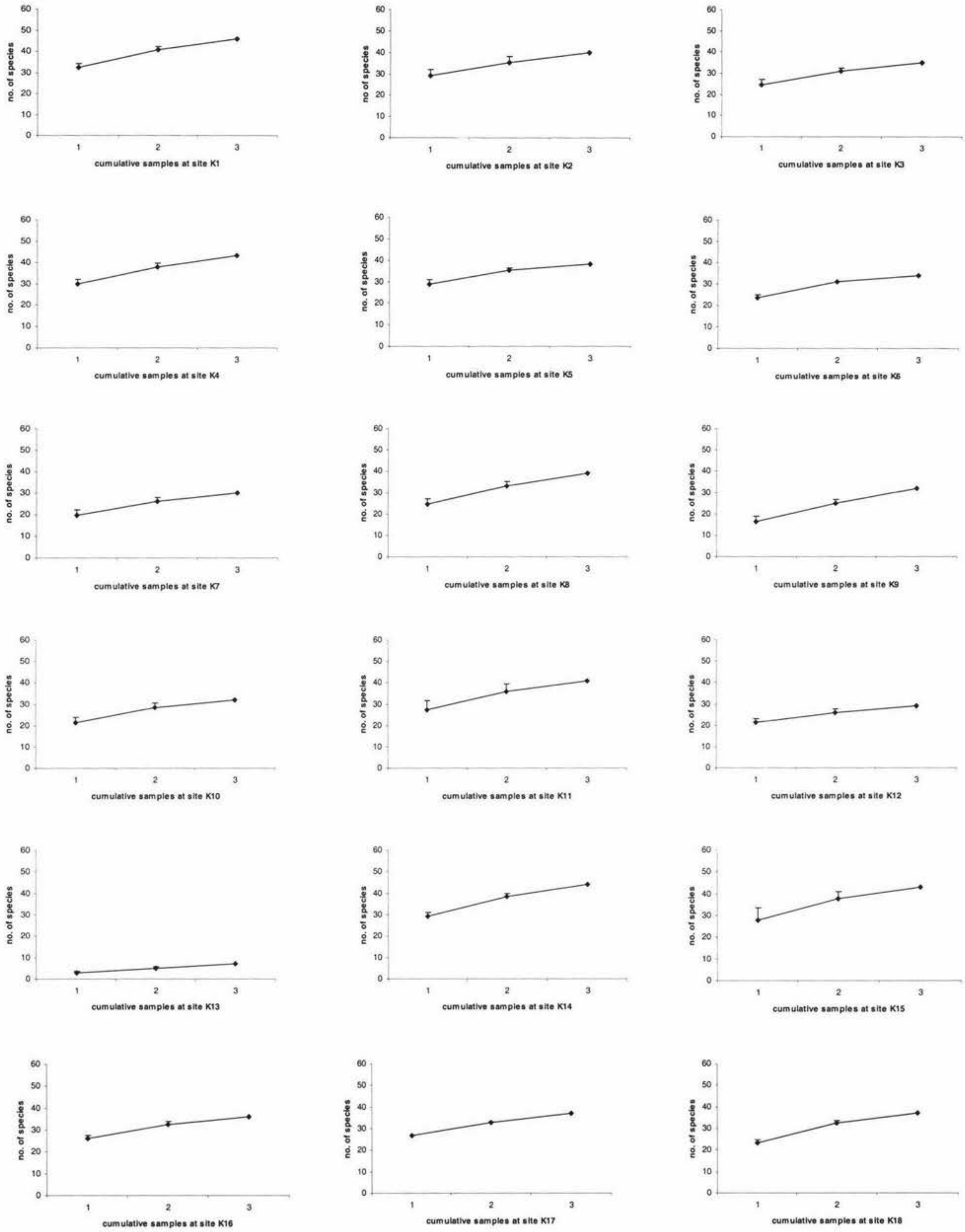

Figure 3.3b. Species accumulation curves for three replicate kicknet samples collected during November and December 2000, at each of the 18 streams (represented by K1 – K18) in Kahurangi National Park

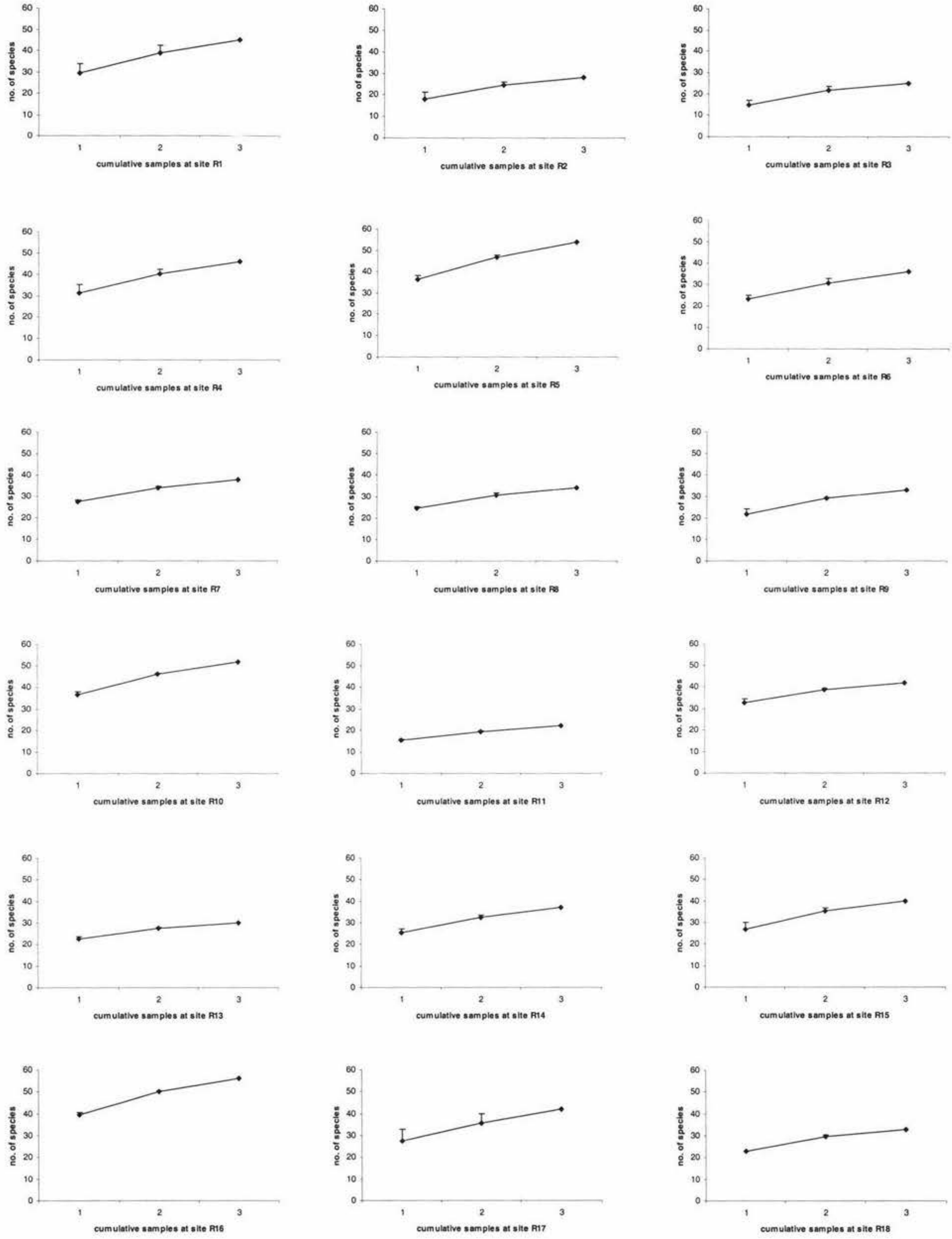

Figure 3.3c. Species accumulation curves for three replicate kicknet samples collected during November and December 2000, at each of the 18 streams (represented by R1 – R18) in Mt Richmond Forest Park.

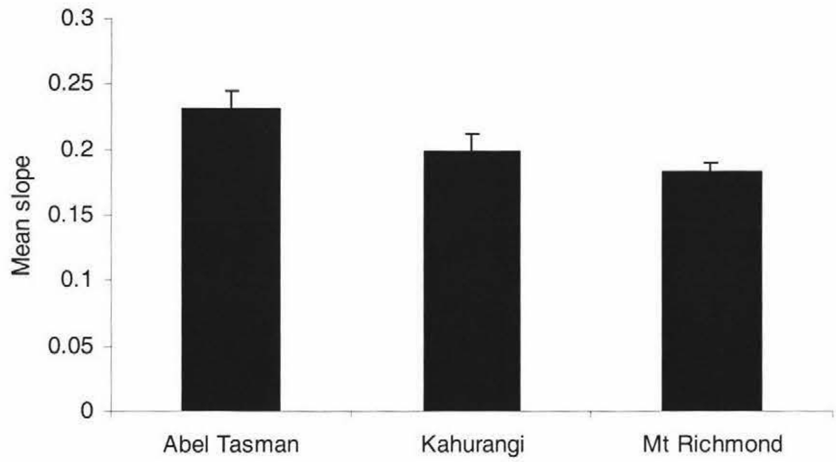

Figure 3.4. Mean (± 1 SE) slopes of log transformed taxa accumulation curves of kicknet samples collected at Abel Tasman National Park, Kahurangi National Park and Mt Richmond Forest Park in November and December 2000.

The 3 combinations of sample collection a) 3 samples within 1 stream, b) 3 samples in 3 streams in 1 region and c) 3 samples from 3 streams in 3 regions showed a significant increase ($F_{2,375} = 48.56$, $P < 0.0001$) in mean taxa richness (by approximately 10 species) between method 1 and the other two methods as scale increased. There was no significant difference between methods 2 & 3. (Fig. 3.5).

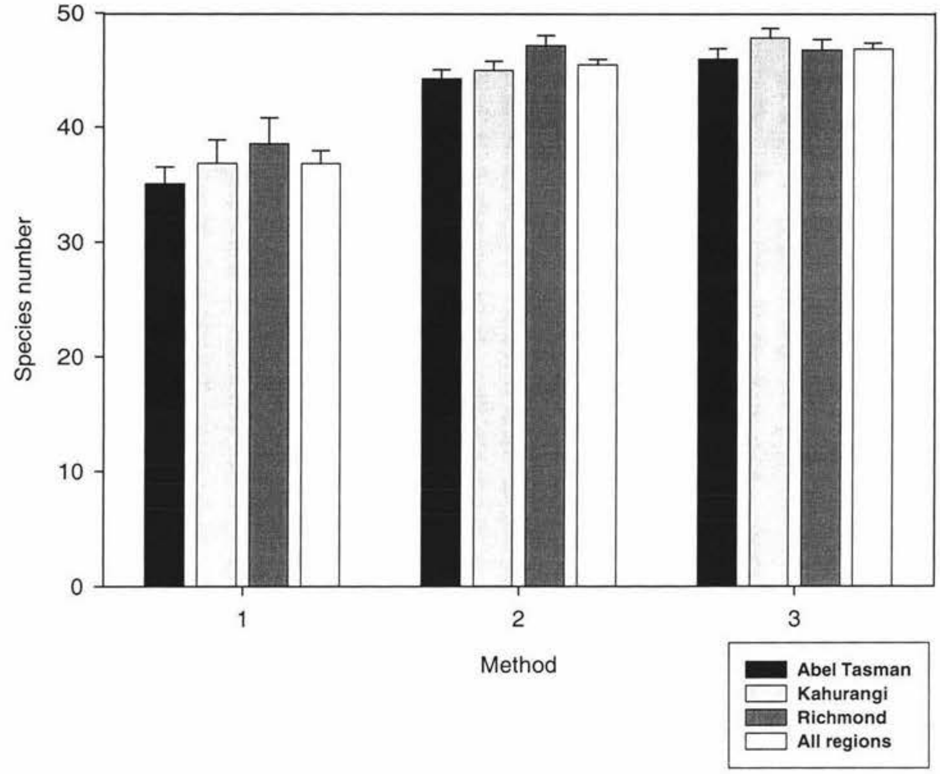

Figure 3.5. Comparison of mean numbers of species collected for three sampling methods during November and December 2000, in Abel Tasman National Park, Kahurangi National Park and Mt Richmond Forest Park. Method 1, three samples collected from 1 stream; Method 2, three randomly selected samples collected from 1 region; Method 3, three randomly selected samples, 1 from each region.

When Mt Richmond Forest Park was split into 3 subregions and the same procedure examined, the second (within 1 subregion) and third methods (over all 3 subregions) had significantly higher mean taxa richness ($F_{2,124} = 11.43$, $P < 0.0001$), than the first method. Although not significant, their orders were reversed with higher mean taxon richness being shown within method 2, (within 1 section) than method 3, (over the 3 sections).

DISCUSSION

The development of a sampling protocol for assessing freshwater macroinvertebrate biodiversity will help us to expand our knowledge of our indigenous freshwater biodiversity and the factors which may affect that diversity (Department of Conservation 2000). In this study I have investigated a sampling strategy to maximise collected macroinvertebrate biodiversity as measured by taxa richness for a given sampling effort.

Streams in Mt Richmond Forest Park had a high taxa richness. The sites sampled in this park covered a range of habitat, and geology types from small coastal forest streams (i.e., Haupiaka Stream), open canopy low altitude streams (i.e., Collins Stream) to the steeper mountain streams of the Pelorus catchment and the unstable, braided Stony Creek. These habitats types were intermediate between the predominantly mountainous Kahurangi streams and the low altitude Abel Tasman streams. This combination of habitats may have lead to the increased diversity in streams in Mt Richmond Forest Park. Of the three parks and areas sampled, Abel Tasman was the smallest, lowest altitude park, and had the lowest taxa richness (Conner and McCoy 1979; Hart and Horwitz 1991; Have 1993). The absence of fauna that prefer the fast flowing, cooler temperatures of higher altitude streams (e.g., the stonefly *Cristaperla fimbria*, the dipteran *Neocurupira campbelli* and several of the freeliving *Hydrobiosis* taxa), or those that prefer beech forest streams (i.e., the cased caddis *Zelandopsyche ingens*), found in both Mt Richmond and Kahurangi may explain the lower taxa richness of Abel Tasman. However several taxa were collected only from Abel Tasman National Park including the stonefly *Megaleptoperla grandis*. It is also one of the more modified regions, with extensive forest clearance and high levels of tourism and along with being a smaller area sampled, this may also have played a role in the lower overall taxa richness of Abel Tasman.

The taxa accumulation curves for each stream showed more species were collected with each successive replicate because of the greater area and number of habitats sampled (Mackey et al. 1984; Stark 1993). None of the streams showed steep increases in collected species suggesting that the majority of taxa present were collected initially. The number of taxa encountered increases as functions of both the area sampled and the number of individuals in the sample. Larger numbers of individuals per sample increase the likelihood that new taxa will be encountered (Hart and Horwitz 1991; Soberon and Llorente 1993; Vinson and Hawkins 1996; Keating and Quinn 1998). It is thought that most relatively undisturbed stream faunas include a few abundant species and a large number of less common ones, such that as sampling effort is increased the number of taxa should increase as more rare species are encountered (Winterbourn 1985; Death 1996). The taxa accumulation curves reflected the differences between the three regions. The slopes of the accumulation curves developed for Mt Richmond streams were significantly lower than the slopes of the Abel Tasman streams. This would suggest that Mt Richmond streams had a less variable instream habitat than that of Abel Tasman streams, with the majority of taxa collected initially, in contrast to the more patchy streams of Abel Tasman.

A higher taxa richness was collected in each case when sampling effort was spread over a larger scale i.e., samples in different streams (Kerans et al. 1992). This was true both at a regional scale and at the larger scale of all 3 regions, although there was no significant difference within a region and between all three regions; that is, the most variation is between streams rather than regions. Thus while taxa richness does increase with increasing sampling effort in a stream it increases more dramatically for the same effort in different streams. When only 1 region i.e., Mt Richmond Forest park was analysed, slightly lower taxa richness, was collected when effort was spread over the whole region than when the same effort was put into 1 sub-region. The only sub-region of the 3 sections within Mount Richmond Forest Park that did not exhibit this trend was the central sub-region in which streams were within only 1 catchment, the Pelorus catchment.

The findings of an increase in species numbers over a larger scale, are not unexpected and fit with species-area relationship theory (Arrhenius 1921; MacArthur and Wilson 1967; Conner 1979; Angermeier and Schlosser 1989; Hart and Horwitz 1991; Have, 1993). The increase in taxa richness shown in this study is probably attributable to the greater diversity of stream habitats associated with the larger sampled area and illustrates that habitat diversity is greater between streams than within streams (Kerans et al. 1992; Downes et al. 1995; Vinson and Hawkins 1996; Allan et al. 1997; Li et al. 2001). Habitat diversity is one of several factors thought to control species accumulation with increased sampling area. (Conner and McCoy 1979; Angermeier and Schlosser 1989; Hart and Horwitz 1991; Kerans et al. 1992; Watters 1992; Have 1993). Many of the habitats in this study, which range over a variety of altitudes and environmental characteristics, particularly within Kahurangi National Park are known to be species rich and have high levels of endemism and habitat diversity (Department of Conservation 2002a). Despite that, this study shows that sampling different streams increases taxa richness as much as sampling different regions. This may be due to a common core of taxa being present over a wide geographic range with differences in composition and abundances occurring at the individual stream level (Winterbourn et al. 1981; Death 1995; Harding and Winterbourn 1995; Thompson and Townsend 2000; Death submitted)

With funding and time constraints being an important consideration for conservation managers, less time should be spent intensively sampling within one stream system and efforts reallocated over a larger scale i.e., several streams. The variability at different scales suggests that spatial variation should be considered at every level in biodiversity inventories and sampling must be designed to detect these differences (Kerans et al. 1992; Li et al. 2001). In summary, it is suggested that when designing sampling programmes for collecting stream macroinvertebrate biodiversity, sampling effort should be spread over more than 1 stream, at a catchment and regional level thereby including a greater diversity of stream habitats, and consequently a higher diversity of invertebrates. Streams for such programs should be chosen for their different catchment areas, riparian vegetation, canopy cover, slope, geology, substrate types and altitude to encompass as many habitat types as possible.

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4

BIODIVERSITY IN NELSON STREAM MACROINVERTEBRATES: COMMUNITY STRUCTURE AND THE PRESENCE OF INDICATOR SPECIES

ABSTRACT

To investigate factors influencing community structure, the stream macroinvertebrate fauna of 54 streams in 3 conservation regions in the top of the South Island, New Zealand were sampled with kicknets. A variety of environmental characteristics measured at each stream, were assessed to examine links between community structure and habitat characteristics. Community structure was most strongly linked with altitude, canopy cover, presence of moss, stream width, and temperature. Five groups of communities were identified ranging from those in small high altitude streams with moss and high vegetative cover, to those in larger more open low altitude streams. These groups had the same common core of invertebrate taxa but differed in density and relative abundances. Smaller streams had higher proportions of Plecoptera and Ephemeroptera while larger open streams had higher proportions of Trichoptera, Diptera and Crustacea. To test for the presence of indicator taxa of biodiversity, individual taxa densities were correlated with total taxa richness. Several taxa e.g., *Archichauliodes diversus* and *Coloburiscus humeralis* showed significant relationships, but none were particularly strong suggesting indicator taxa might not be appropriate for the measurement of invertebrate biodiversity in New Zealand streams.

Keywords: biodiversity, community structure, environmental characteristics, indicator taxa, stream macroinvertebrates

INTRODUCTION

The recent emphasis on the protection of biodiversity in conservation management, and limitations to funding and resources, has meant the design of cost effective and efficient species inventories is an important challenge to ecologists (Wilson 1992; Oliver and Beattie 1993; Colwell and Coddington 1994; Harper and Hawksworth 1994; Pearson 1994; Williams and Gaston 1994; Stohlgren et al. 1995; Keating et al. 1998; Suter 1998; Vinson and Hawkins 1998; Department of Conservation 2000; Chapter 3). To design cost effective inventories for stream macroinvertebrates, the allocation of sampling effort in the most efficient manner possible and a sampling methodology which collects greatest biodiversity per unit effort is required (Colwell and Coddington 1994; Vinson and Hawkins 1998). Individual collection techniques (Chapter 2), and sampling protocols to maximise taxa richness per unit effort (Chapter 3), have previously been assessed for the effectiveness in the collection of biodiversity. It was found that by spreading sampling effort over a larger spatial scale (more than one stream) and therefore, encompassing more habitats, more species were collected. However this does not examine whether different community assemblages, resulting from differing stream types are leading to the increased richness collected by sampling at a greater scale.

The composition of stream macroinvertebrate communities is influenced by a variety of factors - physicochemistry, biotic interactions, dispersal, stability and biogeography (Hynes 1970; Townsend et al. 1983; Death 1995; Harding and Winterbourn 1995; Vinson and Hawkins 1998; Thompson and Townsend 2000). Catchment environmental characteristics are thought to be one of the most important factors determining physicochemical conditions and resource availability within the stream and thus invertebrate community structure (Harding and Winterbourn 1995; Death 2000; Thompson and Townsend 2000; Lemke 2002). New Zealand streams are characterised as physically dominated with biological interactions taking a secondary role (Winterbourn et al. 1981; Thompson and Townsend 2000). Within the New Zealand invertebrate fauna, there is thought to be a common core of genera and species that are widely distributed and dominate most stony stream faunas (Winterbourn et al. 1981; Harding and Winterbourn 1995; Thompson and Townsend 2000). If community structure differs in a predictable way with habitat characteristics this will need to be accounted for in biodiversity inventories so that as many taxa as possible are collected.

Pressures from reduced funding and resources, poor taxonomic knowledge and the logistical difficulties in 'all taxa' inventories (Oliver and Beattie 1993; Pearson 1994; Beccaloni and Gaston 1995; Gaston 2000), have required the development of "simpler yet objective ways of predicting where high biodiversity will occur" (Harper and Hawksworth 1994). One possibility is that some taxa may be indicators of biodiversity (Pearson and Cassola 1992; Harper and Hawksworth 1994; Pearson 1994; Beccaloni and Gaston 1995; Landcare 2000). This has received considerable interest and several criteria have been established for potential taxa, which include the species being taxonomically well known, widely distributed, easily identified, with a known biology and life history, and easily surveyed. (Pearson and Cassola 1992; Pearson 1994). The majority of work on indicator groups both here in New Zealand, and overseas have been oriented towards vertebrates and plants e.g., (Landres et al. 1988; Landcare 2000), though recently there has been greater use of invertebrates as indicator species. Examples include tiger beetles (Coleoptera: Cicindelidae) (Pearson and Cassola 1992), butterflies (Lepidoptera: Nymphalidae) (Beccaloni and Gaston 1995) and spider communities (Coombe 2001).

In this study, stream invertebrate communities collected in 3 conservations parks in the upper South Island are examined. The invertebrate community assemblages are analysed to determine if there are differences between areas and if so which environmental characteristics are most closely linked to community structure. The relative abundances of the main taxa groups comprising the communities is also investigated to assess any differences in composition with habitat. Any differences in community assemblages and the characteristics controlling these will be important to take into account when designing sampling programmes for biodiversity assessment. The occurrence of potential biodiversity indicator taxa within these communities is also assessed.

METHODS

Site Selection

Streams in 3 conservation parks in the Nelson region of the South Island were sampled in this study (Refer Fig. 3.1, Chapter 3). The parks in this study were Abel Tasman National Park, Kahurangi National Park and Richmond State Forest Park (Refer Plate 1a,b,c, Chapter 3), and were chosen for their relatively pristine nature and their high diversity of invertebrates. Within each of these 3 regions 18, 2nd and 3rd order streams were selected spread over the parks (with the exception of Kahurangi which was sampled only on the east side), covering a range of stream types, with relatively easy access and native riparian vegetation. Samples were collected during November and December 2000.

Invertebrate samples

One-minute kicknet samples (250μm mesh) were used to collect invertebrates from riffles at 3 sites, 20 metres apart within each stream. The samples were collected by moving progressively upstream disturbing the benthos in front of the kicknet for a 1 minute time period. Riffle areas were selected as these are generally considered to be species rich and have high numbers of insect larvae (Hughes 1975; Winterbourn 1985) Samples were stored in 10% formalin. In the laboratory, samples were filtered through a 500μm sieve and the invertebrates were identified to species level where possible using available keys (McFarlane 1951; Cowley 1978; Towns 1983; Winterbourn and Gregson 1989). Where it was not possible to identify invertebrates they were grouped into apparent morphospecies. (Full species list given in Appendix 3).

Environmental measures

Environmental characteristics of each site were measured when samples were collected. Water chemistry measured included conductivity (measured with an Orion 122 Conductivity meter), temperature and pH (measured with an Oakton waterproof pHTestr). Width, depth, current velocity (measured with a Marsh McBirney velocity metre) and hydraulic radius were measured above and below each of the 3 sites in a stream. Stream slope was measured over a 20m reach using an Abney level. Percent riparian vegetation composition, vegetative cover and moss present were visually assessed. Altitude and stream order were derived from 1:25 000 scale topographical maps (Spence 1985; DSLI 1996; Terralink 1997a; Terralink 1997b; Terralink 1998a; Terralink 1998b; LINZ 1999a; LINZ 1999b; LINZ 2000a; LINZ 2000b). Substrate composition was assessed using a gravelometer and the Wolman walk (Wolman 1954). This was done by assessing 33 stones at each of the 3 sites (approx 100 per stream) and categorising them into 10 size groups. Substrate embededness was subjectively assessed and scaled as (1) loose, (2) loose – moderate, (3) moderate, (4) moderate – tight, (5) tight or (6) very tight. Habitat stability was assessed with the Pfankuch (1975) channel stability index, which involves summing the scores assigned to 15 streambed attributes (weighted in relation to their perceived importance) according to the observer's evaluation of predetermined criteria. The scores are combined to give an overall stream stability score that can range from 40 (most stable) to 160 (least stable). For the purposes of this study I did not include the vegetative bank portion of this index (Pfankuch 1975). Duncan's stability index (Duncan et al. 1999) was calculated using the hydraulic radius measurements taken at each site.

Data analysis

Species richness and total abundance was measured as the total number of taxa and individuals collected in each replicate, in each of the 54 streams. Totals and averages of these measures were calculated for each stream. EPT, Berger Parker Index and Margalef's Index were also calculated. Analysis of Variance (ANOVA) was used to determine the difference in biotic indices between the three regions. (SAS 8e, 2001)

EPT, Ephemeroptera (Mayflies), Plecoptera (Stoneflies) and Trichoptera (Caddisflies) is an index of enrichment. The percentage of EPT taxa is the proportion of taxa collected from a stream, which belong to one of these groups. Therefore as EPT increases organic enrichment decreases (Lenat 1988)

$$\%EPT = \frac{E+P+T}{N}$$

Where E is the number of Ephemeroptera, P is the number of Plecoptera, T is the number of Trichoptera, and N is the total number of individuals.

The Berger-Parker index is a dominance index that focuses on the single most abundant species (Berger and Parker 1970) given by,

$D = N_{max}/N$

where N_{max} is the number of individuals in the most abundant species and N is the total number of individuals.

Margalef's index (Clifford and Stephenson 1975) is a measure of taxonomic richness given by:

$D_{Mg} = (S-1)/\ln N$

where N is the total number of individuals and S is the number of taxa
An increase in the Berger Parker index indicates a decrease in evenness where as an increase in Margalef's index represents an increase in richness.

Community structure was analysed with multivariate ordination and classification techniques. Detrended correspondence analysis (DECORANA), performed with statistical package PC-ORD (McCune and Mefford 1995), was used to assess gradients in community structure, in association with environmental and biological characteristics. Pearson correlations were used to identify significant relationships between the ordination axes and the environmental and biological characteristics. For the purposes of this study individual taxa abundances were log transformed, rare species down weighted and an outlier site Kahurangi National Park (K13), removed.

Classification of stream communities into groups was carried out using the PC-ORD cluster analysis procedure (McCune and Mefford 1995), using the Euclidean distance measure and Wards group linkage.

The presence of biodiversity indicator taxa was assessed by correlating species densities with taxon richness using the Spearman's rank correlation procedure in SAS (8e, 2001).

RESULTS

The mean and range of physicochemical characteristics at the sites and the biotic indices for the 3 areas are given in Table 4.1 (Appendix 4). Abel Tasman streams were generally small, stable, steeper streams at low altitudes with warmer water temperatures. Kahurangi streams were all high altitude, less stable, cold streams with high canopy cover, whereas Mt Richmond sites were intermediate between the Abel Tasman and Kahurangi streams.

There was no significant difference in biotic index scores between the three regions although Abel Tasman streams had less animals at each site ($F_{2,51}= 6.47$, $P<0.003$). A core fauna of several common taxa was found in all streams with the 6 most abundant taxa being, the leptophlebiid mayfly, *Deleatidium* sp.; the elmid beetle, *Hydora* sp.; the cased caddisfly, *Olinga feredayi*; the mayfly *Colorburiscus humeralis*; the freeliving caddisfly *Hydrobiosella mixta* and the tipulid *Aphrophila neozelandica.*

The DECORANA identified several important gradients in community structure in the three regions (Fig. 4.1). These gradients included higher altitude, smaller, streams with high moss and vegetative cover in the top centre to right hand corner of the ordination; predominately the Kahurangi sites. The warmer, wider, more open streams at lower altitudes often in Abel Tasman were near the bottom of the ordination while the more open, larger moderate altitude Mt Richmond sites were scattered amongst these, although mainly to the centre and left of the ordination. The environmental characteristics associated with these gradients were stream width (negative correlation), and vegetative and moss cover (positive correlation) on Axis 1. Axis 2 showed a gradient between stream temperature (negative correlation), and altitude and vegetative cover (positive correlation) (Table 4.2). Axis 1 of the DECORANA accounted for 37% and Axis 2 explained 20% of the variation in the invertebrate communities

Table 4.1. Mean and range for environmental characteristics and biotic indices measured during November and December 2000 in Abel Tasman National Park, Kahurangi National Park and Mt Richmond Forest Park

	Abel Tasman National Park		**Kahurangi National Park**		**Mt Richmond Forest Park**	
	Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**
Altitude	67	10 - 480	488	140 - 940	226	40 - 500
Stream width (m)	3.81	0.45 - 4	4.92	0.6 - 18.5	4.38	0.36 - 20.7
Water depth (cm)	20.82	6 - 55.5	24.07	6 - 61	20.4	6 - 65
Current velocity ($cm\ s^{-1}$)	19.85	0.1 - 58	15.94	0.23 - 48	5.85	0.03 - 31
Conductivity ($\mu S\ cm^{-1}$)	75.48	32.6 - 243	135.79	53.5 - 228	92.8	40.8 - 225
Temperature (°C)	11.5	9.4 - 13.2	8.4	5.4 - 11.1	10.8	6 - 15
pH	8.22	7.9 - 8.8	8.56	8.4 - 4.7	8.5	8.2 - 9.1
Native vegetation (%)	92.8	0 - 100	86.9	50 - 100	86.9	0 - 100
Canopy cover (%)	46.1	5 - 100	48.7	5 - 90	29.7	0 - 85
Moss cover (%)	43.3	0 - 90	33.1	0 - 100	11.2	0 - 80
Embededness	4	1 - 6	3.5	1 - 5	3	1 - 6
Channel slope	0.06	0.01 - 0.22	0.044	0.004 ± 0.15	0.043	0.003 - 0.12
Dominant Geology		Granite		Greywacke/ marble & granite		Greywacke/ granite
Substrate size (mm)	160	Sand -boulders	169	Sand - boulders	155	Sand - boulders
Pfankuch score bottom	25.31	15 - 40	31.5	16 - 45	28.9	18 - 54
Pfankuch score total	45.69	28 - 83	52.4	37 - 71	51.97	33 - 91
Duncan score	0.21	.0004 – 2.87	.05	0.00006 – 0.3	0.08	0.00002 - 0.64
Total taxa richness	35.1	24 - 46	35.72	7 - 46	38.5	22 - 56
EPT	0.58	0.47 - 0.69	0.53	0.14 – 0.67	0.58	0.48 – 0.68
Berger Parker Index	0.38	0.19 – 0.70	0.48	0.26 – 0.95	0.47	0.14 – 0.81
Margalef's index	5.13	3.76 – 6.62	4.74	1.23 – 6.28	5	2.75 – 6.97

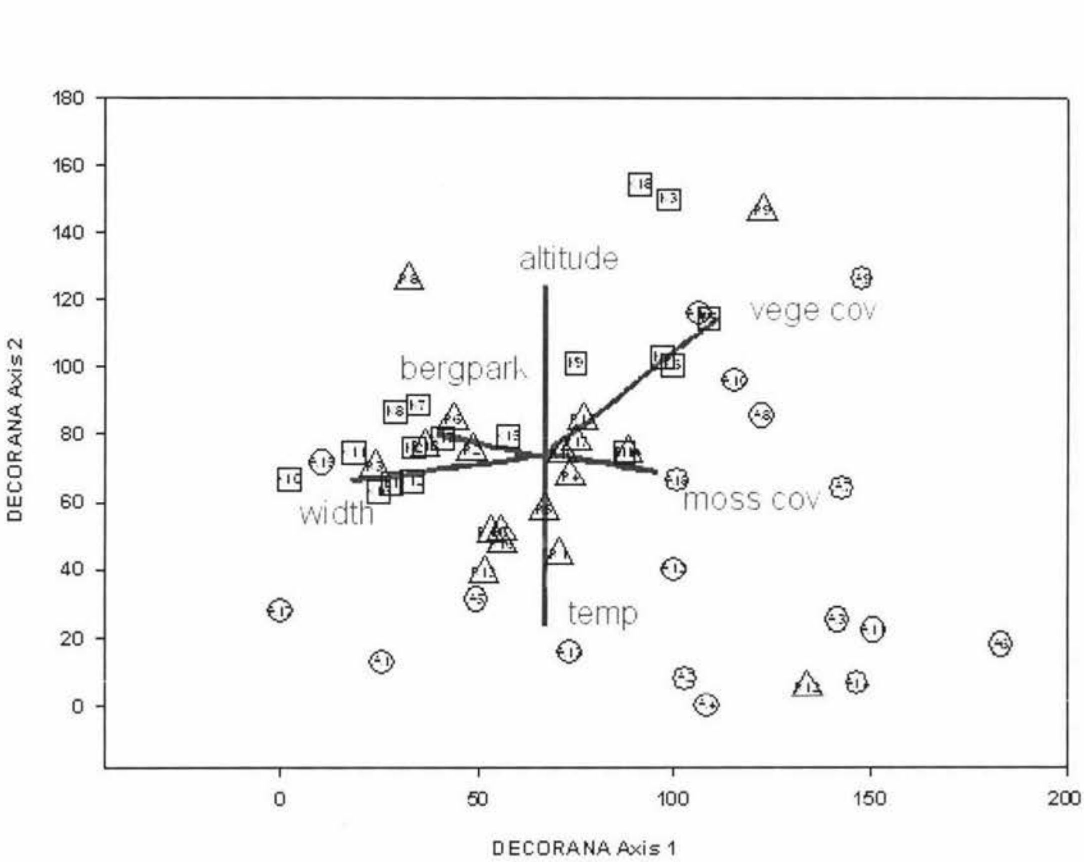

Figure 1. Axis one of a detrended correspondence analysis as a function of axis two for invertebrate communities in streams in Abel Tasman National Park, Kahurangi National Park and Mt Richmond Forest Park sampled in November and December 2000. ○ 1- 18, represent Abel Tasman streams, □ 1- 18, Kahurangi streams and △ 1- 18, Mt Richmond streams.

The Berger Parker dominance index was also linked with Axis 1 with less even communities tending to occur in wider more open streams at moderate to high altitudes. When environmental variables were directly correlated with biotic indices the only significant relationship ($P = <0.05$) was a positive relationship between the Berger Parker index and the Pfankuch bottom and total scores, and a positive relationship between Margalef's index and stream width.

Table 4.2. Variables correlated (* = P<0.05) with Detrended Correspondence Analysis axes for macroinvertebrate communities collected from 54 streams in Abel Tasman National Park, Kahurangi National Park and Mt Richmond Forest Park, sampled in November and December 2000.

	Axis 1	Axis 2
Width	-0.60*	-0.23
Depth	-0.41	-0.37
Velocity	-0.02	-0.23
Conductivity	-0.33	0.15
Temperature	<-0.01	-0.59*
pH	-0.36	0.38
% native vegetation	0.41	0.16
% canopy cover	0.55*	0.52*
% moss	0.45*	-0.16
Embededness	-0.09	-0.15
Slope	0.14	-0.07
Granite	0.17	-0.22
Greywacke	-0.29	0.23
Marble	-0.21	-0.03
Substrate size	-0.33	-0.38
Pfankuch bottom	-0.32	0.35
Pfankuch total	-0.22	0.33
Altitude	-0.01	0.60*
Total richness	-0.11	-0.07
Average Richness	-0.20	-0.02
Berger Parker Index	-0.46*	0.21
EPT	0.40	-0.11
Margalef's Index	0.20	-0.09

Axis 1 and 2 of the DECORANA were correlated with a number of taxa (Table 4.3). At one end of the gradient, taxa that exhibited a negative correlation with Axis 1 (i.e., strong correlations with width and depth), were the mayfly *Deleatidium sp.*, the early instars of free living caddisfly family *Hydrobiosidae*, the Tipulidae *A. neozelandica*, and the cased caddisflies *O. feredayi, Beraeoptera roria* and *Confluens olingoides*. Taxa that exhibited a positive correlation with Axis 1 (i.e., strong relationships with vegetative cover and moss) were the mayfly *Austroclima sepia*, the stonefly *Zelandoperla fenestra*, and the cased caddisfly *Pycnocentria sylvestris*. Axis 2, showed negative correlations with *Zelolessica cheira* and *Pycnocentrodes aureola*. The stoneflies *Spaniocerca zelandica*, *Zelandoperla agnetis*, *Zelandobius unicolour* and *Austroperla cyrene* were all strongly correlated with the other end of Axis 2.

Table 4.3. Taxa correlated (* = $P<0.05$) with Detrended Correspondence Analysis axes for macroinvertebrate communities collected from 54 streams in Abel Tasman National Park, Kahurangi National Park and Mt Richmond Forest Park, sampled in November and December 2000

	Axis 1	**Axis 2**
Austroclima sepia	0.63*	-0.27
Deleatidium sp.	-0.69*	0.21
Austroperla cyrene	0.25	0.51*
Spaniocerca zelandica	0.16	0.64*
Zelandobius unicolour	0.38	0.51*
Zelandoperla agnetis	0.40	0.55*
Zelandoperla fenestra	0.53*	-0.14
Hydrobiosidae early instars	-0.62*	0.08
Zelolessica cheira	0.49	-0.54*
Beraeoptera roria	-0.61*	-0.15
Confluens olingoides	-0.53*	0.05
Olinga feredayi	-0.63*	-0.07
Pycnocentria sylvestris	0.51*	-0.21
Pycnocentrodes aureola	-0.28	-0.51*
Chironomid Unidentified 2	0.02	-0.11
Aphrophila neozelandica	-0.68*	-0.27

Cluster analysis (Fig. 4.2), revealed five community groupings and one outlier stream (R12);

Group A: Consisted of 6 streams all from Abel Tasman National Park with granite geology. These were all small to medium sized, very low altitude streams with warm water temperatures (greater than 10° C), and low Berger Parker index scores. These streams were characterised biologically by even communities with high proportions of cased Trichoptera (particularly *B. roria*), and Diptera (particularly chironomids) and low abundances of Plecoptera

Group B: Consisted of 16 streams from all 3 regions. These were all larger, deeper streams at moderate altitudes. They had low canopy cover and little moss, larger substrates than the other groups and lower streambed gradients. These streams were dominated (average 53 %) by the leptophlebiid mayfly *Deleatidium* sp. with relatively low levels of other mayfly taxa. These streams were also characterised by relatively high levels of cased Trichoptera particularly *B. roria*, *C. olingoides* and *O. feredayi.* Diptera (particularly *A. neozelandica* and chironomids) and the coleopteran *Hydora* sp. were also present in high numbers.

Group C: These were 11 streams from Mt Richmond and Kahurangi Parks. Streams were of average size and had warm water temperatures (9 – 15° C). All had low – moderate canopy cover and moss presence, a gentle streambed gradient and were at low- moderate altitudes. These streams had relatively high abundances of mayflies and the coleopteran *Hydora* sp. The streams also had relatively low levels of Trichoptera, both freeliving and cased. High numbers of the Dobsonfly larvae *Archichauliodes diversus* were found in these streams as well as higher levels of taxa more "tolerant" to increases in water temperature and open canopies, including the freshwater mollusc *Potamopyrgus antipodarum*, Platyhelminthes, and Oligochaeta.

Group D: This group comprised 14 streams from all 3 regions. They were small to medium sized streams of moderate temperatures with average to high moss and canopy cover. The streams were at a range of low to moderate altitudes and had communities with even abundances of taxa. Moderate levels of mayfly taxa and high levels of stonefly taxa, in particular the facultative shredder *A. cyrene* and the *Zelandobius* group were found in these streams. Of the trichopterans, freeliving forms dominated, particularly *Aoteapsyche* sp. Only this group had high abundances of Crustacea (e.g., amphipods).

Group E: The final small group of 5 streams were all from Kahurangi National Park and consisted of midsized, cold, high altitude streams with extensive canopy cover and abundant moss. They had high EPT and Berger Parker indices. They were characterised biologically by a high abundance of *Deleatidium* sp. and *Nesameletus* sp. There was also an abundant plecopteran and coleopteran fauna (*Hydora* sp). The trichopteran and dipteran faunas were less abundant in these streams.

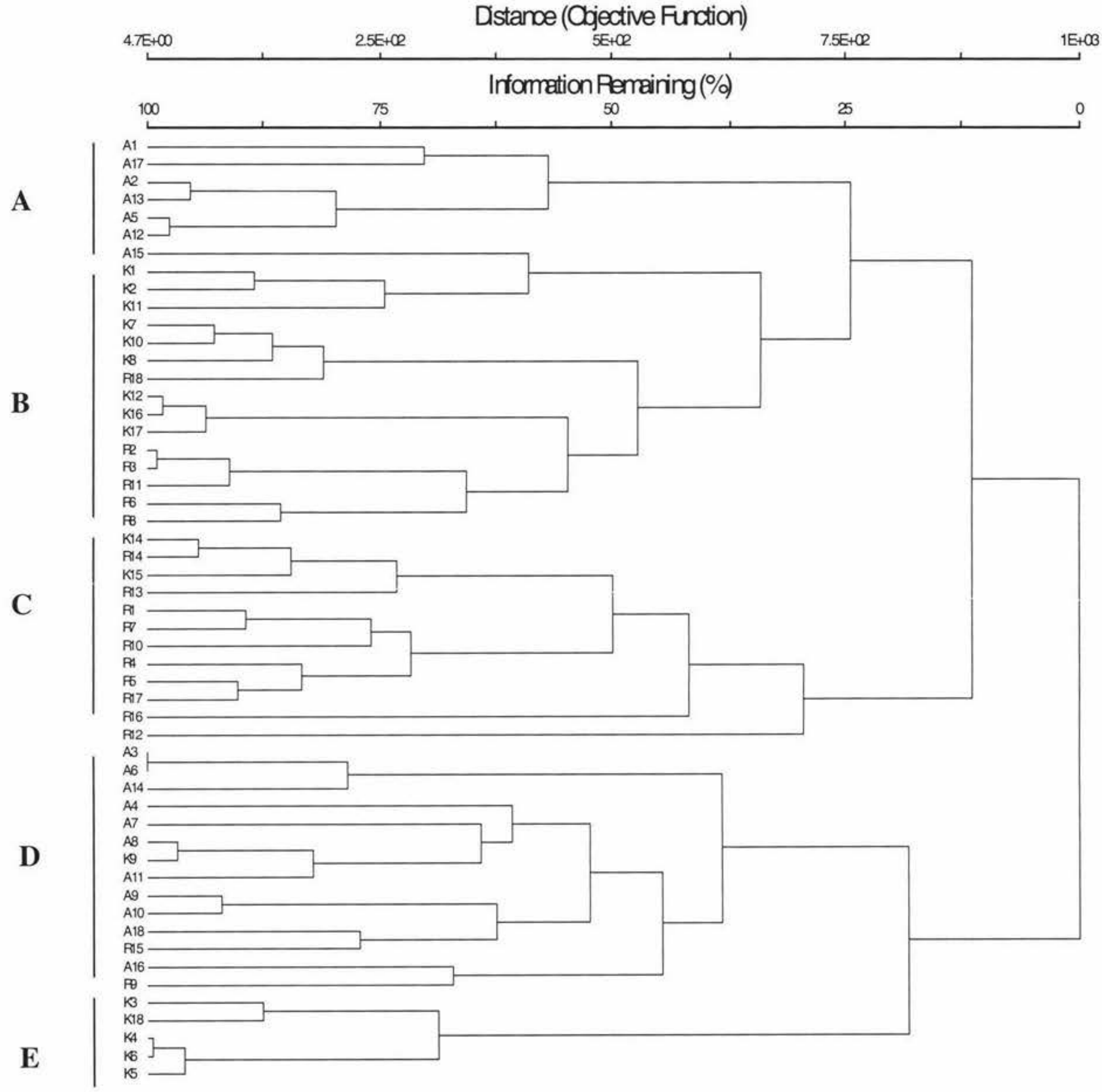

Figure 4.2. Classification by cluster analysis of stream macroinvertebrate communities into 5 groups A – E. Site references A1 – 18, K1 – K18 and R1 – R18 represent stream communities sampled in Abel Tasman National Park, Kahurangi National Park and Mt Richmond Forest Park, during November and December 2000.

The relative abundances of the higher order invertebrate taxa in the five community groups are presented in Fig. 4.3. They have similar invertebrate taxa but these taxa differ in relative abundance. The lower altitude communities in streams with warmer temperatures and less canopy cover have larger trichopteran, dipteran and crustacean components to their communities, whereas the higher altitude, cooler moss covered streams have higher relative abundance of the plecopteran, coleopteran and ephemeropteran components.

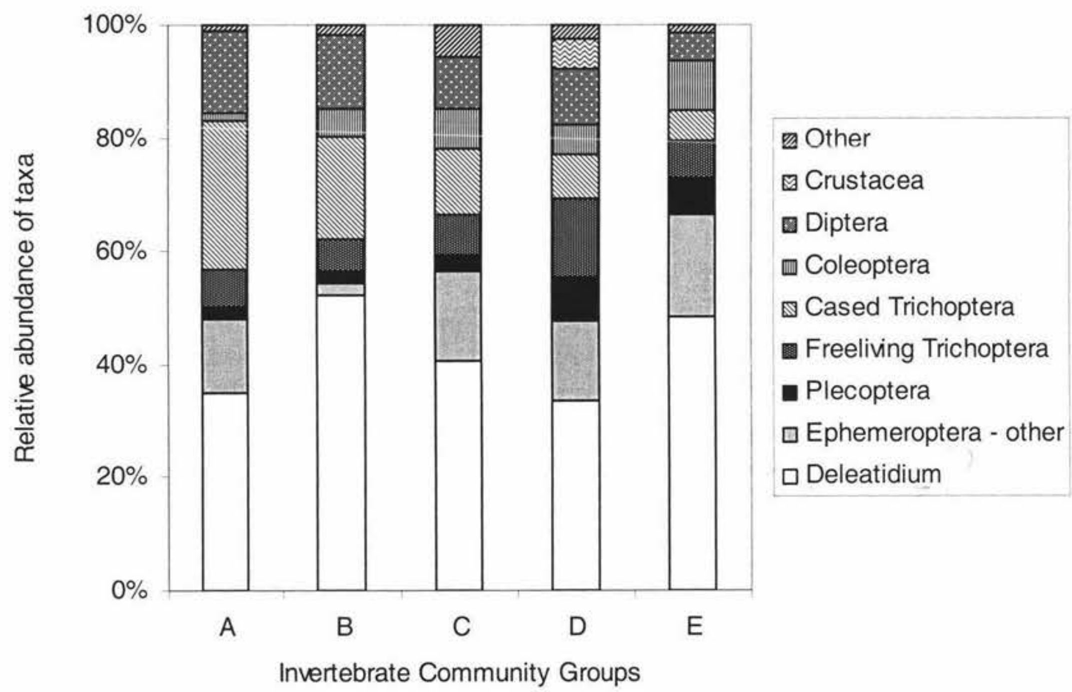

Figure 4.3. Relative abundance of the higher order taxa of macroinvertebrates collected from 54 streams in Able Tasman National Park, Kahurangi National Park and Mt Richmond Forest Park during November and December 2000, within each of the community groups identified by the cluster analysis.

Correlations of individual taxa densities against total taxa richness, used to explore for biodiversity indicators, showed several strong associations (Fig. 4.5). The strongest positive relationships were with *A. diversus* ($r_s = 0.50$) and *C. humeralis* ($r_s = 0.50$). Early instar *Hydrobiosidae* ($r_s = 0.40$) and *O. feredayi* ($r_s = 0.48$) also exhibited strong relationships.

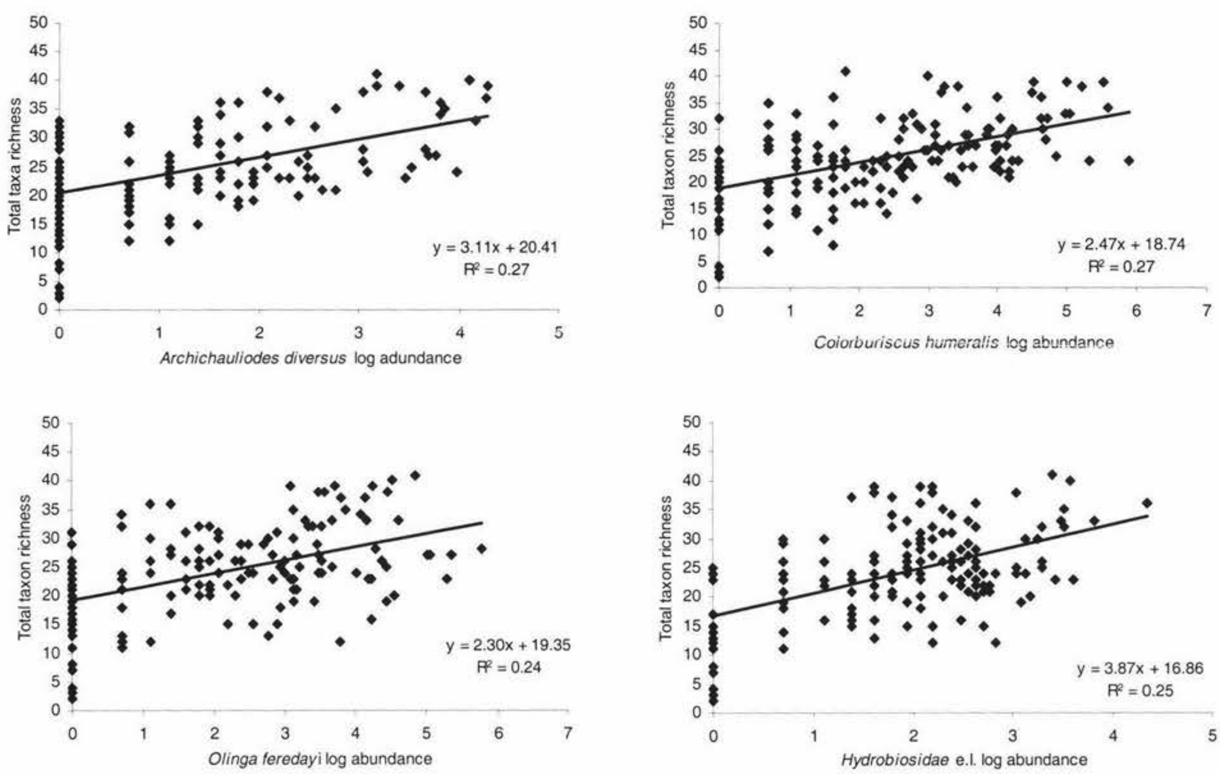

Figure 4.5. Linear regression of natural log species densities with total taxon richness for four potential indicator species; *Archichauliodes diversus, Colorburiscus humeralis, Olinga feredayi* and *Hydrobiosidae* early instars.

DISCUSSION

All of the streams studied in Mt Richmond Forest Park, Kahurangi and Abel Tasman National Parks had invertebrate communities composed of similar species, particularly the more common species, but with differing densities and relative abundances over different habitats. This is similar to other New Zealand studies which have found a common core of taxa that are present over a wide geographic range but differ in relative abundance between habitats (Winterbourn et al. 1981; Death 1995; Harding and Winterbourn 1995; Thompson and Townsend 2000; Death submitted).

Stream characteristics that were most strongly associated with invertebrate community structure were, stream width, water temperature, altitude, canopy cover and moss presence. A number of taxa were associated with the gradients these environmental characteristics created across communities in the ordination. At one end of the gradient on Axis 1 were communities from streams with high canopy cover and abundant moss. The stonefly *Z. fenestrata* and the mayfly *A. sepia* were found mainly in mountain and small forest streams associated with moss (Winterbourn and Gregson 1989). The cased caddisflies, *P. sylvestris* and *Z. cheira*, which are commonly associated with wood in forest streams and on bryophytes in swift rocky streams respectively, were also positively correlated with Axis 1 (Winterbourn and Gregson 1989; Death 2000). On Axis 2, the end of the gradient associated with high canopy cover and high altitude showed strong positive relationships with a number of stonefly species. Stoneflies are known to be sensitive to temperature (Quinn and Hickey 1990; Sponseller et al. 2001) and are often associated with colder, steeper, faster flowing mountain streams and the presence of moss (Winterbourn and Gregson 1989; Quinn and Hickey 1990) and canopy cover (Harding and Winterbourn 1995).

The larger, streams with less canopy cover at the other end of the environmental gradient on Axis 1, have greater exposure to sunlight, warmer water temperatures, and thus higher periphyton growth and yield different invertebrate communities. These communities contained taxa that commonly occur in larger downstream forest sites with more open canopy cover (Collier et al. 2000) including caddisflies, dipterans and Crustacea. Similar community composition has been found in open canopy streams in several other studies within New Zealand (Quinn and Hickey 1990; Harding and Winterbourn 1995; Collier et al. 2000). At the other end of Axis 1 communities were dominated by *Deleatidium* sp. It accounted for an average of 42% abundance in these streams and is known to account for up to 50% of the fauna in large South Island streams (Harding and Winterbourn 1995). Several caddisflies *O. feredayi, B. roria, and C. olingoides* which negatively correlate with Axis 1 and those species that showed strongest negative correlations with Axis 2, the cased caddisflies *Z. cheira,* and *P. aureola*, in this study were associated with open canopy and warmer water temperatures. They have been found to be common in open tussock, scrub catchment and lowland streams throughout the South Island (Winterbourn and Gregson 1989; Harding and Winterbourn 1995).

Regional and local environmental conditions have been shown to play important roles in structuring invertebrate communities (Hynes 1970; Townsend et al. 1983; Currie 1991; Hildrew and Giller 1994; Death 1995; Harding and Winterbourn 1995; Thompson and Townsend 2000), and the 5 environmental characteristics illustrated by the ordination as being important in structuring invertebrate communities in this study, are not surprising. Many if not all of these environmental characteristics are interrelated. Stream size (width) is often positively correlated with taxa richness (Vinson and Hawkins 1998), and often dictates the amount of canopy cover a stream will have and hence the amount of sunlight able to penetrate the canopy. Small streams will often have greater canopy cover, cooler water temperatures, less above stream light penetration and therefore lower periphyton levels (Zimmerman 2001). In this study both a shift in invertebrate composition (Collier et al. 2000), as well as a significant increase in richness was associated with increasing stream size. In Middle Bush Stream, Winterbourn (Winterbourn 1978) found a lower diversity than larger streams, which he attributed to the streams small size, steep unstable channel and almost closed canopy. He suggested the higher diversity was due to the heterogeneous energy base. The increase in invertebrate richness with stream size could also be a result of the larger habitat area sampled, although Townsend et al. (Townsend et al. 1997) and Li et al. (Li et al. 2001) have found no evidence for increased richness with larger stream size as a function of habitat area.

Of the biotic indices only Berger Parker showed a gradient across the invertebrate communities of the three areas, indicating lower evenness in moderate altitude, larger open streams, with communities often dominated by *Deleatidium* sp. (Death 1996). The Berger Parker index also exhibited a strong relationship with stability, indicating more stable streams had more even communities. (Death and Winterbourn 1995; Death 1996; Death in press)

The invertebrate communities could also be considered to form 5 loose groups of communities, ranging from those in small cold mountainous streams with high levels of canopy cover and moss, through to communities in larger, more open streams at lower altitudes. The small higher altitude streams, all within Kahurangi National Park, were generally steep and swift flowing mountain streams with high amounts of moss and canopy cover, whereas all the very low altitude streams were in Abel Tasman National Park and were generally coastal streams. The 3 other groups comprised a range of stream sizes at moderate altitudes from all 3 parks with varying degrees of moss and canopy cover. Streams in these groupings had differing abundances of the main higher taxa groups with ephemeropteran and plecopteran taxa more abundant in high altitude streams with high canopy cover whereas trichopteran and dipteran taxa were more abundant in lower altitude more open streams

The attempt to identify biodiversity indicators in this study by correlating species densities with total taxon richness was not very successful. The strongest of these relationships were with *A. diversus* and *C. humeralis.* These relationships were not strong and should not be the basis for indicator species. Currently, considerable effort is going into finding indicator species as a surrogate for complete taxa inventories in assessing biodiversity (Pearson and Cassola 1992; Harper and Hawksworth 1994; Pearson 1994; Beccaloni and Gaston 1995; Landcare 2000). Similar null results have been found in comparable studies of terrestrial invertebrate communities (Godfrey 2000, Aspin 2002, pers. comm.), although some terrestrial communities have indicated coleopteran, lepidopteran and spider communities are good indicators of community richness (i.e. Pearson and Cassola 1992; Beccaloni and Gaston 1995; Coombe 2001)

In summary, altitude, stream width, canopy cover, moss presence and water temperature were found to be important factors in determining stream invertebrate community composition. The invertebrate fauna of streams in Abel Tasman National Park, Kahurangi National Park and Mt Richmond Forest Park, composed a common core of taxa whose composition and abundances change progressively over these environmental gradients. Plecopteran and ephemeropteran taxa were more abundant in smaller, canopy covered streams than open low altitude streams where trichopteran, dipteran and crustacean taxa were more dominant. It has been suggested that taxa richness of stream invertebrates is jointly structured by historical events and the unique physicochemical conditions in each stream (Vinson and Hawkins 1998; Boothroyd 2000). Given this, and the changes of community structure across habitats at a regional scale, biodiversity inventories will need to encompass as many different environmental gradients to ensure the highest number of taxa are collected.

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5

SYNTHESIS

The pressing need to increase our knowledge of the indigenous biodiversity of New Zealand and identify key threats, as well as develop standards and codes of practice for monitoring biodiversity has been highlighted by the New Zealand Biodiversity Strategy (Department of Conservation 2000). In order to do this, it is necessary to conduct biological inventories of many habitats and areas throughout New Zealand. With restrictions on funding and the increasing demand for these inventories in conservation management, it has become increasingly important to allocate sampling effort in the most efficient manner possible and use a sampling methodology that collects greatest biodiversity per unit effort.

In this thesis I have attempted to develop an inventory sampling protocol for stream macroinvertebrates in New Zealand with which resource and conservation managers can efficiently assess the freshwater biodiversity of a region and effectively focus conservation efforts. Three approaches were used to assess a suitable protocol.

To examine which stream macroinvertebrate sampling technique maximised collected biodiversity (measured as taxa richness) per unit effort, a preliminary study was conducted comparing 3 benthic invertebrate sampling techniques (Surber, kicknet and individual stone sampling). It was found that overall, kicknet samples collected a higher number of taxa than either Surber or individual stone samples, with several shorter time period kicknets (30-second and 1-minute) collecting the greatest diversity per unit effort.

Kicknet samples were then examined over 3 spatial scales using 3 replicates a) within one stream, b) within one region and c) spread over three regions. It was found that greatest taxa richness was collected when sampling effort was spread over more than one stream within a region or over several regions than at the single stream level.

As increased taxa richness was collected at larger scales, the differing stream invertebrate communities between the 3 regions were examined in relation to environmental characteristics to assess links between community structure and habitat characteristics. Altitude, vegetative cover, moss cover, stream width, and water temperature exhibited strongest relationships with community structure. Five groups of communities were identified ranging from small high altitude streams with moss and high vegetative cover, to larger more open low altitude streams. These groups had a common core of invertebrate taxa that differed in density and relative abundance with changes in habitat, highlighting the importance of sampling from a range of habitat types in biodiversity surveys. No taxa were identified as being useful as biodiversity indicators.

To summarise, short time period kicknet samples (1 per stream), in several streams spread over a variety of environmental habitats types (i.e. differing altitude, canopy cover and stream size), will maximise the diversity of community assemblages sampled and thus the level of stream macroinvertebrate taxa collected in freshwater biodiversity inventories for the sampling effort allocated.

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Appendix 1a. List of taxa collected in 10 replicate individual stones samples (ST1 – ST10) at Waiaruhe Stream, Te Urewera National Park in October 2000.

		ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10
Ephemeroptera											
	Early instar	1	3	6	12	1	5	7	15	2	3
	Acanthophlebia cruentata	0	0	0	0	0	0	1	0	0	0
	Austroclima sepia	1	0	0	2	0	2	0	0	1	2
	Coloburiscus humeralis	0	5	14	58	7	58	47	17	12	50
	Deleatidium sp.	18	27	42	26	20	40	67	35	34	27
	Nesameletus sp.	2	0	3	0	1	0	0	0	0	0
	Neozephlebia scita	0	0	0	0	0	1	4	0	0	1
	Zephlebia dentata	4	1	1	1	0	2	3	2	2	0
	Zephlebia spectabilis	1	1	0	0	0	0	0	0	0	0
Plecoptera											
	Early instar	3	1	1	0	0	0	0	1	0	2
	Austroperla cyrene	0	0	0	2	0	0	1	0	0	0
	Megaleptoperla diminuta	1	0	0	0	0	0	0	0	0	0
	Stenoperla prasina	0	0	2	0	0	0	1	0	0	0
	Zelandobius sp.	1	0	0	0	0	0	0	0	0	0
	Zelandobius confusus	0	0	0	0	0	0	3	0	0	0
	Zelandoperla agnetis	0	0	0	0	1	0	0	1	3	6
Trichoptera											
Hydropsychidae											
	Aoteapsyche sp.	0	0	0	2	0	0	0	0	1	1
	Orthopsyche fimbriata	0	1	5	13	1	19	19	15	15	9
	Orthopsyche pupa	0	0	0	0	0	0	0	0	0	1
Hydrobiosidae											
	Hydrobiosidae e.i.	0	0	1	2	0	2	7	2	3	2
Philopotamidae											
	Hydrobiosella mixta	0	0	0	0	0	2	0	0	2	0
Helicopsychidae											
	Helicopysche sp.	78	198	125	23	37	107	67	94	85	17
Leptoceridae											
	Triplectides obsoleta	2	0	0	0	0	0	0	0	0	0
Conoesucidae											
	Beraeoptera roria	9	23	44	72	0	29	15	27	12	68
	Olinga feredayi	0	0	0	0	0	0	1	5	0	0
	Pycnocentria evecta	0	0	1	0	0	1	0	0	1	0
	Pycnocentria funerea	0	1	0	0	0	0	0	0	0	0
	Pycnocentria sylvestris	0	0	0	0	0	0	0	0	0	1
Diptera											
Tipulidae											
	Aphrophila neozelandica	1	3	2	0	0	0	1	1	1	2
	Eriopterini sp.	1	0	0	1	0	0	0	0	1	0
	Molophilus sp.	0	0	1	0	0	0	0	0	0	0
	Dolichopodidae	0	0	0	0	1	0	0	0	1	0
Chironomidae											
	Maoridiamesa sp.	0	0	1	0	1	2	0	1	1	0
	Polypedilum sp.	0	0	17	0	2	1	1	0	5	0

	unknown a	0	0	1	0	0	0	0	0	0	0
	unknown b	0	0	0	0	0	0	0	0	0	0
	unknown c	0	0	0	0	0	0	0	0	0	0
	unknown d	0	0	0	0	0	0	0	0	0	0
Megaloptera											
	Archichauliodes diversus	8	1	14	3	6	3	4	3	8	2
Coleoptera											
Hydraenidae	*Orchymontia* sp.	4	1	8	5	1	3	4	6	3	1
Mollusca											
	Potamopyrgus antipodarum	5	0	2	1	0	3	1	3	2	0
Oligochaeta											
	Large	0	0	1	0	0	0	0	0	0	0
Other											
	Platyhelminthes	3	1	0	3	1	5	10	2	0	3
	Nematomorpha	0	0	0	0	0	0	1	0	0	0
Total individuals		**143**	**267**	**292**	**226**	**80**	**285**	**265**	**230**	**195**	**198**
Total taxa		**18**	**14**	**21**	**16**	**13**	**18**	**21**	**17**	**21**	**18**

Appendix 1b. List of taxa collected in 10 replicate Surber samples (SU 1 – SU 10), at Waiaruhe Stream, Te Urewera National Park in October 2000.

		SU1	SU2	SU3	SU4	SU5	SU6	SU7	SU8	SU9	SU10
Ephemeroptera											
	Early instar	13	5	5	17	13	8	13	7	0	10
	Acanthophlebia cruentata	1	0	1	0	0	0	0	2	0	0
	Ameletopsis perscitus	0	0	0	0	0	0	2	0	0	0
	Austroclima jollyae	0	0	0	0	0	0	5	0	0	0
	Austroclima sepia	0	1	0	1	0	0	0	5	0	0
	Coloburiscus humeralis	1	5	0	10	25	20	34	91	5	252
	Deleatidium sp.	14	65	34	24	64	40	61	29	30	118
	Neozephlebia scita	0	0	0	0	1	0	1	0	0	3
	Nesameletus sp.	0	0	0	0	0	0	0	0	2	1
	Zephlebia dentata	0	0	1	0	0	1	5	1	2	6
	Zephlebia spectabilis	8	2	5	1	0	0	2	0	0	0
Plecoptera											
	Early instar	0	1	0	3	2	0	1	2	0	1
	Austroperla cyrene	0	3	0	0	0	1	0	0	0	3
	Stenoperla prasina	0	0	0	0	0	0	1	2	0	0
	Zelandoperla agnetis	0	0	0	2	0	0	0	0	1	0
	Zelandobius confusus	0	0	0	0	0	0	0	0	0	2
Trichoptera											
Hydropsychidae											
	Orthopsyche fimbriata	3	7	1	12	4	18	17	36	6	49
	Orthopsyche pupa	0	0	0	0	1	0	0	1	0	0
Hydrobiosidae											
	Hydrobiosidae ei	0	0	0	1	1	0	3	1	1	4
	Costachorema callista	0	0	0	0	0	0	0	0	1	0
	Neurochorema forsteri	0	0	0	0	0	0	0	0	0	1
	Psilochorema sp.	0	1	1	0	1	0	0	3	0	1
Philopotamidae											
	Hydrobiosella mixta	0	0	0	0	0	0	0	1	0	1
Helicopsychidae											
	Helicopysche sp.	124	175	129	96	73	87	134	40	42	100
Conoesucidae											
	Beraeoptera roria	18	23	11	28	4	4	3	5	113	171
	Olinga feredayi	0	2	0	0	0	0	1	1	0	1
	Pycnocentria evecta	1	0	1	0	0	0	1	1	0	0
	Pycnocentria funerea	0	0	0	0	0	0	0	0	1	0
	Pycnocentria sylvestris	0	0	0	0	0	0	0	0	1	1
	Pycnocentrodes ei	0	0	0	2	0	0	0	0	0	0
Diptera											
Tipulidae											
	Aphrophila neozelandica	6	5	4	2	0	0	3	0	3	5
	Aphrophila pupa	0	0	1	0	0	0	0	0	0	0
	Eriopterini sp.	0	0	0	0	0	0	0	0	0	0
	Molophilus sp.	1	0	0	0	0	1	0	1	0	0
	Dolichopodidae	3	0	2	0	3	1	5	0	0	1

Chironomidae											
	Maoridiamesa sp	0	0	0	4	0	0	0	1	1	3
	Polypedilum sp.	5	0	8	0	1	4	2	3	0	0
	unknown a	0	0	0	0	0	0	0	0	0	0
	unknown b	0	0	0	0	0	0	1	0	0	0
	unknown c	0	0	0	0	0	0	0	1	0	0
	unknown d	0	0	0	1	0	0	0	0	0	0
Neuroptera											
	Kempynus sp	0	0	0	1	0	0	0	0	0	0
Megaloptera											
	Archichauliodes diversus	14	12	9	4	12	19	32	19	5	10
Coleoptera											
Elmidae	*Hydora nitida*	3	0	1	0	0	0	0	0	0	0
Hydraenidae	*Orchymontia* sp.	0	6	2	0	4	9	5	3	0	4
Ptilodactylidae	*Byrrhocryptus urquharti*	0	0	1	0	0	1	4	2	0	0
Mollusca											
	Potamopyrgus antipodarum	1	4	3	0	4	9	6	0	0	4
Acari											
	Mite	0	0	0	0	0	1	0	0	0	0
Oligochaeta											
	Small	0	0	0	1	0	1	2	0	0	0
Other											
	Platyhelminthes	1	0	3	3	1	4	4	7	3	5
	Nematomorpha	0	0	0	0	0	0	0	0	0	1
Total individuals		**217**	**317**	**223**	**213**	**214**	**229**	**348**	**265**	**217**	**758**
Total taxa		**17**	**16**	**20**	**19**	**17**	**18**	**26**	**25**	**16**	**26**

Appendix 1c. List of taxa collected in 3 replicate, 30 second kicknet samples; 4 replicate, 1 minute kicknet samples and 1, 3 minute kicknet sample at Waiaruhe Stream, Te Urewera National Park in October 2000.

		K30/1	K30/2	K30/3	K1/1	K1/2	K1/3	K1/4	K3
Ephemeroptera									
	Early instar	27	40	13	21	35	30	26	43
	Acanthophlebia cruentata	0	0	0	0	2	1	0	2
	Ameletopsis perscitus	0	2	0	0	0	1	1	3
	Austroclima jollyae	2	2	0	1	2	0	0	13
	Austroclima sepia	5	0	2	0	1	0	2	29
	Coloburiscus humeralis	42	57	27	21	203	44	119	356
	Deleatidium sp.	92	59	95	43	90	67	113	370
	Oniscigaster wakefieldi	0	1	0	0	0	0	0	0
	Nesameletus sp.	2	0	1	0	1	1	1	4
	Neozephlebia scita	1	1	0	0	0	1	0	4
	Zephlebia dentata	2	1	0	1	2	1	0	7
	Zephlebia versicolor	1	0	0	0	0	0	0	0
	Zephlebia spectabilis	5	4	0	3	5	1	0	3
Plecoptera									
	Early instar	1	3	4	0	0	1	4	10
	Acroperla trivacuata	0	0	0	0	0	0	0	5
	Austroperla cyrene	0	0	0	0	0	0	0	4
	Stenoperla prasina	1	2	0	0	1	0	0	1
	Zelandobius furcillatus	0	0	0	0	0	2	0	6
	Zelandoperla ei	0	0	0	0	2	0	0	1
	Zelandoperla agnetis	1	0	9	0	0	0	5	28
	Zelandoperla decorata	0	0	0	0	0	1	0	9
	Zelandoperla fenestrata	0	0	1	0	0	0	1	13
Trichoptera									
Hydropsychidae									
	Orthopsyche fimbriata	9	8	7	3	25	15	17	39
	Orthopsyche pupa	0	0	0	0	0	0	1	1
Hydrobiosidae									
	Hydrobiosidae ei	3	0	1	2	0	1	2	2
	Hydrobiosis ei	0	0	0	0	0	0	0	4
	Costachorema callista	0	0	0	0	0	0	0	1
	Psilochorema sp.	1	0	0	0	2	3	0	0
Philopotamidae									
	Hydrobiosella mixta	0	0	0	0	1	1	0	9
Helicopysche									
	Helicopysche sp.	108	60	55	73	80	24	55	129
Oeconesidae									
	Oeconesus similis	0	1	0	0	0	0	0	0
	Oeconesus pupa	0	0	0	0	0	0	0	1
Conoesucidae									
	Beraeoptera roria	21	5	11	17	11	7	27	238
	Olinga feredayi	0	1	0	0	1	0	0	7
	Pycnocentria evecta	3	4	0	0	3	1	4	7
	Pycnocentria funerea	0	0	0	0	0	0	0	8
	Pycnocentria sylvestris	0	0	0	0	0	0	0	18

	Pycnocentrodes aureola	0	0	0	0	0	0	0	7
Diptera									
Tipulidae	*Aphrophila neozelandica*	1	0	1	0	0	0	0	1
	Hexatomini sp.	0	1	0	0	0	0	0	1
	Eriopterini sp	1	0	0	0	0	1	1	1
	Molophilus sp.	3	0	0	0	0	1	1	0
	Dolichopodidae	8	1	0	1	2	4	0	3
Chironomidae									
	Maoridiamesa sp.	0	0	1	1	0	1	0	1
	Polypedilum sp.	7	2	0	0	4	3	4	0
	unknown a	0	0	0	0	0	0	0	0
	unknown b	0	0	0	0	0	0	0	0
	unknown c	0	0	0	0	0	0	0	0
	unknown d	0	0	0	0	0	1	0	0
Neuroptera									
	Kempynus sp.	0	0	1	0	0	0	0	0
Megaloptera									
	Archichauliodes diversus	31	18	3	6	43	15	24	40
Coleoptera									
Elmidae	*Hydora nitida*	0	0	0	0	0	0	1	0
Hydraenidae	*Orchymontia* sp.	16	10	5	7	17	4	12	9
Hydrophilidae	unknown sp.	0	0	0	0	0	1	0	0
Ptilodactylidae	*Byrrhocryptus urquharti*	0	0	0	0	1	0	0	1
Mollusca									
	Potamopyrgus antipodarum	12	5	13	3	6	5	12	38
Oligochaeta									
	Small	1	0	0	0	2	0	0	0
Other									
	Platyhelminthes	2	4	1	5	7	6	9	13
	Nematomorpha	0	0	0	0	1	0	0	1
	Talitridae (amphipod)	0	0	0	0	0	0	0	1
Total individuals		**409**	**292**	**251**	**208**	**550**	**245**	**442**	**1492**
Total taxa		**29**	**24**	**19**	**16**	**27**	**30**	**23**	**46**

Appendix 2a, Abel Tasman National Park site names and grid references

Site name	Site reference	Grid reference
Marahau River Tributary	A1	2509690E, 6023990N N26
Simonet Creek	A2	2512930E, 6025085N N26
Lesson Creek	A3	2513505E, 6026030N N26
Tregidga Creek	A4	2513535E, 6028900N N26
Tinline Stream	A5	2511945E, 6024405N N26
Huffam Stream	A6	2513670E, 6032525N N26
Kaikau Stream	A7	2509560E, 6043565N N25
Totaranui Stream	A8	2509940E, 6042435N N25
Waiharakeke Stream	A9	2509795E, 6040515N N25
Nakahi Stream	A10	2509335E, 6039980N N26
Torrent Bay Creek	A11	2514100E, 6029215N N26
Tinline Stream Tributary	A12	2511965E, 6024475N N26
Cleopatras Pool Stream	A13	2513080E, 6027855N N26
Riwaka River (North Branch)	A14	2501630E, 6019255N N26
Flat Creek (Riwaka South Branch)	A15	2501040E, 6015275N N26
Whiskey Creek	A16	2497545E, 6019620N N26
Wainui River	A17	2504200E, 6039990N N25
Wainui River Tributary	A18	2504605E, 6040315N N25

Appendix 2b, Kahurangi National Park site names and grid references

Site name	Site reference	Grid reference
Graham Stream (South Branch)	K1	2491560E, 6000520N N27
Graham Stream (North Branch)	K2	2494200E, 6001035N N27
Flora Stream (Upper)	K3	2486455E, 6003865N M27
Quartz Creek	K4	2487430E, 6002630N M27
Holmwood Creek	K5	2486580E, 6003520N M27
Lodestone Creek	K6	2486975E, 6003735N M27
Granity Creek	K7	2473900E, 5970775N M28
Blue Creek	K8	2473660E, 5970565N M28
Conor Creek	K9	2474120E, 5971850N M28
Rolling River	K10	2473930E, 5971875N M28
Percy Creek	K11	2476055E, 5973465N M28
Chummeys Creek	K12	2476615E, 5975015N M28
Trilobite Creek	K13	2477085E, 6008340N M27
Murray Stream	K14	2484765E, 5991455N M27
Ellis Stream	K15	2484760E, 5991665N M27
Baton River	K16	2485095E, 5989140N M27
Clarke Stream	K17	2483440E, 5983885N M27
Thorns Creek (Cobb River Tributary)	K18	2476650E, 6008945N M27

Appendix 2 c, Mt Richmond Forest Park site names and grid references

Site name	Site reference	Grid reference
Wakamarina Tributary	R1	2560440E, 5982495N O27
Johnsons Creek	R2	2559945E, 5981350N O27
Wakamarina River	R3	2559940E, 5981245N O27
Elvy Stream	R4	2556515E, 5988870N O27
Tinline Tributary 1	R5	2554225E, 5990880N O27
Scott Creek	R6	2548820E, 5985545N O27
Tinline Tributary 2	R7	2554100E, 5990945N O27
Motueka River Tributary	R8	2502870E, 5952635N N28
Sandy Creek	R9	2503640E, 5952165N N28
Upper 6 Mile Creek	R10	2506495E, 5937690N N29
Stoney Creek	R11	2511945E, 5941155N N29
6 Mile Creek	R12	2516715E, 5943505N N29
Eves Creek	R13	2517735E, 5943605N N29
Brown Stream Tributary	R14	2556050E, 6000860N O27
Haipiata Stream	R15	2566995E, 6011250N O26
Collins Stream	R16	2555930E, 6004700N O27
Brook Stream	R17	2534360E, 5988005N O27
Maitai River (above reservoir)	R18	2541920E, 5989425N O27

Appendix 3a. List of taxa collected from 18 streams (A1-A18) in Abel Tasman National Park during November and December 2000. Mean values calculated from 3 replicate samples at each site

		A1	A2	A3	A4	A5	A6	A7	A8	A9
Ephemeroptera										
	Ameletopsis perscitus	0	0	0	0	0.3	0	0	0	0
	Austroclima jollyae	0.7	4.7	0	0.3	1.7	1.3	0	0.3	0.7
	Austroclima sepia	0	1.3	29	0	0	21	3.3	1	14
	Coloburiscus humeralis	71	47	10	11	62	4.3	17	1.3	5.7
	Deleatidium sp.	372	56	30	16	117	30	101	94	37
	Ichthybotus hudsoni	0	0	0	0	0	0	0	0	0
	Neozephlebia scita	0.7	0.3	0	0	3	0.3	3.7	1	0
	Nesameletus sp.	0	0	2.7	0	4.7	1.7	0	0	0
	Oniscigaster wakefieldi	0	0	0	0	0	0	0	0	0
	Zephlebia dentata	0	0	0	0	0	0	0	0	0.3
	Zephlebia spectabilis	0	0.3	0	0	0	0	0	0	0
	Zephlebia versicolor	0	0	0.3	0	0	0.3	0.3	0.3	0
Plecoptera										
	Acroperla trivacuata	0.7	0	0	0	0	0	0	0	0
	Austroperla cyrene	0	1.3	0.7	1	1	0	49	4	10
	Cristaperla fimbria	0	0	0	0	0	0	0	0	0
	Megaleptoperla diminuta	0	0	0	0	0	0	0	0	0
	Megaleptoperla grandis	0	0	0	0	0	0	0.3	0.3	0
	Spaniocerca sp.	0	0	0	0	0	0	0.3	0	0.3
	Spaniocerca zelandica	0	0	0	0	0	0	0.3	0.3	0
	Spaniocercoides philpotti	0	0	0	0	0	0	0	0	0
	Stenoperla prasina	0	0	0.7	2.7	1.3	0.3	0.3	0.3	0.7
	Zelandobius confusus	0	0	0	0	0	0	0	0	0
	Zelandobius furcillatus	0	3	0.3	0.7	0	0	0	0	4.3
	Zelandobius unicolor	0	0	0	0	0	0	0	0	5
	Zelandoperla decorata	0	0	0	0	0	0	0	0	0
	Zelandoperla agnetis	0	0	0.7	0	0	0	0.3	0	2.7
	Zelandoperla fenestrata	1	3.7	2.3	0	0	6	0	0	0.3
Trichoptera										
Hydropsychidae										
	Aoteapsyche sp.	51	6.7	9.3	3	19	1.3	7.7	0.3	1.3
Hydroptilidae										
	Oxyethira albiceps	0	0	0	0	0	0	0	0	0
Hydrobiosidae										
	Early instar	21	2.7	3	2	7.7	2	5	1	1
	Costachorema brachyptera	0	0	0	0.7	0	0	0	0	0
	Costachorema callista	0	0.3	0	0	0	0	1.7	0	0
	Costachorema psaroptera	3	0	0	0	0	0	0	0	0
	Costachorema xanthoptera	1.7	0	0	0	0	0	0	0	0
	Edpercivalia maxima	0	0	0	0	0	0	0	0	0
	Hydrobiosis umbripennis	0	0	0	0	0	0	0	0	0
	Hydrobiosis parumbripennis	5.3	0	0.3	1.3	0.7	0	0.3	0	0
	Hydrobiosis clavigera	0.7	0	0	0	0.3	0	0	0	0
	Hydrobiosis charadiacea	0	0	0	0	0	0	0	0	0
	Hydrobiosis spatulata	0	0	0	0	0	0	0	0	0
	Hydrobiosis silvicolor	0	0	0	0	0	0	0	0	0
	Hydrochorema sp.	0	0	0	0	0	0	0	0	0

		A1	A2	A3	A4	A5	A6	A7	A8	A9
	Psilochorema sp.	2	0	0	1	1	0	1	0	0
	Tiphobiosis sp.	0	0	0	0	0	0	0	0	0
Polycentropodidae										
	Polyplectropus sp.	1.3	0	0	0	1.7	0	0	0	0.3
Philopotamidae										
	Hydrobiosella mixta	2.3	2.7	0.3	2.7	6	0	0	0	2.3
	Hydrobiosella stenocerca	0	0	0	0	0	0	0	0	0
Helicopsychidae										
	Rakiura vernale	0	0	0	0	1.7	0	0	0	0
	Helicopysche sp.	2	11	1	21	37	0	5.7	0	0.3
Oeconesidae										
	Oeconesus similis	0	0	0	0	0	0	0	0	0
	Zelandopsyche ingens	0	0	0	0	0	0	0	0	0
Leptoceridae										
	Hudsonema amabilis	0	0	0	0	0	0	0	0	0
	Hudsonema aliena	0	0	0	0	0	0	1.7	0.3	0
	Triplectides obsoleta	0	0	0	0.3	0	0	5.3	0.3	0
Philorheithridae										
	Philorheithrus agilis	0	0.3	0.3	2	0	0	0	0	0
Helicophidae										
	Zelolessica cheira	0.3	2	19	0	1	13	0.3	0	0
	Alloecentrella magnicornis	0	0	0	0.3	0	1	0	0	0
Conoesucidae										
	Beraeoptera roria	5	0	0	0	31	0	0	0	0
	Confluens olingoides	0.7	0	0	0	2.3	0	0	0	0
	Olinga feredayi	46	9	0.3	6.7	35	0	0	0	0
	Pycnocentria evecta	3.3	0.7	0	2.3	3.3	0.3	2.3	0	0.3
	Pycnocentria funerea	0.7	7.3	0	0	0	0	0.3	0	0
	Pycnocentria hawdonia	0	7.3	0	0	0	0.7	0	0	0
	Pycnocentria mordax	0	3.7	7.7	0	0	0	0	0	0
	Pycnocentria sylvestris	0	0	1.7	1	0	38	3.7	0	0
	Pycnocentrodes aureola	12	2.3	0	7.7	1	0	0	0	0
	Unidentified trichoptera 1	0	0	0	0	0	0	0	0	0
Coleoptera										
Elmidae										
	Hydora nitida (adult & larvae)	5.3	4.7	22	0	1	22	5.7	1.3	0.3
Hydrophilidae										
	Unidentified larvae	0	0	0	0.3	0	0	0	0	0
Hydraenidae										
	Red	0.3	0.7	0	0.3	1.3	0.3	0.3	0	0.7
	Black	0.3	0	0	0	0	0	0	0	0
	Brown	0	0	0	0	0	0	0	0	0
Ptilodactylidae										
	Byrrhocryptus urquharti	0	0	0	0	0.3	0	5.7	0	0
Scirtidae										
	type A	0	0	0	0	0	0	0	0	0
	Unidentified beetle larvae	0	0	0	0	0	0	0	0	0

		A1	A2	A3	A4	A5	A6	A7	A8	A9
Diptera										
Blephariceridae										
	Neocurupira campbelli	0	0	0	0	0	0	0	0	0
	Neocurupira tonnoiri	1	0.7	0.3	0	1	0	0	0	0.7
	Neocurupira hudsoni-complex	4.3	0	0	0	0	0	0	0	0
Ceratopogonidae		1	1	0.3	3	1	0	0	0	0
Chironomidae										
	Polypedium sp.	0	0	0	0	0.7	0	12	0.3	2
	Maoridiamesa sp.	58	0	0	0	0.3	0	0	0	0
	A	44	6	2	0	0.3	0	0	0	0
	B	20	1.7	0	6.7	1.3	0	0	0.3	0
	C	0	3	0	6.7	0	0	4.7	2	0
	D	0	0	0.7	0	0	0.3	0.3	0	0
	E	0	0	0	0	0	0	0	0	0
	U1	61	9	3	0	2.3	2	0.3	1.7	0
	U2	1.7	0.7	0	0.3	0.7	0	1.3	0.3	0
	U3	0.3	0	0	0	0	0	0	0	0
	U4	0	0.3	0	0	0.3	0	0	0	0
	U5	0	1.3	0.3	0	0	0	0	0	0
	U6	0	0	0	0	9.7	0.3	15	0	0
	U7	0	0	0	0	0	0	21	0.7	0
	U8	0	0	0	0	0	0	1.7	0.7	0
	U9	0	0	0	0	0	0	0	0	0
	U11	0	0	0	0	0	0	0	0	0
	U12	0	0	0	0	0	0	0	0	0
Dixidae										
	Nothodixa campbelli	0	0	0	0	0	0	1.3	0	0
Empididae										
	Type a	0.3	0.7	1	2.3	0	0.3	1	0	0
Simuliidae										
	Austrosimulium sp.	5	0.7	1	0	0.3	1	0.3	6.7	0
Tipulidae										
	Zelandotipula sp.	0	0	0	0	0	0	0	0	0
	Limonia nigrescens	0	0	0	0	0	0	0	0	0
	Aphrophila neozelandica	11	0.7	1.3	0.3	6.3	0	0.3	0	0
	Paralimnophila skusei	0	0	0	0	0	0	1.3	0.7	0.3
	Hexatomini sp.	0	0.3	0	0	0	0	0	0	0
	Eriopterini sp.	0	0.3	0	2.3	0	0	8	14	0
	Molophilus sp.	0	0	0	0	0	0	0.3	0	1
	Unidentified diptera 1	0	0	0	0	0	0	0	0	0
Neuroptera										
	Kempynus sp.	0	0	0	0	0	0	0	0	0
Megaloptera										
	Archichauliodes diversus	2.3	1	0	0	12	0	1	0.3	0
Oligochaeta	Small	1.3	0	0	1.3	0	0	0.7	0.3	0
	Medium	0	0	0	0	0	0	0	0	0
	Large	0	0	0	0	0	0	0	0	0

		A1	A2	A3	A4	A5	A6	A7	A8	A9
Mollusca	*Potamopyrgus antipodarum*	0	0	1	1.3	0	0	1	0	0
	Unidentified mollusc 1	0	0	0	0	0	0	0	0	0
Crustacea	Amphipod	0	0	2.7	128	0	2.3	5	0	0
	Paranephrops planifrons	0	0	0	0	0	0	0	0	0
	Paratya sp.	0	0	0	0	0	0	0	0	0
Acari	Mites	0	0	0	0	0	0	0	0	0
Other	Platyhelminthes	1.3	0.7	0.3	0	1	0	0.3	0	0.7
	Nematomorpha	0	0.3	0	0.7	0	0	0	0	0.3
Total individuals		**824**	**207**	**155**	**238**	**380**	**151**	**300**	**134**	**93**
Total taxa		**41**	**41**	**33**	**33**	**40**	**24**	**46**	**27**	**26**

Appendix 3a continued. Sites A10 – A18

		A10	A11	A12	A13	A14	A15	A16	A17	A18
Ephemeroptera										
	Ameletopsis perscitus	0.3	0	0.3	0	0	0	0	0	0
	Austroclima jollyae	0	0.3	4.3	10	24	0	0	0	7.3
	Austroclima sepia	34	0.7	0.3	0.3	22	0	0	0	1
	Coloburiscus humeralis	57	6	79	10	3	0	3	6.3	47
	Deleatidium sp.	71	6	51	76	139	251	134	165	140
	Ichthybotus hudsoni	0	0	0	0	0	0	0	0	0
	Neozephlebia scita	0	0.7	2.3	0	1.7	2.7	0	0	0
	Nesameletus sp.	1.3	0	2	0	0.3	3	13	0.3	3
	Oniscigaster wakefieldi	0	0	0	0	0	0	0	0	0
	Zephlebia dentata	1	2	0	0.7	0	0	0	0	0
	Zephlebia spectabilis	0	0	0	0.3	2.3	0	0	0	0
	Zephlebia versicolor	0.3	0	0.3	0	0.7	0	0	0	0
Plecoptera										
	Acroperla trivacuata	0	0	0.3	0	1.3	0	0	0	0.3
	Austroperla cyrene	8.3	0	1	1.7	0.3	2.3	28	0.3	5.7
	Cristaperla fimbria	0	0	0	0	0	0	0	0	0
	Megaleptoperla diminuta	0	0	0	0	0.3	0	0	0	0
	Megaleptoperla grandis	0	0	0	0	0.7	4.3	1	0	1.3
	Spaniocerca sp.	0	0	0	0	0	0	0	0	0.3
	Spaniocerca zelandica	0	0	0	0	0	0	9.3	0	0.3
	Spaniocercoides philpotti	0	0	0	0	0	0	0	0	0
	Stenoperla prasina	3.7	0.7	1.7	0.7	0	3.7	1	0	0
	Zelandobius confusus	0	1	0	0	0.3	0	0	0	0
	Zelandobius furcillatus	15	0	0	0	0	0	0	0.7	4
	Zelandobius unicolor	1.7	0	0.3	0	0	0	0	0	3
	Zelandoperla decorata	0	0	0.3	0	0	10	5.3	22	2
	Zelandoperla agnetis	1.3	0	1	0	0	0	5.7	0	0.3
	Zelandoperla fenestrata	0	0	1	0.3	2.3	0	0	0	0.3
Trichoptera										
Hydropsychidae										
	Aoteapsyche sp.	9	3	1.7	2.7	1	6.7	101	3	16
Hydroptilidae										
	Oxyethira albiceps	0	0	0	0	0	0	0	0	0
Hydrobiosidae										
	Early instar	3	0.3	3	4.7	2	10	11	4.7	4.7
	Costachorema brachyptera	0	0	0	0.7	0	0	0	0	0
	Costachorema callista	0	0	1	0	0	0	0	0.7	0
	Costachorema psaroptera	0.3	0	0	0	0	0.7	0	0.7	0
	Costachorema xanthoptera	0	0	0	0	0	0	0	0	0
	Edpercivalia maxima	0	0	0	0	0	0	0	0	0
	Hydrobiosis umbripennis	0	0	0	0	0	0	0	0.3	0
	Hydrobiosis parumbripennis	1.3	0	0.3	0	0	0	3	0.7	0
	Hydrobiosis clavigera	0	0	0	0	0	0	0	0	0
	Hydrobiosis charadiacea	0	0	0	0	0	0	0	0	0
	Hydrobiosis spatulata	0	0	0	0	0	0	0	0	0
	Hydrobiosis silvicolor	0	0	0	0	0	0	0	0	0
	Hydrochorema sp.	0	0	0	0	0	0	0	0	0

		A10	A11	A12	A13	A14	A15	A16	A17	A18
	Psilochorema sp.	3.3	0.3	0	0.3	0	0.7	0	0.3	2
	Tiphobiosis sp.	0	0	0	0	0	0	0	0	0
Polycentropodidae										
	Polyplectropus sp.	0	0	0	0.7	0	0	0	0	0.3
Philopotamidae										
	Hydrobiosella mixta	124	0.3	0.7	5	4	4	1.3	0.3	3.7
	Hydrobiosella stenocerca	0	0	0	0	0	0	0	0	0
Helicopsychidae										
	Rakiura vernale	0	2.3	0	0	0	0	0	0	0
	Helicopysche sp.	0	12	13	3	3.7	14	0.3	6	0.3
Oeconesidae										
	Oeconesus similis	0.3	0	0	0	0	0	1.7	0	0
	Zelandopsyche ingens	0	0	0	0	0	0	0	0	0
Leptoceridae										
	Hudsonema amabilis	0	0	0	0	0	0	0	0	0
	Hudsonema aliena	0	0	0	0	0	0	0	0	0
	Triplectides obsoleta	0	0.7	0	0	0	0	0	0	0
Philorheithridae										
	Philorheithrus agilis	0	0	2	0	0	3	15	0.3	0
Helicophidae										
	Zelolessica cheira	0	4	0.7	5.3	30	0	0	0	0.3
	Alloecentrella magnicornis	0	0	0	0	0	0	0	0	0
Conoesucidae										
	Beraeoptera roria	0.3	0	1.7	3.3	0.7	0	0	286	0
	Confluens olingoides	0	0	0	1.7	0	333	0	0	0
	Olinga feredayi	0	0	19	11	0	4.7	3.7	16	4
	Pycnocentria evecta	0	7	3	0.3	0	0	0	0	6.3
	Pycnocentria funerea	4.7	0	0	0	0	0	0	0	0
	Pyconcentria hawdonia	0	0	0	0	0	0	0	0	0
	Pycnocentria mordax	0	0	0	0	0	0	0	9.3	0
	Pycnocentria sylvestris	0	1.3	0	0	0	0	3	0	0
	Pycnocentrodes aureola	0	0.3	0	0.3	0	0	0	14	0
	unidentified trichoptera 1	0	0	0	0	0	0	0	0	0
Coleoptera										
Elmidae										
	Hydora nitida (adult & larvae)	2.3	0.3	3.7	10	49	6.3	0	1.7	1.7
Hydrophilidae										
	unidentified larvae	0	0	0	0	0	0	0.3	0	0
Hydraenidae										
	Red	0.7	2	0.3	0.3	0	0	3.7	0.3	2.7
	Black	0	0	0	0	0	1	0	0.3	1
	Brown	0	0	0	0	0	0	0	0	0
Ptilodactylidae										
	Byrrhocryptus urquharti	0.7	0.3	0	0	0	0	0	0.3	0.3
Scirtidae										
	type A	0	0	0	0	0	0	0	0	0
	unidentified beetle larvae	0	0	0	0	0	0	0	0	0

		A10	A11	A12	A13	A14	A15	A16	A17	A18
Diptera										
Blephariceridae										
	Neocurupira campbelli	0	0	0	0	0	0	0	0	0
	Neocurupira tonnoiri	0	0	0	1.3	0	0.3	2.7	2	4.3
	Neocurupira hudsoni-complex	0	0	0	0	0	0	0	0.3	0
Ceratopogonidae		0	0	0	0	0	0	0	0	0
Chironomidae										
	Polypedium sp.	26	0.7	0	0	0.3	2	4.7	0	31
	Maoridiamesa sp.	0	0	0	0	0	14	0	11	0
	A	0	0	0	12	0	37	4	6	3.3
	B	0	0	0.7	3.3	0	0.3	0.3	0	4.3
	C	0	1.7	0.3	2	0	0	1	0	6.3
	D	0	0	0	0.7	0	0	1.3	0	0.3
	E	0	0	0	0	0	0	0	0	0
	U1	0	0	1	14	0	6.3	2.3	1.7	1.3
	U2	0	0.7	2	2	0	0	0.7	0.7	0
	U3	0	0	0	0	0	0.3	0	0.3	0
	U4	0	0	0	0	0	0	0	0	0
	U5	0	0	0	0	0	0	0	0	0
	U6	0	0.3	5	3	0	0.3	0.7	0	1
	U7	0	0	0	7.3	0	0	2.7	0.3	2.3
	U8	0	1	0.7	0.7	0	1.7	0.3	0	1
	U9	0	0	0	0	0	0	0	0	0
	U11	0	0	0	0	8	0.3	0	0	0
	U12	0	0	0	0	0	2.3	0	0	0
Dixidae										
	Nothodixa campbelli	0	0	1	0	0	0	0	0	0
Empididae										
	type a	0	0	0	0.7	3.7	0	2	0	0
Simuliidae										
	Austrosimulium sp.	0	0.7	1	0	0	1.7	4	0.3	0
Tipulidae										
	Zelandotipula sp.	0	0	0	0	0	0	0	0	0
	Limonia nigrescens	0	0	0	0	0	0	0.3	0	0
	Aphrophila neozelandica	0.3	0	1.3	2.3	7.3	39	0	5.7	0
	Paralimnophila skusei	0.7	0.3	0	0	0	0	0	0	0
	Hexatomini sp.	0	0	0	0	0	0	0	0	0
	Eriopterini sp.	1	0	0	0	0.3	0.3	1	0	1.3
	Molophilus sp.	0.3	0	0	0	0	0	11	0	1.3
	unidentified diptera 1	0	0	0	0	0	0	0	0	0
Neuroptera										
	Kempynus sp.	0	0	0	0	0	0	0	0.3	0
Megaloptera										
	Archichauliodes diversus	8.7	0	2.3	0.7	4.7	1.3	0	0	2
Oligochaeta										
	small	0.3	0	1.7	0.3	0.3	0	1.7	0	1.3
	medium	0	0	0	0	0	0	0	0	0
	large	0	0	0	0	0	0	0	0	0

		A10	A11	A12	A13	A14	A15	A16	A17	A18
Mollusca										
	Potamopyrgus antipodarum	0	4.7	2.3	0	0.3	0	0	0	3
	unidentified mollusc 1	0	0	0	0	0	0	0	0	0
Crustacea	Amphipod	7	0	0	0	47	0	0	0	0
	Paranephrops planifrons	0	0	0	0	0	0	0	0	0
	Paratya sp.	0	0	0	0	0	0	0	0	0
Acari										
	mites	0	0	0	0	0	0	0	0	0
Other	Platyhelminthes	0	0	0	0	1	0	16	0	0
	Nematomorpha	0.3	0	0	0	0	0	0	0	0
total individuals		**391**	**62**	**215**	**200**	**362**	**770**	**402**	**568**	**324**
total taxon		**33**	**30**	**40**	**38**	**31**	**33**	**38**	**35**	**43**

Appendix 3b. List of taxa collected from 18 streams (K1-K18) in Kahurangi National Park during November and December 2000. Mean values calculated from 3 replicate samples at each site

		K1	K2	K3	K4	K5	K6	K7	K8	K9
Ephemeroptera										
	Ameletopsis perscitus	0	0	0	0	0	0	0	0	0.3
	Austroclima jollyae	0	0	0	7.7	11	3.3	0	0.7	0
	Austroclima sepia	0	0.7	0	0	0	0.3	0	0	0
	Coloburiscus humeralis	6	2.7	0.7	2.3	9	4.7	2.7	0.7	0.3
	Deleatidium sp.	494	515	129	301	217	488	234	150	101
	Ichthybotus hudsoni	0	0	0	0	0	0	0	0	0
	Neozephlebia scita	0.7	1.3	0	0	0.7	0	0	0	0
	Nesameletus sp.	5.3	11	38	91	169	106	31	2	0.7
	Oniscigaster wakefieldi	0	0	0.3	0.3	0	0	0	0	0
	Zephlebia dentata	0	0	0	0	0	0	0	0	0
	Zephlebia spectabilis	0	0	0	0	0	0	0	0	0
	Zephlebia versicolor	0	0	0	0	0	0	0	0	0
Plecoptera										
	Acroperla trivacuata	0	0	0	0	0	0	0.3	0	0
	Austroperla cyrene	0.3	0	11	3.7	21	2.7	6	1.3	0.3
	Cristaperla fimbria	0	0	0.3	0	0	0	0	0	0
	Megaleptoperla diminuta	0	0	0	0	0	0	0	0	0
	Megaleptoperla grandis	0	0	0	0	0	0	0	0	0
	Spaniocerca sp.	0	0	0	0	0	0	0	0	0
	Spaniocerca zelandica	0	0	9.3	3.7	0	0	0	0	0
	Spaniocercoides philpotti	0	0	11	0	1	0	0	0	0
	Stenoperla prasina	14	13	2.3	2.3	2.7	3.3	2.7	6	2
	Zelandobius confusus	0.3	0	0.3	0.7	0.3	2.7	0	1	0
	Zelandobius furcillatus	0	0	1.7	4	0	0	0	0	0
	Zelandobius unicolor	0	0	0.3	1	5.7	4.7	0	0	0
	Zelandoperla decorata	0	0.3	14	4	0	0.7	1.7	1	0
	Zelandoperla agnetis	0	0	5.3	1.7	3.3	0.7	0	0	0
	Zelandoperla fenestrata	0	0	0	0.3	0.3	0.3	0	0	0
Trichoptera										
Hydropsychidae										
	Aoteapsyche sp.	26.7	15	0	0	0.3	0	0.3	5.3	0.3
Hydroptilidae										
	Oxyethira albiceps	0.7	0	0	0	0	0	0	0	0
Hydrobiosidae										
	Early instar	25.7	12	8.7	7.7	23	18	13	10	2.7
	Costachorema brachyptera	0	0	0	0	0	0	0	0	0
	Costachorema callista	5	0.3	0	0	0	0.3	0	0	0
	Costachorema psaroptera	0	0	0	0	0	0	0	0	0
	Costachorema xanthoptera	0	0	0	0	0	0	0	0	0
	Edpercivalia maxima	0	0	0	0.7	0.7	0	0.3	0.3	0
	Hydrobiosis umbripennis	0	0	0	0	0	0	0	0	0
	Hydrobiosis parumbripennis	1	0	0	0	0	0	0	0	0
	Hydrobiosis clavigera	0	0.7	0.3	1	0	0	0.3	0.7	0
	Hydrobiosis charadiacea	0	0	0	0	0	0	0	0	0
	Hydrobiosis spatulata	0	0	0	0	0	0	0	0	0
	Hydrobiosis silvicolor	0	0	0	0	0	0	0	0	0

		K1	K2	K3	K4	K5	K6	K7	K8	K9
	Hydrochorema sp.	0	0	0	0	0	0	0	0	0
	Psilochorema sp.	2	2	0.7	0.7	0.3	0.7	0	0.7	0
	Tiphobiosis sp.	0	0	0	0	0	0	0	0.3	0
Polycentropodidae										
	Polyplectropus sp.	0	0	0	0	0	0	0	0	0
Philopotamidae										
	Hydrobiosella mixta	27.3	7	16	7.7	25	25	14	65	5.7
	Hydrobiosella stenocerca	0	0	0	0	0	0	0	0	0
Helicopsychidae										
	Rakiura vernale	0	0	0	0	0	0	0	0	0
	Helicopysche sp.	2	0.3	0	8.3	2	0.7	0	0	0.3
Oeconesidae										
	Oeconesus similis	0	0.3	0	0	0	0.3	0	0	0
	Zelandopsyche ingens	0	0	0	0.7	1.3	0	0	0.7	0
Leptoceridae										
	Hudsonema amabilis	0	0	0	0	0	0	0.3	0	0
	Hudsonema aliena									
	Triplectides obsoleta	0	0	1.3	0.7	0	0	0	0	0
Philorheithridae										
	Philorheithrus agilis	2.7	0.7	0.3	3	3	1.7	0	0	0.3
Helicophidae										
	Zelolessica cheira	0	0	0	0.3	0	0	0	0	0.7
	Alloecentrella magnicornis	0	0	0	0.3	0	0	0	0	0
Conoesucidae										
	Beraeoptera roria	0	0.3	0	0	0	0	35	19	0
	Confluens olingoides	19.3	3.7	0	0.3	0	0	2.3	106	0.3
	Olinga feredayi	24	39	6	17	28	29	1.7	1.7	2.3
	Pycnocentria evecta	2	5	1	0.7	3	5.3	0.3	0.7	0
	Pycnocentria funerea	1	0	0	0	0	0	0	0	0.7
	Pycnocentria hawdonia	0	0	0	0	0	0	0	0	0
	Pycnocentria mordax	0	0	0	0	0	0	0	0	0
	Pycnocentria sylvestris	0.3	0	0	1	1	0.3	0	0.3	0
	Pycnocentrodes aureola	0	0	0	0	0	0	0	0	0
	Unidentified trichoptera 1	0	0	0	0	1	0	0	0	0
Coleoptera										
Elmidae										
	Hydora nitida (adult & larvae)	38.7	3.7	6.7	32	27	68	111	70	46
Hydrophilidae										
	Unidentified larvae	0	0	0.3	0	0	0	0	0.3	0
Hydraenidae										
	Red	0	0	11	21	16	25	0.7	1.7	5.3
	Black	0.7	0.3	0	0.3	0	0	0.3	0.3	0
	Brown	0	0	0	0	0	0	0	0	0
Ptilodactylidae										
	Byrrhocryptus urquharti	0	0.7	0	0	0	0	0	0	1
Scirtidae										
	type A	0	0	0	0	0.3	0	0	0	0
	Unidentified beetle larvae	0	0	0	0	0	0	0	0	0

		K1	K2	K3	K4	K5	K6	K7	K8	K9
Diptera										
Blephariceridae										
	Neocurupira campbelli	0	0	0	0	0	0	0	0	0
	Neocurupira tonnoiri	20.7	73	0	0	0.7	0.3	3	28	0.3
	Neocurupira hudsoni-complex	0	0	0	0	0	0	0	0	0
Ceratopogonidae		1	4	0	0	0	0	0	0	0
Chironomidae										
	Polypedium sp.	88	21	0	0	0	0	1	38	5
	Maoridiamesa sp.	70.3	0	0	0	0	0	0	11	0
	A	72.7	2.3	0.3	1.7	0	0	0	0	0
	B	0.7	0	0	0	0	0	0	0	0
	C	0.3	0	0	0.3	0	0	0	0	0
	D	0.7	0	0	0	0	0	0	0	0
	E	2	13	1	0	5.7	0	0	0	0
	U1	37	7	0	3.3	0	18	0.3	0.3	0.3
	U2	1	0.7	0	0.7	1.7	1	0	0.3	0.7
	U3	0.3	0	0.3	0	0	0	0	0	0
	U4	0	0	0	0	0	0	0	0	0
	U5	0	0	0	0	0	0	0	0	0
	U6	0.7	2	0	0	0	0	0	0	0.3
	U7	0	0	0	0	0	0	0	0	0
	U8	6	11	1.7	7.7	6	2.7	0	0.7	0.7
	U9	0	0	0	0	0	0	0	0	1
	U11	0	0	0	0	0	0	0	0	0
	U12	0	0	0	0	0	0	0	0	0
Dixidae										
	Nothodixa campbelli	0	0	0	0	0	0	0	0	0
Empididae										
	type a	0.7	0	1.7	2.3	1	1	0	0.3	0
Simuliidae										
	Austrosimulium sp.	0	0	22	16	4.3	5.7	0.7	0	0.7
Tipulidae										
	Zelandotipula sp.	0	0	0	0	0	0	0	0	0
	Limonia nigrescens	0	0	0	0	0	0	0	0	0
	Aphrophila neozelandica	101	56	0	0.3	0	0.3	50	28	0.3
	Paralimnophila skusei	0.3	0	0	0	0.7	0	0	0	0
	Hexatomini sp.	0	0	0	0	0	0	0	0	0
	Eriopterini sp.	10.7	5	1	0	1	0	4.7	2	3.3
	Molophilus sp.	0	0	0	0	0	0	0	0	0
	Unidentified diptera 1	0	0.3	0	0	0	0	0	0	0
Neuroptera										
	Kempynus sp.	0	0	0	0	0	0	0	0	0
Megaloptera										
	Archichauliodes diversus	27.3	40	0	0	0	0	1	0.7	0.3
Oligochaeta										
	Small	0.3	2.3	0.3	0.7	6.7	0.3	17	1.3	1
	Medium	0	0.7	0	0	0	0	0	0	0
	Large	0.3	0.3	0	0	0	0	0	0	0

		K1	K2	K3	K4	K5	K6	K7	K8	K9
Mollusca										
	Potamopyrgus antipodarum	0	0	0	0	0	0	0	3.7	0
	Unidentified mollusc 1	0	0.3	0	0	0	0	0	0	0
Crustacea										
	Amphipod	0	0	0	0	0	0	0.3	0.3	0.3
	Paranephrops planifrons	0	0	0	0	0	0	0	0	0
	Paratya sp.	0	0	0	0	0	0	0	0	0
Acari										
	Mites	0	0	0	0	0	0	0	0	0
Other										
	Platyhelminthes	1.7	0	2.7	0.7	11	3.7	0	15	0
	Nematomorpha	0.3	0	2.7	0.3	1	0.3	0.3	0	1
Total individuals		**1144**	**876**	**309**	**561**	**614**	**826**	**535**	**576**	**186**
Total taxa		**46**	**40**	**35**	**43**	**38**	**34**	**30**	**39**	**32**

Appendix 3b continued. Sites K10 – K18

		K10	K11	K12	K13	K14	K15	K16	K17	K18
Ephemeroptera										
	Ameletopsis perscitus	0	0	0	0	0	0	0	0.7	0
	Austroclima jollyae	0	0	0.3	0	4.7	4.3	0.67	0	0
	Austroclima sepia	0	0	0	0	0	1.33	0	1.67	0
	Coloburiscus humeralis	2	4.3	3	0	60	99	7.67	35	0
	Deleatidium sp.	365	169	432	0	106	152	501	615	67.3
	Ichthybotus hudsoni	0	0	0	0	0	0.67	0	0	0
	Neozephlebia scita	0	1.67	0.33	0	3.67	1.33	1.33	0	0
	Nesameletus sp.	2	1	2	0	1	3.33	20.7	19	5
	Oniscigaster wakefieldi	0	0	0	0	0	0	0	0	0
	Zephlebia dentata	0	0	0	0	0	0	0	0	0
	Zephlebia spectabilis	0	0	0	0	0	0	0	0	0
	Zephlebia versicolor	0	0	0	0	0	0	0	0	0
Plecoptera										
	Acroperla trivacuata	0.33	0	0	0	0	0.33	0	0	0
	Austroperla cyrene	0	0.33	1.33	0	2.67	8.33	1.33	7	1.33
	Cristaperla fimbria	0	0	0	0	0	0	0	0	1
	Megaleptoperla diminuta	0	0	0	0	0	0	0	0	0
	Megaleptoperla grandis	0	0	0	0	0	0	0	0	0
	Spaniocerca sp.	0	0	0	0	0	0	0	0	0
	Spaniocerca zelandica	0	0	0	0.3	0	0	0	0	14
	Spaniocercoides philpotti	0	0	0	0	0	0	0	0	0
	Stenoperla prasina	4.3	1.3	18.7	0	2.3	4.7	17.3	17.3	3
	Zelandobius confusus	0	0	0	0	0	0	0	0	0
	Zelandobius furcillatus	0	0	1	0	1.7	0.3	0.3	3	0
	Zelandobius unicolor	0	0	0	0	0	0	0	0	0.7
	Zelandoperla decorata	0	0	0	0	2.3	1.7	0.3	0.3	0
	Zelandoperla agnetis	0	0	0	0	0.3	0	0	0	6.3
	Zelandoperla fenestrata	0	0	0	0	0.7	0	0	0	1
Trichoptera										
Hydropsychidae										
	Aoteapsyche sp.	11	0	13.7	0	10	22.3	40.7	9	2
Hydroptilidae										
	Oxyethira albiceps	0	0	0	0	0	0	0	0	0
Hydrobiosidae										
	Early instar	9.7	38	6.3	0	12.3	3	8.7	7.7	4
	Costachorema brachyptera	0	0	0	0	0	0	0	0	0
	Costachorema callista	0.3	2	0	0	0.7	1	0	0.7	0.3
	Costachorema psaroptera	0	0	0	0	0	0	0	0	0
	Costachorema xanthoptera	0	0	0	0	0	0	0	0	0
	Edpercivalia maxima	0	0	0	0	0	0	0	0	0
	Hydrobiosis umbripennis	0	0	0	0	0	0	0	0	0
	Hydrobiosis parumbripennis	0	1.7	0	0	0.3	0	0	0	0.3
	Hydrobiosis clavigera	0	0	0	0	0.3	0	0	0.3	0
	Hydrobiosis charadiacea	0.7	0	0	0	0	0	0	0	0
	Hydrobiosis spatulata	0	0	0	0	0	0	0	0	0
	Hydrobiosis silvicolor	0	0	0	0	0	0	0	0	0
	Hydrochorema sp.	0	0	0	0	0	0	0	0	0

		K10	K11	K12	K13	K14	K15	K16	K17	K18
	Psilochorema sp.	0.3	0.7	2	0	0	1	1.7	1	2.3
	Tiphobiosis sp.	0	1	0	0	0	0	0	0	0
Polycentropodidae										
	Polyplectropus sp.	3.7	0	0	0	0	0	0.7	0	0.3
Philopotamidae										
	Hydrobiosella mixta	4	17	9.3	0	20.3	26	3.3	5.3	22.7
	Hydrobiosella stenocerca	0	0	0	0	0	2	0	0	0
Helicopsychidae										
	Rakiura vernale	0	0	0	0	0	0	0	0	0
	Helicopysche sp.	3.3	0	18.7	0	3	9.3	9.3	40.7	0.3
Oeconesidae										
	Oeconesus similis	0	0	0	0	0	0	0	0	0.7
	Zelandopsyche ingens	0	0	0	0	0	0	0	0	0
Leptoceridae										
	Hudsonema amabilis	0	0	0	0	0	0	0	0	0
	Hudsonema aliena									
	Triplectides obsoleta	0	0	0	0	0	0	0	0	0
Philorheithridae										
	Philorheithrus agilis	0	0.3	0.7	0	1.3	0.3	1.7	1.3	4.3
Helicophidae										
	Zelolessica cheira	0	0	0	0	8.3	0	0	0	0
	Alloecentrella magnicornis	0	0	0	0	0	0	0	0	0
Conoesucidae										
	Beraeoptera roria	206	2.7	74	0	1	3	209	14.3	0
	Confluens olingoides	21.7	2	0	0	0	3	0	2	1
	Olinga feredayi	20	1.7	68.7	0	3	8.7	222	149	7
	Pycnocentria evecta	0	0	0	0	0	0	0	0	0
	Pycnocentria funerea	0	0	0	0	4.3	1	0	1.3	0
	Pyconcentria hawdonia	0	0	0	0	0	3.7	0	0	0
	Pycnocentria mordax	0	0	0	0	0	0	0	0	0
	Pycnocentria sylvestris	0	0	0	0	0	0	0	0	1
	Pycnocentrodes aureola	0	0	0.3	0	0	0	2.3	0	0
	unidentified trichoptera 1	0	0	0	0	0	0	0	0	0
Coleoptera										
Elmidae										
	Hydora nitida (adult & larvae)	28.7	13.3	85.7	0	18.3	23.3	32.7	10.7	3
Hydrophilidae										
	unidentified larvae	0	0	0	0.3	0.7	0.3	0	0	0
Hydraenidae										
	Red	2	0.3	0.3	0	1.7	3	0.3	1	7.7
	Black	0	0.3	1	0	0.3	0	1.7	10	0
	Brown	0	0	0	0	0	0	0	0	0
Ptilodactylidae										
	Byrrhocryptus urquharti	0	0.3	0	0	3.3	6	0	0	0
Scirtidae										
	type A	0	0.7	0	0.3	0	0	0	0	0
	unidentified beetle larvae	0	0	0	0	0	0	0	0	0.7

		K10	K11	K12	K13	K14	K15	K16	K17	K18
Diptera										
Blephariceridae										
	Neocurupira campbelli	0	0	26.7	0	0	0	0	0	0
	Neocurupira tonnoiri	0.7	1.3	0	0	5	3	10	28.7	2.3
	Neocurupira hudsoni-complex	0.7	0	0	0	0	10.3	10	0	0
Ceratopogonidae		0	1	0	0	0	0.3	0.3	0	0
Chironomidae										
	Polypedium sp.	4.7	22.3	1	0	11.3	34.7	5	3.3	2.3
	Maoridiamesa sp.	1.7	34.3	0	0	0	0	0	0	0
	A	1.3	26.7	0	0	0	0	0.3	1	0
	B	0	2.7	0	0	0	0.3	0	0	0
	C	0	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	0	0	0	0
	E	0	1.3	0	0	0	0	0	0	0.7
	U1	2.3	5.7	0	0	1	0.7	0.3	1.7	0
	U2	0	0.7	0	0	0	0	0	0	0.7
	U3	0	0	0	0	0	0	0	0	0
	U4	0	0	0	0	0	0	0	0	0
	U5	0	0	0	0	0	0	0	0	0
	U6	0	0	0.3	0	0.3	0	0.7	0	0
	U7	0	0	0	0	0.33	0	0	0	0
	U8	0.3	9.3	1	0	0.7	0.3	0.7	033	4.7
	U9	0.3	8	0.3	0	0.3	1.7	0.3	0.3	0
	U11	0	0	0	0	0	0	0	0	0
	U12	0	0	0	0	0	0	0	0	0
Dixidae										
	Nothodixa campbelli	0	0	0	0	0	0	0	0	0
Empididae										
	type a	0	0.3	0	0	1	0	0.3	0.3	0
Simuliidae										
	Austrosimulium sp.	0	0	0	0	0.7	0	0	0.3	2.3
Tipulidae										
	Zelandotipula sp.	0	0	0	0	0	0	0	0	0
	Limonia nigrescens	0	0	0	0	0	0	0	0	0.3
	Aphrophila neozelandica	25.7	5	17.7	0	1.3	8.7	23.3	2.7	0
	Paralimnophila skusei	0	0	0	0	0	0	0	0.3	0
	Hexatomini sp.	0	0	0	0	0	0	0	0	0
	Eriopterini sp.	1	11.3	1.7	0	0.3	0.3	2.3	1	0.3
	Molophilus sp.	0	0.7	0	0.3	0	0	0	0	1.3
	unidentified diptera 1	0	0.7	0	0	0	0	0	0	0
Neuroptera										
	Kempynus sp.	0	0	0	0.3	0	0	0	0	0
Megaloptera										
	Archichauliodes diversus	0.7	3.7	8.7	0	1.7	28.3	36	12.7	0
Oligochaeta										
	Small	0.3	4.3	0	41.3	5.3	2	0	0.3	0
	Medium	0	0	0	0	0	0	0	0	0
	Large	0	1.3	0	0	0	0	0	0	2

		K10	K11	K12	K13	K14	K15	K16	K17	K18
Mollusca										
	Potamopyrgus antipodarum	0.3	0	0	0	0.3	0	0	0	0
	unidentified mollusc 1	0	0	0	0	0	0	0	0	0
Crustacea										
	Amphipod	0.3	0	0.3	0	0	0	0.7	0	0
	Paranephrops planifrons	0	0	0	0	0	0	0	0	0
	Paratya sp.	0	0	0	0	0	0	0	0	0
Acari										
	mites	0	0	0	0	10	0	0	0	0
Other										
	Platyhelminthes	0	1.33	0	0.33	0.67	0.33	0	0	1.33
	Nematomorpha	0	0	0	0	0	0.33	0	0	0.33
total individuals		**726**	**401**	**797**	**43.3**	**315**	**486**	**1175**	**1007**	**176**
total taxon		**32**	**41**	**29**	**7**	**44**	**43**	**36**	**37**	**37**

Appendix 3c. List of taxa collected from 18 streams (R1-R18) in Mt Richmond Forest Park during November and December 2000. Mean values calculated from 3 replicate samples at each site

		R1	R2	R3	R4	R5	R6	R7	R8	R9
Ephemeroptera										
	Ameletopsis perscitus	0.3	0.3	0	2.7	6	0.3	0.3	0	0
	Austroclima jollyae	3.3	0	0	0	8.3	0	15	0	0
	Austroclima sepia	0	0	0	0	0	0.7	0	0	0
	Coloburiscus humeralis	76	7.7	0.3	36	85	5	45	4	48
	Deleatidium sp.	68	341	473	429	168	256	266	297	70
	Ichthybotus hudsoni	0	0	0	0.7	0.3	0.3	0	0	0
	Neozephlebia scita	0.7	0	0	2.3	3.3	0.3	0.3	0	8.3
	Nesameletus sp.	1.7	17	4	14	12	0.7	4.3	2.3	0
	Oniscigaster wakefieldi	0	0	0	0	0.3	0	0.3	0	0
	Zephlebia dentata	0	0	0	0	0.3	0	0	0	0
	Zephlebia spectabilis	0	0	0	1.7	0	0	0	0	0
	Zephlebia versicolor	0	0	0	0	0.7	0	0	0	0
Plecoptera										
	Acroperla trivacuata	0	0.3	0	0	0.3	0	0	0	0
	Austroperla cyrene	7	2	3	4.7	0.7	5.3	5.3	2	22
	Cristaperla fimbria	0	0	0	0.7	0	0	0	0	0
	Megaleptoperla diminuta	0	0	0	0	0	0	0	0	0
	Megaleptoperla grandis	0	0	0	0	0	0	0	0	0
	Spaniocerca sp.	0	0	0	0	0	0	0	0	0
	Spaniocerca zelandica	0.3	0	0.3	0	0	1.3	0	2.7	8
	Spaniocercoides philpotti	0	0	0	0	0	0	0	0	0
	Stenoperla prasina	2.7	3.3	2.7	11	10	4.7	2	14	1.3
	Zelandobius confusus	0	0	0	0	0	0	0	0	0
	Zelandobius furcillatus	0.7	3	4	1.3	3	10	1.3	6.7	0
	Zelandobius unicolor	0	0	0	0	0	0	0	0	6.7
	Zelandoperla decorata	0.3	0	0	0	0	0	1	4.7	1.7
	Zelandoperla agnetis	0	0	0	0	0	0	0	0	0
	Zelandoperla fenestrata	0	0	0	0	0	0	0	0	5.3
Trichoptera										
Hydropsychidae										
	Aoteapsyche sp.	1.7	4.3	0	1.3	13	12	34	0.3	75
Hydroptilidae										
	Oxyethira albiceps	0	0	0	0	0	0	0	0	0
Hydrobiosidae										
	Early instar	2.7	13	14	9.7	5.7	21	5.7	6	0.3
	Costachorema brachyptera	0.3	2	0	0.7	0.7	0	0	0	0
	Costachorema callista	0	0	1.7	0.3	0	0	0.7	0	0
	Costachorema psaroptera	0	0	0	0	0	0	0	0	0
	Costachorema xanthoptera	0	0	0	0	0.3	0	0.3	0	0
	Edpercivalia maxima	0	0	0	0	0	0	0	0	0
	Hydrobiosis umbripennis	0	0	0.3	0	0	0	0	0	0
	Hydrobiosis parumbripennis	0	0	0	0	0	0	0	0	0.3
	Hydrobiosis clavigera	0	0.3	0.7	0.3	0.3	0	0.3	0.3	0
	Hydrobiosis charadiacea	0	0	0	0	0	0	0	0	0
	Hydrobiosis spatulata	0	0	0	0	0	0	0	0	0
	Hydrobiosis silvicolor	0	0	0	0	0	0	0	0	0
	Hydrochorema sp.	0	0	0	0	0	0	0	0.7	0.3

		R1	R2	R3	R4	R5	R6	R7	R8	R9
	Psilochorema sp.	0	0.7	2	0.3	0.7	0	0	1	0
	Tiphobiosis sp.	0	0	0	0	0	0	0	0	0
Polycentropodidae										
	Polyplectropus sp.	0	0.3	2	0	1	4	0	0	0
Philopotamidae										
	Hydrobiosella mixta	13	16	0	4.7	17	0	6.7	30	1
	Hydrobiosella stenocerca	0	0	0	0	0	0	0	0	0
Helicopsychidae										
	Rakiura vernale	0	0	0	0	0	0	0	0	0
	Helicopysche sp.	39	0.7	0	51	54	0	4.3	0	0.3
Oeconesidae										
	Oeconesus similis	0	0	0	0	0.3	0	0	0	0
	Zelandopsyche ingens	0	0	0	0	0	0	0	0	0
Leptoceridae										
	Hudsonema amabilis	0	0	0	0	0	0	0	0	0
	Hudsonema aliena	0	0	0	0	0.7	0	0	0	0
	Triplectides obsoleta	0.7	0	0	0	1	0	0	0	0
Philorheithridae										
	Philorheithrus agilis	1.3	0	0	0	1.3	0	0	2.3	0
Helicophidae										
	Zelolessica cheira	10	0	0	0.7	0.7	0	8.7	0	0
	Alloecentrella magnicornis	0.7	0	0	0	0	0	0	0	0
Conoesucidae										
	Beraeoptera roria	0.7	0	0.3	1	5.7	6	14	2	0
	Confluens olingoides	4.7	0.7	0	0.7	7.3	1	80	2	0
	Olinga feredayi	19	31	47	1	55	10	6.7	7.3	0.3
	Pycnocentria evecta	0.3	0.3	0	0	0.3	0	0	0	0
	Pycnocentria funerea	0	0	0	0	0	0	0	0	0
	Pycnocentria hawdonia	0	0	0	0	0	0	0	0	0
	Pycnocentria mordax	0	0	0	0	0	0	0	0	0
	Pycnocentria sylvestris	4	0	0	0.7	0	0.3	2	0	0
	Pycnocentrodes aureola	1.3	0	1.7	0	0.3	0	1.3	0	0
	Unidentified trichoptera 1									
Coleoptera										
Elmidae										
	Hydora nitida (adult & larvae)	4.3	7.7	14	2.7	71	60	23	18	3.7
Hydrophilidae										
	Unidentified larvae	0	0	0	0	0	0.3	0	0	0.3
Hydraenidae										
	Red	0.7	0	0	10	4.7	1.3	1	0.7	1.7
	Black	4.7	0.7	1	7.7	5	4.3	2.7	3	0
	Brown	0	0	0	0	0	0	0	0	0
Ptilodactylidae										
	Byrrhocryptus urquharti	0	0	0	1.7	0.7	0	0	0	2
Scirtidae										
	Type A	0	0	0	0	0	0	0	0	0
	Unidentified beetle larvae	0	0	0	0	0	0	0	0	0

		R1	R2	R3	R4	R5	R6	R7	R8	R9
Diptera										
Blephariceridae										
	Neocurupira campbelli	0	0	0	0	0	0	0	0	0
	Neocurupira tonnoiri	0	0	0	0	0	0	0	0	0
	Neocurupira hudsoni-complex	0.3	0.3	0	0	0	4.3	1.7	33	0.7
Ceratopogonidae		0.3	0	0.3	2.3	1.7	1	0	0	0
Chironomidae										
	Polypedilum sp.	1.3	0.3	0.3	1.3	1.7	2.3	1	9	0.3
	Maoridiamesa sp.	0.3	0	0	0	0	0	0.3	0.7	0
	A	2	0	2.3	0.3	5.3	0.3	0.7	0	0
	B	0	0	0	0	1	0	0.3	0	0
	C	2	0.3	0	0.3	0	0.3	0	0	0
	D	0	0	0	0.3	0	0	0	0	0
	E	0	0	0	0	0	0	0	1.3	0
	U1	2	2	2.3	0.3	0	0	4.3	0.3	0
	U2	0	0	0	0	0	0	0	0	0
	U3	0	0	0	0	0	0	0	0	0
	U4	0	0	0	0	0	0	0	0	0
	U5	0	0	0	0	0	0	0	0	0
	U6	2.3	0	0	0.3	0.7	0	0	0	0
	U7	0	0	0	0	0	0	0	0	0
	U8	2.3	0	2.7	4	4	0	0	0.7	0
	U9	1.3	0	0	0	0.7	0.3	0	0.3	1.3
	U11	0	0	0	0	0	0	0	0	0
	U12	0	0	0	0	0	0.3	0	0	0
Dixidae										
	Nothodixa campbelli	0	0	0	0	0.7	0	0	0.3	0.7
Empididae										
	type a	0.3	0	0	0.3	0	0.3	0	0	0
Simuliidae										
	Austrosimulium sp.	0	0	0	1.7	9.7	0.7	1.7	7	0.7
Tipulidae										
	Zelandotipula sp.	0	0	0	0	0	0	0	0	0.3
	Limonia nigrescens	0	0	0	0	0	0	0	0	0
	Aphrophila neozelandica	6.7	4	4.7	7	11	97	12	3	0
	Paralimnophila skusei	0	0	0	0	0	0	0	0	1
	Hexatomini sp.	0	0	0	0	0	0	0	0	0
	Eriopterini sp.	0.7	1	0	0.7	0	7.3	0	0	1
	Molophilus sp.	0	0	0	0	0	0	0	0	5.3
	Unidentified diptera 1	0	0	0	0	0	0	0	0	0
Neuroptera										
	Kempynus sp.	0	0	0	0	0	0	0	0	0
Megaloptera										
	Archichauliodes diversus	5.3	6	2.7	36	34	4.3	3.3	1.3	0
Oligochaeta										
	Small	0.3	0	0	4	0.3	0	0	0	2.3
	Medium	0	0	0	0.7	1	0	0	0.7	1.7
	Large	0	0	0	0	0	0	0	0.7	2.3

		R1	R2	R3	R4	R5	R6	R7	R8	R9
Mollusca										
	Potamopyrgus antipodarum	0.7	0	0	4.3	38	0	28	0	0
	Unidentified mollusc 1	0	0	0	0	0	0	0	0	0
Crustacea										
	Amphipod	0	0	0	0	0.3	0.3	0	0	0
	Paranephrops planifrons	0	0	0	0	0	0	0	0	0
	Paratya sp.	0	0	0	0	0	0	0	0	0
Acari										
	Mites	0	0	0	0	0	0	0	0	0
Others										
	Platyhelminthes	0	0	0	0.7	17	0.3	6.7	0	11
	Nematomorpha	0	0	0	0.7	0.7	0	0	0	0
Total individuals		**298**	**467**	**587**	**666**	**672**	**524**	**593**	**464**	**284**
Total taxa		**45**	**28**	**25**	**46**	**54**	**36**	**38**	**34**	**33**

Appendix 3c continued. Sites R10 – R18

		R10	R11	R12	R13	R14	R15	R16	R17	R18
Ephemeroptera										
	Ameletopsis perscitus	0	0.3	0	0	0.3	0	2.7	18	0
	Austroclima jollyae	19.3	0	87.7	21	19	0.3	1	1	0.7
	Austroclima sepia	0	0	151	0	1	2	0.3	0	0
	Coloburiscus humeralis	167	0.3	43.3	41	22	72	18	191	5.7
	Deleatidium sp.	250	441	122	230	138	209	734	390	442
	Ichthybotus hudsoni	0	0	3	0	0.3	0	0.7	0	0
	Neozephlebia scita	10.7	0	72.3	1	3.3	5.7	17.7	12	0
	Nesameletus sp.	1	25	11.7	20	24	1	27.7	1.7	0.7
	Oniscigaster wakefieldi	0.3	0	0	0	0	0	0.3	0	0
	Zephlebia dentata	0	0	25.7	0	0	0	0.3	0	0
	Zephlebia spectabilis	0	0	0	0	0	0	0	0	0
	Zephlebia versicolor	0	0	14.7	0	0	0	0	0	0
Plecoptera										
	Acroperla trivacuata	0	0	0	0	0	0	0	0	0
	Austroperla cyrene	11.3	0	1.7	0.3	0.3	2.3	1.7	6.3	0
	Cristaperla fimbria	0	0	0	0	0	0	0	0	0
	Megaleptoperla diminuta	0	0	2	0	0	0	0	0	0
	Megaleptoperla grandis	0	0	0	0	0	0	0	0	0
	Spaniocerca sp.	0	0	0	0	0	0	0	0	0
	Spaniocerca zelandica	0.3	0	0	0	0	2.7	0	1	0
	Spaniocercoides philpotti	0	0	0	0	0	0	0	0	0
	Stenoperla prasina	3	4	0	0	0.7	1	2.3	3	1
	Zelandobius confusus	0	0	0	0	0	1	0	0	0.7
	Zelandobius furcillatus	16	0	0	0	47	10	0	15	0
	Zelandobius unicolor	0	0	0	0	0	0	0	0	0
	Zelandoperla decorata	0.7	0	0	2	5.3	1	0.7	0	2.7
	Zelandoperla agnetis	0	0	0	0	2	0.3	0	1.3	0
	Zelandoperla fenestrata	0	0	0	0	1	0	0.3	0.3	0
Trichoptera										
Hydropsychidae										
	Aoteapsyche sp.	2	2.7	4.3	11	2.7	0	14.3	34	9.7
Hydroptilidae										
	Oxyethira albiceps	0	0	0	0	0	0	1.3	0	0
Hydrobiosidae										
	Early instar	5.7	8.3	7.7	14	4.7	16	28	9	26
	Costachorema brachyptera	0	0	0	0	0	1	0	1	0
	Costachorema callista	0.3	0	0.3	0	0	1.3	0.3	0	0.3
	Costachorema psaroptera	0	0	0	0	0	0	0	0	0
	Costachorema xanthoptera	0	0	0	1.3	0	0	0	0	0
	Edpercivalia maxima	0	0	0	0	0	0	0	0	0
	Hydrobiosis umbripennis	0	0	0	0	0	0	0	0	0
	Hydrobiosis parumbripennis	0	0	0	1	0.3	0	1.3	0	0
	Hydrobiosis clavigera	1	0.3	0	0	0	0	5.3	0	4
	Hydrobiosis charadiacea	0	0	0	0	0	0	0	0	0
	Hydrobiosis spatulata	0	0	0	0	0	0	0.3	0	0
	Hydrobiosis silvicolor	0	0	0	0	0	0.3	0	0	0
	Hydrochorema sp.	0	0	0	0	0	0	0	0	0
	Psilochorema sp.	2.7	1.7	1.7	0.3	0	0.7	1.7	0	4.7

		R11	R12	R13	R14	R15	R16	R17	R18	R19
	Tiphobiosis sp.	0	0	0	0	0	0	0	0	0
Polycentropodidae										
	Polyplectropus sp.	0	1.3	0	0.7	0.3	0.7	0.3	3	0
Philopotamidae										
	Hydrobiosella mixta	79	0	0	15	8	34	3	52	15
	Hydrobiosella stenocerca	0	0	0	0	0	0	0	0	0
Helicopsychidae										
	Rakiura vernale	0	0	0	0	0	0	0	0	0
	Helicopysche sp.	40.7	146	21.3	9.7	10	3.3	35	6.3	1
Oeconesidae										
	Oeconesus similis	0.3	0	1	0	0	0	0	0	0
	Zelandopsyche ingens	0	0	0	0	0	0	0	0	0
Leptoceridae										
	Hudsonema amabilis	0	0	3	0	0	0	0	0	0
	Hudsonema aliena	0	0	0	0	0	0	0	0	0
	Triplectides obsoleta	0.3	0	0	0.3	0.3	0	0.7	0.3	0
Philorheithridae										
	Philorheithrus agilis	2	0	0	0	1.3	1	0	0	0
Helicophidae										
	Zelolessica cheira	3.7	0	25.3	0	5.3	0.3	0	1.3	0
	Alloecentrella magnicornis	0	0	0	0	0	0	0	0	0
Conoesucidae										
	Beraeoptera roria	0	0	0	0	0	1.7	0	0	1.7
	Confluens olingoides	50	0	0	0	0	0	0	1.3	15
	Olinga feredayi	57	32	14.3	7	8.3	17	101	37	34
	Pycnocentria evecta	0.7	6.7	109	0.3	0	0	2	0	0
	Pycnocentria funerea	0	0	0	0	0	0	0	0.3	0
	Pyconcentria hawdonia	0.7	0	78.3	0	0	0	0	0	0
	Pycnocentria mordax	0.7	0	71.3	0	0	0	0	0	0
	Pycnocentria sylvestris	1	0	22	0	0	0.7	0	0	0.7
	Pycnocentrodes aureola	0	0	0	2.7	0	0	7.7	0	0
	unidentified trichoptera 1	0	0	0	0	0	0	0	0	0
Coleoptera										
Elmidae										
	Hydora nitida (adult & larvae)	146	21	88.7	21	11	0.7	42.3	6.7	21
Hydrophilidae										
	unidentified larvae	0.33	0	0	0	0	0	0	0	0
Hydraenidae										
	Red	4	0	0.7	0.3	5	5.7	9.3	0.3	2.7
	Black	10.3	0	3	4	1.7	2.3	52.3	2.7	0
	Brown	0	0	0	0	0	0	5.7	0	0
Ptilodactylidae										
	Byrrhocryptus urquharti	0	0	0.3	0	0	0	1	0	0
Scirtidae										
	type A	0	0	0	0	0	0	0	0	0
	unidentified beetle larvae	0	0	0	0	0	0	0	0	0

		R10	R11	R12	R13	R14	R15	R16	R17	R18
Diptera										
Blephariceridae										
	Neocurupira campbelli	0	0	0	0	0	0	0	0	0.7
	Neocurupira tonnoiri	1.7	0	0	0	1	0	0	0	0.3
	Neocurupira hudsoni-complex	2	0	0	0	3	6.3	0	0.7	0
Ceratopogonidae		0.3	0	0	3.7	0	0	9	0.3	0
Chironomidae										
	Polypedium sp.	117	0	12.7	0	1.7	13	7.7	16	0
	Maoridiamesa sp.	0	0	6.3	0	0	0	2	0	0
	A	0.3	0.3	0	1.7	0	0	12	0.3	0
	B	0	0	2.3	0	0	0	20.3	0	1
	C	0.7	0	0	0	0	7	2.7	0.3	0
	D	0	0	0	0	0	0	0	0	3.7
	E	0.3	0	0	0	0	0	0	0	0
	U1	1	0.3	0	1	1	3.3	1	0.3	1
	U2	0	0	0	0	0	0.7	1.3	0	0.7
	U3	0	0	0	0	0	0	0.3	0	0
	U4	0	0	0	0	0	0	0	0	0
	U5	0	0	0	0	0	0	0	0	0
	U6	0	0	0.3	0	0	0	2.7	0	0
	U7	0	0	0	0	0	0	0	0	0
	U8	2	0	0.3	0	0	0.7	5.7	0.7	2
	U9	0	0.3	0	0.7	0	4.7	26.7	0	0.7
	U11	0	0	0	0	0	0	0	0	0
	U12	0	0	0	0	0	0	0	0	0
Dixidae										
	Nothodixa campbelli	0	0	0	0	0	0	0	0.3	0
Empididae										
	type a	1	0.3	0	0	0	0	0	0	0
Simuliidae										
	Austrosimulium sp.	8.7	0	1	0	0.3	0.3	15.7	2.7	1
Tipulidae										
	Zelandotipula sp.	0	0	0	0	0	0	0	0	0
	Limonia nigrescens	0	0	0	0	0	0	0	0	0
	Aphrophila neozelandica	28	3.3	23.3	62	2.3	0	59.7	39	68
	Paralimnophila skusei	0	0	0	0	0	0	0.3	0	0
	Hexatomini sp.	0.7	0	0	0	0	0	0	0	0
	Eriopterini sp.	2.3	0.3	0.3	1.7	0.3	0.3	3.3	0.7	1.7
	Molophilus sp.	0	0	0	0	0	0	0	0	0
	unidentified diptera 1	0	0	0	0	0	0	0	0	0
Neuroptera										
	Kempynus sp.	0	0	0	0	0	0	0	0	0
Megaloptera										
	Archichauliodes diversus	13.7	2	5.7	5	2.7	4.3	34	34	6.3
Oligochaeta										
	Small	0	0	3	32	0.7	0	6	0	0
	Medium	1	0	0	0	0	0	2	0.3	0
	Large	0	0	0	0	0	0	0	0	0

		R10	R11	R12	R13	R14	R15	R16	R17	R18
Mollusca										
	Potamopyrgus antipodarum	6.3	0	52.3	0	0	1.7	2	5.7	0
	unidentified mollusc 1	0	0	0	0	0	0	0	0	0
Crustacea										
	Amphipod	0	0.3	0.3	0	0	0	0	0	0
	Paranephrops planifrons	0	0	0.3	0	0	0	0	0	0
	Paratya sp.	0	0	0	0	0	0	0.3	0	0
Acari										
	mites	0.3	0	0	0	0	0	0	0	0
Others										
	Platyhelminthes	1.3	0	7.7	0	0.3	0	6	16	1.3
	Nematomorpha	0.3	0	0	0	0	0	0	0.3	0
total individuals		**1077**	**697**	**1104**	**512**	**336**	**437**	**1341**	**913**	**678**
total taxa		**52**	**22**	**42**	**30**	**37**	**40**	**56**	**42**	**33**

Appendix 4a. Environmental characteristics measured at 18 streams (A1-A18) in Abel Tasman National Park during November and December 2000. Mean values given for width, depth, velocity and substrate size.

Stream Ref.	Altitude (m)	Width (m)	Depth (cm)	Velocity	Cond.	Temp (°C)	pH	Native vege (%)	Canopy (%)	Moss (%)	Embed. (1-6)	Slope (m/m)	Dom. Geology	Sub size (mm)	Pfank Score	Duncans Index
A1	20	3.2	16.8	0.57	35.2	10.8	8.1	0	5	0	5	0.05	Soft granite	219	35	0.0009
A2	30	3.5	29.8	31.1	40.2	11.8	8	90	20	80	5	0.22	Granite boulders	260	40	2.87
A3	40	3.2	26	27.3	41.7	13.2	8.1	100	30	80	5	0.11	Granite boulders	282	38	0.270
A4	10	4.3	19.3	21.3	112.4	12	7.9	100	30	0	2	0.03	Granite	102	44	0.023
A5	40	2.7	22.2	0.45	40.2	11.7	8.1	100	20	40	5	0.05	Soft granite	223	63	0.009
A6	40	2.6	31	33.8	46.2	10.4	8.2	100	25	90	6	0.06	Crumbly granite	274	29	0.002
A7	10	1.5	14.2	15.8	81.7	11.3	8.2	100	100	0	3	0.01	Granite sand	32.6	83	0.0009
A8	10	2.9	17.3	20.3	77.4	12.8	8.3	100	90	0	1	0.01	Coarse sand	16.9	74	0.006
A9	80	1.3	11.2	13.4	66.6	11.5	8.4	100	100	0	5	0.01	Sand / quartz	44	53	0.001
A10	80	1.3	11.2	13.2	58.3	11.9	8.5	100	95	15	3	0.03	Sand / quartz	94.5	52	0.0004
A11	10	0.7	8.8	9.9	48.1	11.3	8.7	100	80	30	5	0.09	Granite / sand	128	28	0.025
A12	40	1.6	14	0.36	40.6	12.5	7.9	100	30	80	3	0.05	Granite/ quartz	116	34	0.002
A13	20	4.6	24	28.2	39.3	12.7	7.9	100	<10	90	5	0.05	Granite	195	40	0.015
A14	80	10.5	26.9	28.8	243	10	8.3	100	<10	90	5	0.03	Marble / granite	182.5	28	0.043

Appendix 4a. continued.

Stream Ref	Altitude (m)	Width (m)	Depth (cm)	Velocity	Cond.	Temp (°C)	pH	Native vege (%)	Canopy (%)	Moss (%)	Embed. (1-6)	Slope (m/m)	Geology	Sub size (mm)	Pfank	Duncans
A15	140	9.9	29.3	31.7	192	11.4	8.8	80	5	10	4	0.04	Granite / marble	185	51	0.140
A16	480	1.7	9.8	11.3	32.6	9.4	8.1	100	90	60	2	0.16	Flat / glittery schist	98	39	0.261
A17	60	10.4	40.7	45.2	93.2	11.3	8.4	100	<10	30	5	0.05	Granite boulders	270	47.5	0.030
A18	20	2.8	22.6	24.9	70	11.3	8.1	100	85	80	4	0.09	Granite boulders / sand	172.5	44	0.106

Appendix 4b. Environmental characteristics measured at 18 streams (K1-K18) in Kahurangi National Park during November and December 2000. Mean values given for width, depth, velocity and substrate size.

Stream Ref.	Altitude (m)	Width (m)	Depth (cm)	Velocity	Cond.	Temp. (ºC)	pH	Native vege (%)	Canopy (%)	Moss (%)	Embed. (1-6)	Slope (m/m)	Dom. Geology	Sub size (mm)	Pfank Score	Duncans Index
K1	300	5.9	41.5	0.7	228	9.6	8.5	50	30	10	5	0.07	Greywacke - pale stone	203	42	0.20
K2	140	6.8	34.8	38.7	216	8.4	8.6	50	50	70	5	0.02	Granite and pale stone	185.5	37	0.01
K3	940	1.4	10.8	11.9	83.8	5.8	8.7	100	90	80	2	0.067	Slate Greywacke	153	58	0.11
K4	920	1.6	13.7	15.3	138.7	6	8.4	100	85	95	4	0.05	Granite / quartz /slate	164.1	49.5	0.01
K5	880	2.2	13	0.4	80.5	7.5	8.4	100	80	5	3	0.04	Schist	145.8	50	0.01
K6	880	2.6	19	0.4	83	6.5	8.4	100	60	100	5	0.05	Greywacke / Schist	162.9	49	0.003
K7	360	6.6	26.2	28.7	139	7.9	8.7	80	<5	0	5	0.04	Granite Greywacke	172	55	0.03
K8	380	8.5	45.3	0.7	161	7.1	8.4	80	20	10	5	0.02	Greywacke boulders / sand	228	53	0.004
K9	240	1.7	22.5	0.6	151.9	8.7	8.6	100	60	0	1	0.06	Silica boulders / bedrock	143	70	0.01
K10	300	11.6	28.1	30.5	162.1	9.9	8.7	80	30	10	5	0.05	Granite / marble	199	62	0.30
K11	380	2.4	16.2	18.4	195.9	11	8.7	90	30	5	4	0.04	Granite / greywacke	158	42	0.02
K12	280	7.3	36	0.5	110.5	10.8	8.4	100	30	0	1	0.004	Greywacke	174	71	0.00006
K13	840	2.1	12.5	14.3	53.5	5.4	8.7	100	70	20	5	0.15	Greywacke / coarse sedimentary	154	51	0.12
K14	300	2.4	23.8	25.5	77.2	9.2	8.4	100	75	80	2	0.08	Marble / granite	163.5	51	0.05

Appendix 4b. continued

Stream Ref	Altitude (m)	Width (m)	Depth (cm)	Velocity	Cond.	Temp. (°C)	pH	Native vege (%)	Canopy (%)	Moss (%)	Embed. (1-6)	Slope (m/m)	Geology	Sub size (mm)	Pfank	Duncans
K15	300	5	27.7	29.9	111.5	9.3	8.6	100	<10	60	2	0.03	Marble / quartz	167.8	44	0.003
K16	240	11.1	28.7	32.2	145.7	10.6	8.7	50	<5	0	3	0.01	Marble / green rocks	163.6	53	0.002
K17	260	6.9	26	29.1	101.9	11.1	8.5	85	30	<10	4	0.01	Marble / granite	165.7	48.5	0.001
K18	840	1.6	7.7	9.1	204	6.8	8.7	100	80	10	3	0.02	Granite	135.8	56.5	0.0001

Appendix 4c. Environmental characteristics measured at 18 streams (R1-R18) in Mt Richmond Forest Park during November and December 2000. Mean values given for width, depth, velocity and substrate size.

Stream Ref.	Altitude (m)	Width (m)	Depth (cm)	Velocity	Cond.	Temp. (°C)	pH	Native vege (%)	Canopy (%)	Moss (%)	Embed. (1-6)	Slope (m/m)	Dom. Geology	Sub size (mm)	Pfank Score	Duncans Index
R1	70	1.8	16.5	0.3	42	10.1	9.1	100	40	80	5	0.11	greywacke / bedrock	182	33	0.17
R2	70	5.1	34.7	0.6	44.4	10.4	8.7	100	15	0	5	0.05	Greywacke / Bedrock	210	47	0.05
R3	60	13.8	31.2	0.6	40.8	10.5	8.4	100	0	0	2	0.03	Slate Greywacke	152	82	0.08
R4	40	3.2	11.8	0.2	62.7	9.8	8.6	100	60	10	1	0.02	greywacke	128	56	0.001
R5	150	2.4	12.8	0.4	69.6	15	8.5	100	10	15	1	0.02	Schist	124	44	0.001
R6	120	5.2	21.8	23.1	99	9.6	8.7	50	<5	0	5	0.08	Greywacke / iron rich rock	130	38.5	0.41
R7	180	3.1	22.3	23	64.4	12.4	8.3	30	20	0	5	0.08	Granite	191	47	0.02
R8	380	4	22	1	78.4	11.2	8.6	100	20	0	6	0.12	Greywacke boulders	227	76	0.64
R9	420	1	6.7	9	88.1	6	8.3	100	90	50	3	0.05	Granite / silt greywacke	83.3	51	0.01
R10	500	3.9	17.7	20.8	52.2	6.7	8.2	85	85	0	3	0.01	Greywacke / granite	100	45	0.001
R11	440	6.5	17.3	0.5	115.5	14.6	8.4	0	0	0	1	0.006	Greywacke cobbles	115	91	0.001
R12	480	4.5	40.2	0.4	109.3	11.5	8.4	100	20	40	1	0.003	Greywacke / cobbles	158	51	0.00002
R13	440	5.1	19.3	23	103.3	11.7	8.4	100	0	5	3	0.02	Greywacke / iron rich rock	179	44	0.01
R14	250	1.7	22.3	0.2	94.8	10.5	8.9	100	20	20	3	0.06	Greywacke / marble	182	36	0.05

Appendix 4c. continued

Stream Ref	Altitude (m)	Width (m)	Depth (cm)	Velocity	Cond.	Temp. (ºC)	pH	Native vege (%)	Canopy (%)	Moss (%)	Embed. (1-6)	Slope (m/m)	Geology	Sub size (mm)	Pfank	Duncans
R15	60	3.8	17.8	0.3	100.8	11	8.7	100	70	0	3	0.05	Greywacke cobbles	166	56	0.04
R16	100	3.4	15.2	0.3	165.2	14.3	8.7	100	50	1	1	0.005	Greywacke cobbles / bedrock	137	60	0.00004
R17	120	4.4	15.7	0.4	114.9	11.4	8.6	100	60	0	1	0.03	Flat slaty rock	133	33	0.01
R18	180	6.2	22.7	0.5	225	9.1	8.7	100	0	0	5	0.03	Marble / greywacke	201	45	0.01