AQUATIC INVERTEBRATE FAUNA OF MATAPOURI, NORTHLAND.

A thesis submitted to Auckland University of Technology
in partial fulfilment of the requirements for the degree of
Master of Applied Science (MAppSc).

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Dedication

In memory of my father, Ivan Francis Pohe (1949–2003), who passed away during the final year of my undergraduate studies. Fond memories will live on always dad.

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Attestation of authorship

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning."

Signed: ……..

Date: ……..

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Abstract

A study of the aquatic invertebrate communities from two locations (Location 1 and Location 2) within the Matapouri catchment in Northland, New Zealand, was conducted to assess community structure in differing local-scale habitats. Four data collection methods were utilised generating 33,058 adult or larval invertebrates. The sampling methods comprised benthic kick-sampling, sticky trapping, light trapping, and emergence trapping. For the sticky trapping and light trapping, sampling was carried out at three different sites (Sites 1–3) within each location. The sites were situated within three habitat types; native forest, native forest-fringe, and raupo wetland. Emergence trapping also commenced within the three sites, at both locations, but was discontinued after two months, due to the equipment being destroyed by consecutive flooding events (method described in Appendix 1). Benthic sampling was carried out within the Forest and Forest-fringe habitats. Benthic sampling, sticky trapping, and light trapping were carried out following a monthly schedule between June and November 2005. Conductivity, pH, and water temperature measurements were taken concurrently with benthic sampling on a monthly basis, while water velocity and substrate measurements were taken once to assist in habitat characterisation.

Overall, 71 taxa were recorded by benthic sampling over the six month period, with a mean of approximately 30 taxa per site per month. In comparison with similar studies elsewhere in New Zealand, a figure of around 30 taxa per sample was high. The benthic macroinvertebrate fauna at all sites was dominated by Trichoptera (19 taxa), Diptera (16 taxa) and Ephemeroptera (10 taxa). This pattern of diversity is similar to that reported in other New Zealand studies. However, in contrast to previous studies, the leptophlebiid mayfly genus *Deleatidium* was not numerically dominant over the rest of the community, and other leptophlebiid genera (*Acanthophlebia*, *Atalophlebioides*, *Mauiulus* and *Zephlebia*) were equally represented, possibly reflecting niche partitioning between the groups. The genus *Nesameletus* was not recorded at any site, despite being one of the core mayfly species in New Zealand streams. The rare mayfly *Isothraulus abditus* was recorded at one of the forest locations. There are no published records of this species from Northland. Although acknowledged as another of the core New Zealand benthic taxa, the hydropsychid caddisfly *Aoteapsyche* was not recorded during the study. However, another hydropsychid, *Orthopsyche*, was commonly recorded, and these may be filling a similar niche to the *Aoteapsyche* genus.

In contrast to the Trichoptera, Diptera, and Ephemeroptera, the Plecoptera fauna was relatively depauperate, probably reflecting the warmer climate of the region and lack of temperature-buffered spring-fed streams. Surprisingly, *Zelandobius*, a core New Zealand genus, was absent but is regularly recorded in Northland. A species of conservation interest, *Spaniocercoides watti*, currently recognised as a Northland endemic, was recorded in low numbers.

There were no apparent trends in diversity or abundance of benthic invertebrates over time. Also, there were no significant differences in species diversity between the two locations. However, in many cases, taxa were more abundant at Location 2. This may have been due to steeper gradients at Location 2, and the consequent effects on substrate size and streambed stability, as all other physical factors appeared similar between locations. Although several significant differences of individual benthic taxa were recorded, no broad effect of habitat (sites) on species diversity was observable. However, at Location 2, abundances were significantly higher at Site 3 (Forest) compared to Site 2 (Forest-fringe). The reasons were uncertain, but may be attributed to higher retention of allochthonous organic materials, trapped by in-stream cover and larger substrates.

Investigations of adult stages by sticky traps supported benthic results recording community compositions and abundances dominated by Trichoptera and Diptera. Plecoptera were poorly represented. Location 2 recorded higher abundances of taxa, particularly Ephemeroptera and Plecoptera. Investigations of adult stages by light traps however did not produce any statistically significant differences in abundances between sites, between locations, or between sites across locations, and it is believed to be due to limited sampling replication combined with some biases of light trapping.

This study indicates that the aquatic invertebrate community at Matapouri is diverse but also reasonably representative. Several rare or uncommon insects inhabit the catchment. It is therefore important that Iwi and the local Landcare Group, who invited and supported this research, together with the Department of Conservation, continue their efforts in protecting these areas. The resident fauna have the capacity to restock areas downstream, which are intended to be improved and restored through sediment control and riparian management.

Glossary

Allochthonous	– energy or material created outside the system.
Autochthonous	– energy or material created within the system.
Benthic	– bottom dwelling; usually referring to organisms living on the substrate.
Benthos	– community or assemblage living on the streambed.
Biodiversity	– the variability among living organisms from all sources and the ecological complexity of which they are part, including diversity within species, between species and of ecosystems.
Course Particulate Organic Matter	– particulate organic matter >1mm.
Dissolved Organic Carbon	– dissolved organic matter <0.45µm.
Dry weight	– the weight of the material after all moisture has been removed.
Ecological sequence	– a series of two or more connected ecosystem or vegetation types that retain natural transition zones along an environmental gradient.
Ecological Region	– large geographical regions including multiple ecosystems, often of similar function.
Ecosystem	– a dynamic complex of plant, animal, and micro-organism communities and their non-living environments, interacting as a functional unit.
Epigean	– biological term for taxa typically associated with benthic (surface sediment) habitats.
Fine Particulate Organic Matter	– particulate organic matter 0.45µm–1mm.
Flood	– rise in water level to exceed channel capacity, followed by recession.
Floodplain	– temporarily inundated lateral stream and river margins; often referring to lowland rivers.
Fresh (plural: freshes)	– sudden increase in stream or river flow due to rainfall or snow/ice-melt.
Hyporheic zone	– The wetted interstitial zone below and alongside streams and rivers; inhabited by many organisms specialised for a subsurface existence.
Functional Feeding Group	– categories assigned to aquatic invertebrates to describe their main feeding strategy e.g. shredder, grazer, predator.
Hypogean	– biological term for taxa typically associated with true groundwater habitats.
Invertebrate	– an animal without a vertebral column.
Kaitiakitanga[1]	– the exercise of guardianship; and, in relation to a resource, includes the ethic of stewardship based on the nature of the resource itself.
Larva (plural: larvae)	– an immature stage of a holometabolous insect following the egg stage, preceding the pupal stage, and differing fundamentally from the adult.

[1] As defined by the New Zealand Resource Management Act 1991.

Macroinvertebrate	– invertebrates, functionally defined as >500 μm for convenience without fundamental or taxonomic significance.
Niche	– term describing the relational position of a species or population in its ecosystem.
Nymph	– an immature stage of a non-holometabolous insect following the egg stage and preceding the adult.
pH	– the negative logarithm to base 10 of the hydrogen ion concentration. Acidic solutions have a pH <7, basic solutions have a pH >7.
Physico-chemical	– pertaining to both physical and chemical properties of parameters.
Pool	– an area of slow-flowing of standing water, not including breaking water, usually occurring at the base of a riffle, and being the deepest part of a stream or river.
Riffle	– a reach of fast-flowing shallow water, breaking on the surface over obstacles, and usually associated with a constriction in channel width, and increase in gradient.
Riparian margin	– a strip of land, usually of varying width, adjacent to a waterway and which contributes, or may contribute, to the maintenance and enhancement of the natural functioning, quality and character of the waterway and its margins.
Rohe	– a territory or boundary which defines the area within which a tangata whenua group claims traditional association and mana whenua (customary authority).
Run	– a reach of stream or river intermediate in character between a riffle and a pool, usually of laminar flow and not including breaking water.
Tangata whenua	– tribe, sub-tribe, or people in general belonging to the land i.e. custodians or guardians.
Total Dissolved Solids	– the sum of dissolved salts and organic residues.
Wetland	– permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals that are adapted to wet conditions.

List of acronyms

a.s.l. – above sea level

CPOM – Course Particulate Organic Matter

DOC – Dissolved Organic Carbon

FFG – Functional Feeding Group

FPOM – Fine Particulate Organic Matter

GIS – Geographical Information Systems

GPS – Global Positioning System

MCI – Macroinvertebrate Community Index

NIWA – National Institute of Water and Atmospheric Research

NRC – Northland Regional Council

pH – Potential of Hydrogen

REC – River Environment Classification

SEM – Standard Error of the Mean

TDS – Total Dissolved Solids

Chapter 1 – *Introduction*

1.1 General introduction

1.1.1 New Zealand's physical environment

New Zealand's stream environments are recognised as distinctive from others around the world, which is important as many general stream environment models are based on North American systems (Winterbourn *et al*. 1981).

Aquatic environments can be divided into two overriding bodies; those receiving a lotic (running water) system, and those of a lentic (still water) system. Some major New Zealand natural habitats surrounding aquatic environments include indigenous forest, scrub/shrubland, tussock grassland, herbfield, wetland and duneland. Other modified habitats include urbanised land, farmland and exotic plantations (Wardle 1991). The predominant New Zealand forest types, beech (*Nothofagus* spp.) and conifer-broadleaf, both consist primarily of evergreen species (Dawson 1988) that have sparse under-stories and produce relatively small quantities of woody debris (Salmon 1999).

Although New Zealand has a small landmass i.e. 270,000 km^2 (Worthy & Holdaway 2002, Hogg *et al*. 2002), it has an incredibly diverse and complex landscape that includes many large (>2500m) mountain ranges (Cochrane 1973). Much of New Zealand's topography has a steep relief, and streams and rivers are short (Worthy & Holdaway 2002), seldom having stream orders (Strahler 1957) greater than five or six. In most places, tree-line vegetation occurs at low elevations (<1500m) due to latitudinal position (Druce 1959), and consequently large water catchments can occur in steep and desolate environments. These locations are natural sources for continual sediment-loading of streams, aided by unstable streambeds, poor debris retention characteristics, and fast-flowing systems. Furthermore, many lowland foothill and floodplain streams today drain highly modified, urban and agricultural sub-catchments, which are subjected to intense anthropogenic disturbance. These factors, in combination with New Zealand's temperate climate and unpredictable but frequent high rainfall (mean annual rainfall of 1300mm; mean annual temperature of 14°C; source NIWA Climate Data Centre) produce some of the highest rates of erosion reported in the world (Griffiths 1979), and result in rivers and streams that yield extremely large sediment loads.

1.1.2 New Zealand's invertebrate fauna

Various elements of New Zealand's biota have been described as unusual and often primitive. This is largely due to their gondwanan heritage and geographic isolation. Some well known examples include the moa (Dinornithiformes), tuatara (*Sphenodon punctatus*), and kiwi (*Apteryx* spp.). New Zealand's aquatic ecosystems also possess an interesting fauna. Aquatic ecosystems consist of a biological community and its physical environment (Harding *et al*. 2004). It is generally acknowledged that, excluding microscopic organisms, invertebrates, and in particular insects, are the dominant group of terrestrial animals, occurring in almost every recognised environment (Marples 1962). Invertebrates are an abundant faunal component of any healthy New Zealand aquatic ecosystem and play important ecological roles in ecosystem processes. Fisher & Likens (1973) and Cummins & Klug (1979) reported that invertebrates contribute to the processing of allochthonous and autochthonous organic carbon, and influence periphyton growth and nutrient levels, while others identify them as an important food source for fish (Sagar & Eldon 1983, McDowall 1990) and birds (Pierce 1979, 1986).

New Zealand invertebrate communities are recorded as unique from other stream assemblages around the world. Although several taxa (e.g. Oligochaeta and Diptera) have species with a cosmopolitan distribution, many invertebrate groups are poorly represented or absent altogether. In addition, Collier (1993) reported a high degree of speciation amongst some groups, a large number of primitive species, and a high degree of endemicity.

Many studies have reported invertebrate communities throughout New Zealand, from unmodified streams, to be dominated by a core of common taxa i.e. *Coloburiscus*, *Deleatidium*, *Nesameletus* (Ephemeroptera); *Stenoperla*, *Zelandobius*, *Zelandoperla* (Plecoptera); *Aoteapsyche*, *Hydrobiosis*, *Olinga*, *Psilochorema*, *Pycnocentria* (Trichoptera); *Archichauliodes* (Megaloptera); *Potamopyrgus* (Gastropoda) (Winterbourn *et al*. 1981, Rounick & Winterbourn 1982, Quinn & Hickey 1990a). Research indicates that the most diverse insect faunas are associated with reasonably stable stream channels hosting a high degree of substrate heterogeneity (Winterbourn *et al*. 1981) and in-stream debris. Winterbourn *et al*. (1981) noted that large stoneflies (Plecoptera) are poorly represented, while several other orders have very few

representatives in New Zealand e.g. Gastropoda, Crustacea, Megaloptera, Mecoptera, and Odonata (Collier & Winterbourn 2000). In contrast, caddisflies (Trichoptera) are well represented, but like the stoneflies, are relatively small compared to species in other countries.

In New Zealand, large particle detritivores (shredders) are poorly represented, with the most dominant functional feeding invertebrates being browsers, feeding on fine suspended particulate matter (FPOM) or surface organic layers (Winterbourn 2000b). Vannote *et al*. (1980) identified a continuum (the River Continuum Concept) of functional feeding groups along North American rivers, however in New Zealand, representation of functional feeding groups shows little change downstream (Winterbourn *et al*. 1981). In addition, they stated that many of New Zealand's benthic invertebrates are ecologically flexible species, while Winterbourn (1995) concluded that New Zealand hosts a range of resilient, opportunistic fauna, characterised by flexible life histories, and lacking specialisation to specific temporal and spatial habitats.

1.1.3 Factors influencing New Zealand's invertebrate fauna

Many studies have investigated invertebrate community composition in New Zealand streams and the factors influencing them e.g. Quinn & Hickey (1990a & b), Clausen & Biggs (1997), Storey & Cowley (1997), Milner *et al*. (2001a & b), Scarsbrook (2002), Boyero (2003), Collier & Quinn (2003), Townsend *et al*. (2003), Collier & Quinn (2004). There are many factors that influence the distribution of species, and ultimately characterise community composition. Catchment land cover, substrate composition, hydrology, vegetation cover (influencing light, temperature, primary production, and oxygen levels), and physico-chemical conditions have all been identified as major factors. However, water depth and velocity, sedimentation, and biological interactions are also recognised as strong contributors (Jowett 2000). It is currently accepted that stream life in New Zealand is generally physically dominated with biological interactions as secondary factors (Winterbourn *et al*. 1981).

Major degradation of New Zealand's natural aquatic ecosystems is well documented (see Collier & Winterbourn (2000) and Parkyn *et al*. (2003) and references therein), and these considerable changes have been shown to have substantial impacts on aquatic invertebrate communities (Quinn 2000). Because aquatic invertebrates are abundant in

healthy streams, and different groups display a range of tolerances to changing environments, they have become widely used as biological indicators in monitoring stream water quality, all around the world.

Invertebrates are cold-blooded, meaning they do not regulate the temperature of their bodies. This implies that their body temperatures are ambient with the surroundings (Mellanby 1963), thus their temperatures fluctuate, not only with diurnal, seasonal and climatic changes, but also with differences in habitat use at meso- and micro-habitat scales. A study by Duggan *et al*. (2002) investigated macroinvertebrate (and macrophyte) communities across large distances; their results suggesting that macroinvertebrate communities are also affected by large ecoregional scales which "may override smaller-scale habitat influences".

1.1.4 Methods of sampling aquatic benthic invertebrates

Three methods commonly used for collecting benthic invertebrates are Surber sampling (Surber 1937), kick-sampling (Frost *et al*. 1971), and individual stone sampling (Macan 1958) (Cummins 1962, Hynes 1970b, Kroger 1972, Slobodchikoff & Parrott 1977, Winterbourn 1985b).

Surber sampling is the most common method used for collecting quantitative data for community and life history investigations (Hughes 1975, Winterbourn 1985b). Individual stone sampling also collects quantitative data, using individual stones as sampling units. Although recognised as a useful method for sampling rocky and irregular sediments, which can not easily be sampled by Surber sampler (Winterbourn 1985b, Death & Winterbourn 1995), a number of flaws have also been reported (see Doeg & Lake (1981) and references within).

Kick-sampling is widely considered a convenient and effective semi-quantitative method for collecting invertebrate data, requiring minimal equipment and providing comparative data between locations, especially for faunal surveys (Mackey *et al*. 1984). It also one of the few methods available for sampling rocky and irregular sediments (Winterbourn 1985b), including those encountered in headwater streams.

Natural forest stream faunas include few numerically abundant taxa and numerous rare ones, thus as sampling efforts increase, the number of taxa recorded will also increase (Winterbourn 1985b, Allan 1995, Death 1996). Three to six replicates appear necessary to collect representative taxonomic inventories (Mackey *et al*. 1984, Stark 1993 & 1998, Boothroyd & Stark 2000), while considerable replication (12–16 samples) would probably be required to accurately produce faunal inventories (Stark 1993). However, Boothroyd & Stark (2000) stated that the area of streambed sampled, as well as the number of replicates taken, was important to the defensibility and precision of data obtained in a study. It is reported that three kicks yield almost 90% of the organisms secured by ten (Frost *et al*. 1971) and that a representative invertebrate sample can be obtained using a kick-net by sampling 0.6–1.0m^2 of streambed (Stark *et al*. 2001). In addition, approximately 20% fewer kick-net samples would achieve similar results to Surber samples (Stark 1993).

1.1.5 Flighted stages of aquatic insects

The final stage of most aquatic insects is a terrestrial stage (exception being some aquatic Coleoptera and Hemiptera); the sole purpose being to reproduce. The adults leave the stream, which is known as emergence, and take flight. Flight of aquatic insects has received much attention, nationally and internationally (Kovats *et al*. 1996, Collier & Smith 1998, Winterbourn & Crowe 2001, Smith *et al*. 2002, Elliott 2003, Briers *et al*. 2004). Dispersal of the adult females upstream, prior to oviposition, is suggested to be a behaviour that compensates for possible downstream drift by larvae, allowing completion of the colonisation cycle (Muller 1982).

Oviposition behaviour can strongly influence between-stream and within-stream distributions of larvae (Winterbourn & Crowe 2001), however prior to oviposition, females must find a suitable habitat. This preference varies between species, but most mayfly (Ephemeroptera), stonefly (Plecoptera) and caddisfly (Trichoptera) adults favour stream-side riparian vegetation, and a suitable gravel substrate (Jackson & Resh 1991). The adults of many aquatic insects spend much of their lives in and around the riparian zone, which also provides a refuge from predators, food supplies, preferred sites for metamorphosis, mating and completion of ovarian maturation, along with corridors for dispersal (Collier & Smith 1998 & 2000, Jackson & Resh 1989). Successful dispersal of the adult stages has important consequences for processes of colonisation, gene flow,

and evolutionary divergence (Bilton *et al*. 2001). Blakely *et al*. (2006) identified road culverts and poor oviposition habitat as potential barriers to upstream flight and larval recruitment.

1.1.6 Justification, aims, and objectives of the study

Few studies have been carried out on aquatic invertebrate compositions within Northland (see Quinn & Hickey 1990a & b, Seitzer 1994 & 1995, Collier 1995, Cook 2002, Collier 2004) and only one (Pohe 2003) within the catchment of Matapouri (Personal Communications: Mrs Tanya Gray, Environmental Reporting Coordinator, Northland Regional Council; Miss Amy MacDonald, TSO Freshwater, Northland Conservancy, Department of Conservation).

Pohe (2003) carried out the only study of benthic invertebrate community composition within Matapouri, assessing catchment water quality and paralleled invertebrate composition. No collections or published studies of winged stages have been undertaken in Northland, other than for taxonomic purposes.

A number of other studies have been jointly conducted by the Auckland University of Technology and University of Auckland in recent years within the estuary environments of Matapouri, looking at the geology, biological diversity, and productivity of the estuarine system. Building an understanding the ecology of stream ecosystems will provide important links from the headwaters to the sea, for conservation and resource managers.

Furthermore, the results of this study will help increase our scientific knowledge of the Matapouri catchment invertebrate fauna. Such understanding may enable resource managers, local iwi, and the Matapouri Landcare Group to develop appropriate management strategies to improve biodiversity in the region. The study may also promote wider understanding of the vital ecological role of invertebrates which may help conservation efforts to effectively protect this unique ecosystem.

Thus, the aims of this research are to gather biological, environmental and habitat data on aquatic invertebrate communities that will aid conservation efforts at both the ecosystem and species levels of management.

These aims were achieved by:

- providing baseline data on larval and winged stages of aquatic invertebrates from longitudinal sequences within two locations of the Matapouri catchment.
- investigating the community compositions and relative abundances of benthic invertebrates from longitudinal sequences within two locations of the Matapouri catchment.
- investigating the community compositions and relative abundances of winged stages from longitudinal sequences within two locations of the Matapouri catchment.

Chapter 2 – *Study area and site descriptions*

2.1 Introduction

The coastal town of Matapouri (35° 34.0′ S, 174° 30.4′ E) is situated approximately 35km northeast of Whangarei on the east coast of Northland, New Zealand (Figure 1). The first settlers to the area were bushmen who logged kauri (*Agathis australis*), puriri (*Vitex lucens*) and totara (*Podocarpus totara* var. *totara*[2]) for a range of industries including shipbuilding, house construction, telephone poles, and fence posts (Morrison 1974). As the land was cleared, and accessible timbers became scarce, farming took the place of logging. Sheep were first brought to Matapouri in 1913 and by 1925 dairy farming was prominent together with extensive cropping of kumara, water melons, maize, corn, and oats (Morrison 1974). Today land use is dominated by drystock farming (Soliman 2004), with native forest in the upper catchment and isolated patches of exotic plantings on some sloping sites (Figure 2). The catchment is sparsely populated with the small coastal township housing the majority of the community.

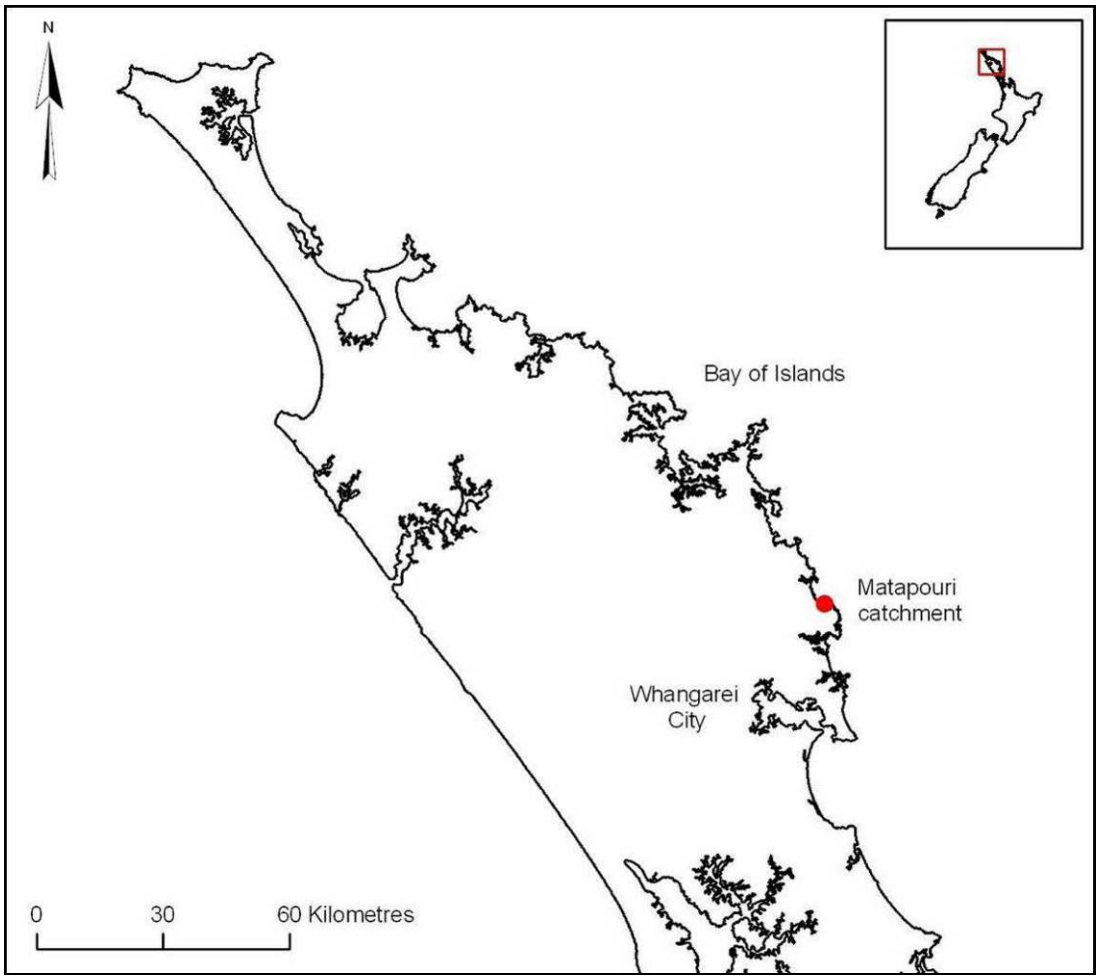

Figure 1. Location of Matapouri catchment, Northland, New Zealand.

[2] Botanical nomenclature following Eagle (2006).

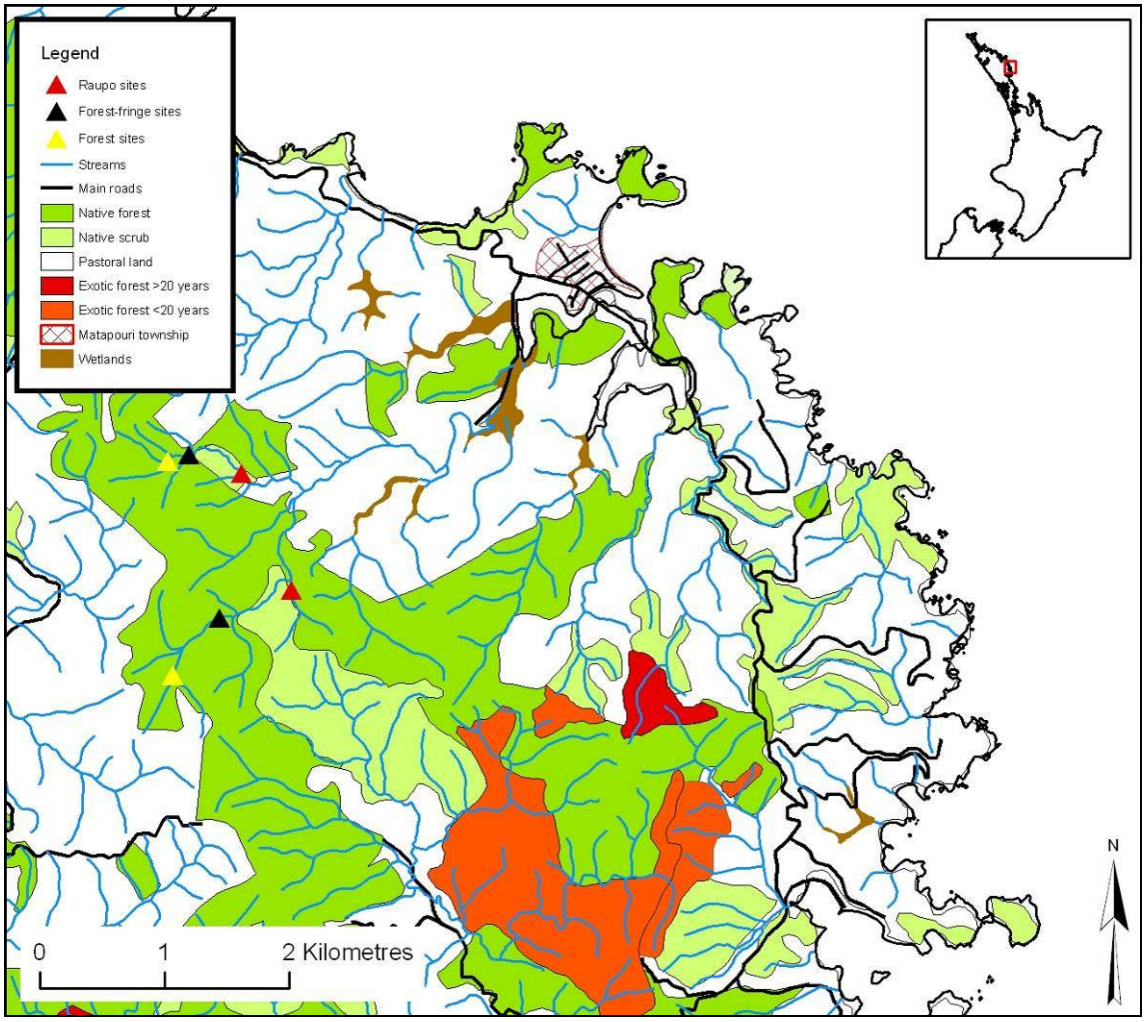

Figure 2. Land cover and land use within the vicinity of Matapouri with study sites and township included.

A highly active Landcare Group, together with the Department of Conservation and local Iwi are working hard to improve the regions biodiversity by planting, pest and weed removal, and native species reintroductions/translocations. Stream riparian zone management and sedimentation control measures are currently being discussed, and information on the catchment's aquatic fauna is required.

A high-standing fault block extends from the northwest of Matapouri through to Ngunguru in the south, rising in height to approximately 120m a.s.l. (Elliot 1966), forming the 14.2 km^2 catchment. This is drained by two sub-catchment streams, Te Wairoa (8.3 km^2 catchment) in the north and Parangarau (5.9 km^2 catchment) in the south, which both discharge into two mangrove[3]-lined arms of the Matapouri Estuary.

[3] Mangrove (*Avicennia marina* ssp. *australasica*). Botanical nomenclature following Eagle (2006).

2.2 Geology, soils, flora and fauna, and climate

Data on catchment attributes including geology, soil type, land cover, and climate were obtained from the New Zealand Land Resource Inventory (NZLRI) and New Zealand Land Cover Database (NZLCDB), together with the classification frameworks of Land Environments of New Zealand (LENZ) (Leathwick *et al*. 2003) and the New Zealand River Environment Classification (REC) (Snelder & Biggs 2002). Minimum and maximum temperatures and rainfall were sourced from the NIWA Climate Data Centre.

Geology of the region is dominated by underlying basement rock of the Waipapa Group (Morgan 2003), comprised of relatively hard palaeozoic greywacke and poorly bedded argillite (Thompson 1961) (Figure 3).

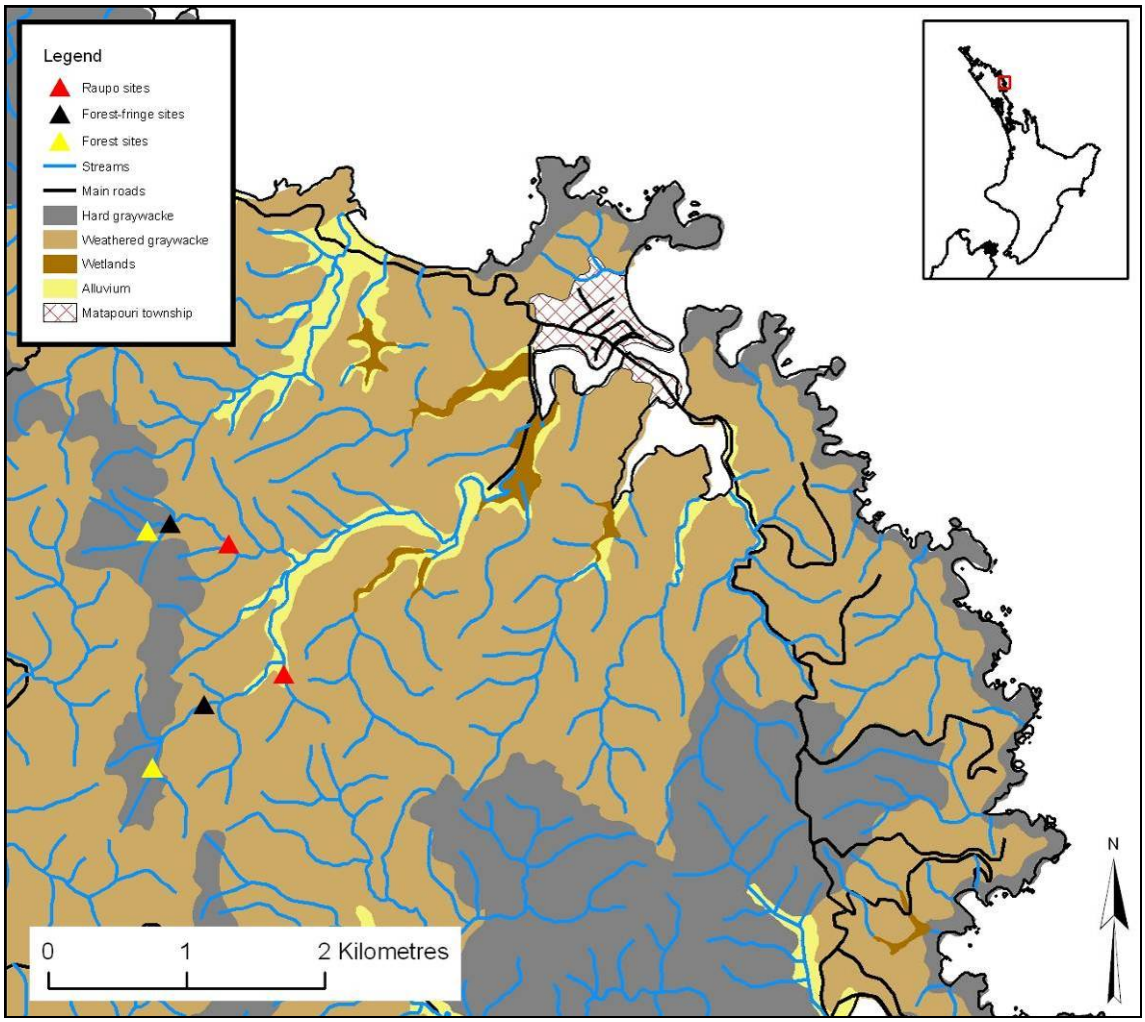

Figure 3. Underlying parent rock of the Matapouri catchment with study sites and township included.

Greywacke is the oldest rock type in the region and under the warm, humid, Northland climate, has become deeply weathered in large areas to brown clay loams, often to depths of 30m (Harmsworth 1991). Undulating and easy rolling hills of Marua clay loams dominate the catchment's topography, with strongly rolling hills of Te Ranga

stony clay loams forming the upper catchment. Floodplains consisting of alluvium are rested above poorly draining Whakapara mottled clay loams (Sutherland *et al*. 1981).

The catchment contains a number of significant points of conservation interest. Nationally rare coastal forest remnants (Appendix 2) cloak the headlands and numerous highly diverse forest types shroud parts of the mid and upper catchment. These include one of the few stands of kawaka (*Libocedrous plumosa*) in the region, and healthy stands of kauri-rimu-tanekaha[4] and totara-taraire[5] forests which form contiguous ecological sequences linking several ecosystems from northern Matapouri through to the Ngunguru Estuary in the south (Booth 2005). Raupo (*Typha orientalis*) and *Ageratina* spp. dominate low-gradient floodplains while mangrove-*Juncus* spp. associations dominate the upper estuary and mangrove forest prevails towards the coast.

Within these environments are a high diversity of plant and animal species (Booth 2005) including a number listed by Hitchmough *et al*. (2007) as threatened (Appendix 3). Several fish species were observed during visits to the catchment and included banded kokopu (*Galaxias fasciatus*), eels (*Anguilla dieffenbachii* and *Anguilla australis*), redfin bullies (*Gobiomorphus huttoni*), and unidentified bullies (*Gobiomorphus* sp.).

Matapouri Bay is more prone to 'cycling'-type rain storms than other parts of New Zealand, with storms usually occurring between November and April (Dreadon, 2001). Annual rainfall in the region is often 1000–1400mm with maximum rainfall occurring in winter (Harmsworth, 1996). The mean annual rainfall recorded in the Matapouri township (1967–2004) was 1388.5mm and mean annual minimum and maximum air temperatures recorded in the region (1991–2004) were 11.9 and 19.7 °C respectively (raw data sourced from NIWA Climate Data Centre). During the present study it was not possible to obtain continuous relative humidity or air and stream water temperature readings as data-loggers were not available. However minimum and maximum daily air temperature records were supplied by NIWA Climate Data Centre. The temperature recorder station was located at the Whangarei Airport (35° 46.14′ S, 174° 21.84′ E), approximately 35km to the southwest of Matapouri.

[4] Rimu (*Dacrydium cupressinum*), tanekaha (*Phyllocladus trichomanoides*)
[5] Taraire (*Beilschmiedia tarairi*)

2.3 Study location selection

Little was known of the catchment, and a preliminary study was undertaken to establish tentative locations for intensive study. To incorporate an element of randomness into the selection, major stream flows within the Matapouri catchment were identified using a topographical map. Six sub-catchments were recognised and a bearing line was drawn in the general direction of each stream flow (Figure 4).

Figure 4. The Matapouri catchment. Black lines identify catchment boundaries of the two named systems. Red arrows indicate the bearings of the six identified sub-catchments.

On the map, potential study location points were marked off at 50m intervals on each bearing line. Each potential sampling point was allocated a different number. No two points on any of the bearing lines had the same number. A total of 278 points were allocated on all six bearing lines.

Ten potential study location points were randomly selected (using a random numbers table (Fowler *et al*. 1998)) such that no more than two points fell within a single bearing line. This was to provide a greater degree of spatial representation.

A radius was drawn from each of the ten points on the topographical map to the closest stream. This resulted in ten tentative study locations being selected within the catchment (Figure 5). These locations were then located in the field with the use of a hand-held GPS.

Of the ten tentative locations, only four had manageable access and of these, only two had obvious longitudinal sequences of native forest, native forest-fringe and raupo wetland habitats, which were to be the focus of the current study.

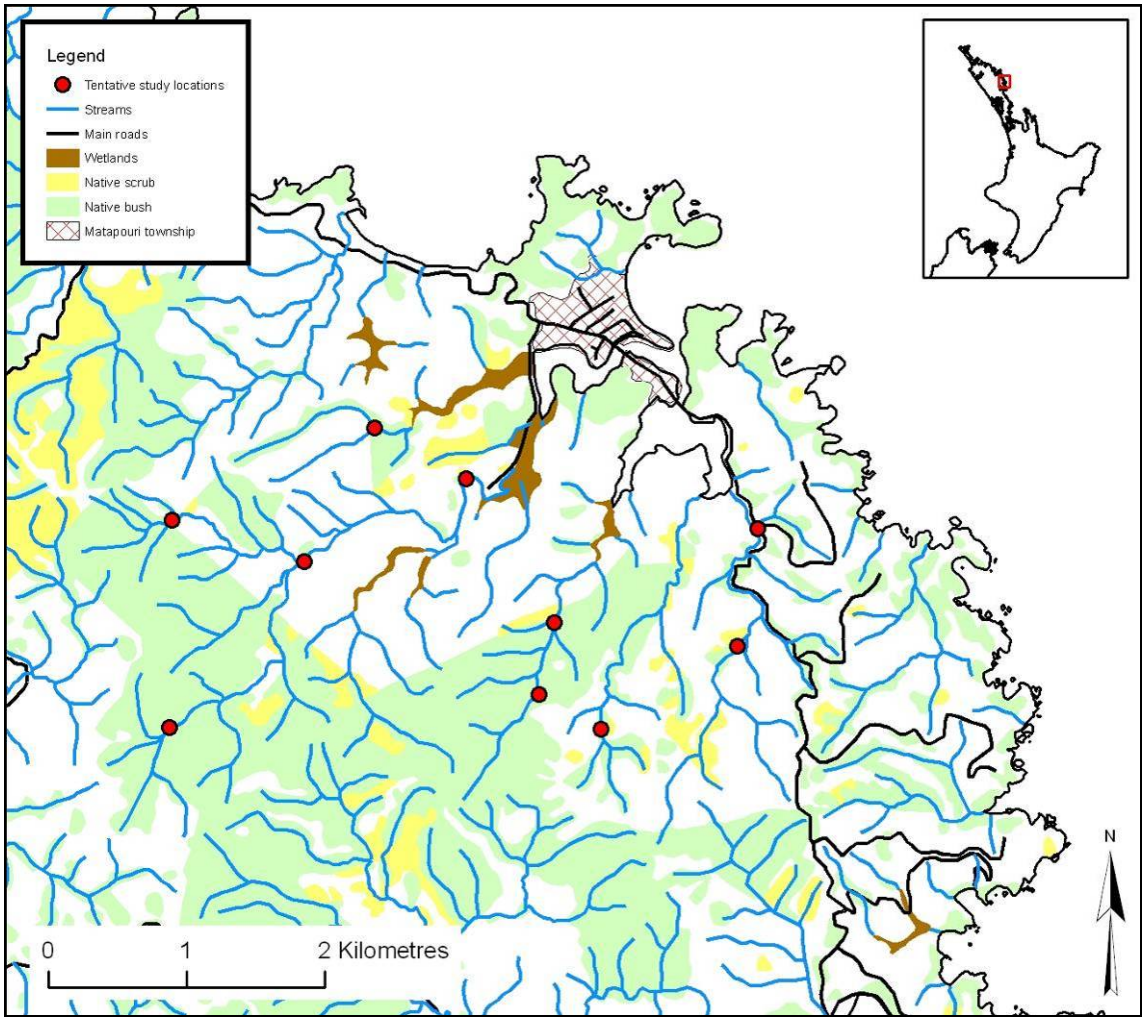

Figure 5. The Matapouri catchment displaying the ten tentative study locations.

2.4 Study site characterisation

2.4.1 Site locations and descriptions

Two study locations were selected based on the methods described previously and are formally referred to as Location 1 and Location 2 throughout this research. Both locations were situated within the upper catchment of Te Wairoa Stream, on both private and conservation land, and each exhibited similar sequences of geology, gradient, and vegetation type. Within each location three sampling sites, of differing habitat, were established (Figure 6).

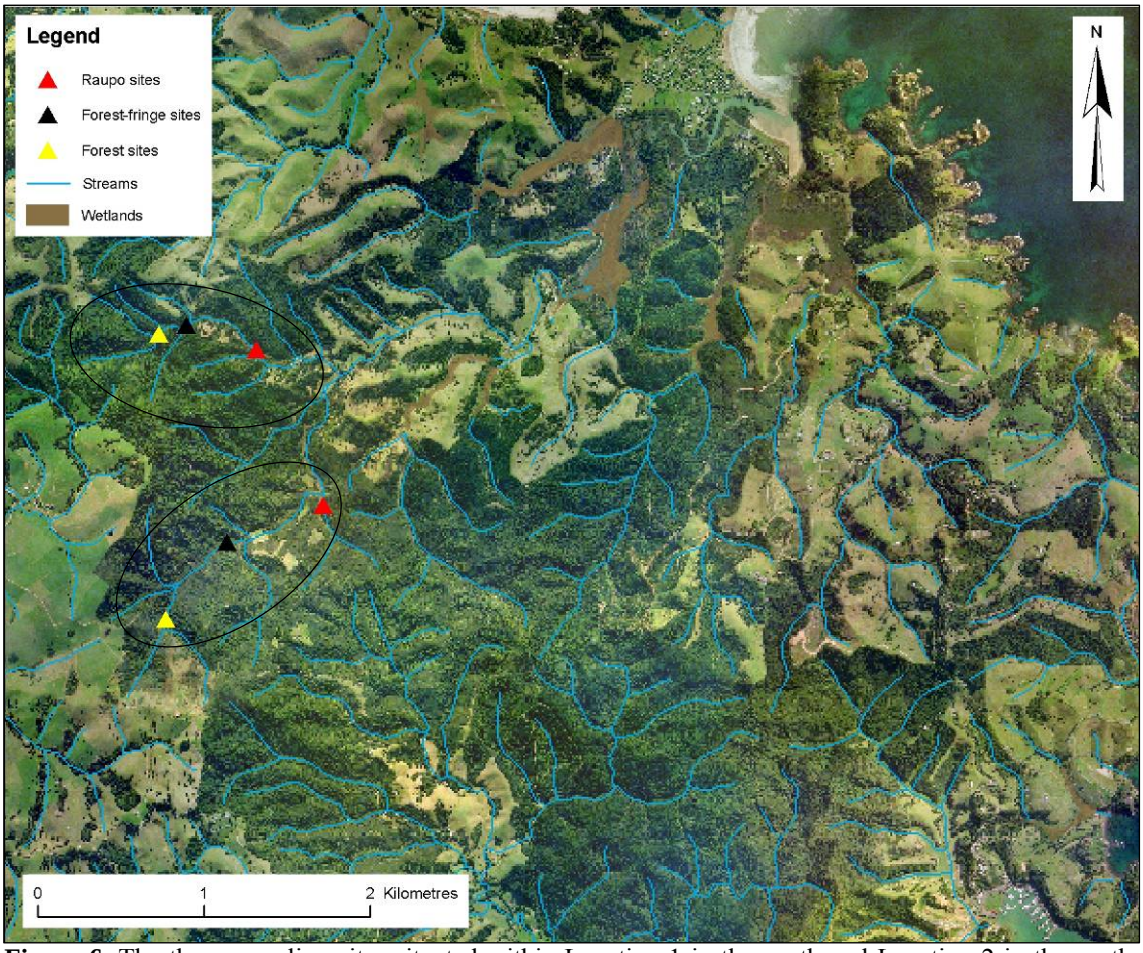

Figure 6. The three sampling sites situated within Location 1 in the south and Location 2 in the north. Aerial imagery provided by Northland Regional Council (NRC).

These sites were identified as Forest (consisting of dense native forest vegetation with an intact overhead canopy) (Figure 7 & Figure 8), Forest-fringe (consisting of a reduction in native forest habitat, sparse overhead canopy, and downstream edge effects) (Figure 9 & Figure 10), and Raupo (consisting of streams dominated by open raupo wetlands) (Figure 11 & Figure 12). Hereafter, Forest, Forest-fringe, and Raupo sampling sites will be formally referred to as Sites 3, 2, and 1 respectively.

Figure 7. Forest habitat at Location 1, Site 3.

Figure 8. Forest habitat at Location 2, Site 3.

Figure 9. Forest-fringe habitat at Location 1, Site 2 with trial emergence tents (foreground) and sticky trap lines (background) present.

Figure 10. Forest-fringe habitat at Location 2, Site 2 with trial emergence tents (foreground) and sticky trap poles (background) present.

Figure 11. Raupo habitat at Location 1, Site 1.

Figure 12. Raupo habitat at Location 2, Site 1.

All sites were located on second order stream reaches (as defined by Strahler 1957), with small catchment areas and low elevations (Table 1). Stream widths generally ranged from 0.5–2.4m, with extensive low-gradient raupo waterway environments up to 45m (Table 2).

Table 1. Physical catchment attributes of sampling sites within Location 1 and Location 2 at Matapouri. For LENZ category explanations see Appendix 4.

	Location 1			Location 2		
	Site 1 (Raupo)	Site 2 (Forest-fringe)	Site 3 (Forest)	Site 1 (Raupo)	Site 2 (Forest-fringe)	Site 3 (Forest)
Stream order	2	2	2	2	2	2
Distance to sea (km)	3.6	4.2	4.8	3.3	3.8	4.1
Elevation (m)	30	40	60	40	50	70
Gradient	Low	Medium	Medium	Low	Medium	High
Catchment area (km^2)	0.20	0.87	0.40	0.59	0.38	0.20
LENZ category	G3.1b	A6.1b	D1.1a	G3.1b	D1.1a/A6.1b[6]	D1.1a

Water velocity readings using a Global Water Flow Probe (Model FP201) were taken on 20th March 2005 to assist in characterising the physical environment from all sites at both locations. Velocities at both Site 1 locations were too slow to be recorded by the meter i.e. <0.08m/s. Average water velocity readings (averaged by the meter) were taken at a range of depths in riffle microhabitats. Mean water velocities seldom exceeded 0.30m/s (readings taken at approximately base flow conditions) (Table 2).

Table 2. Physical attributes of sampling sites within Location 1 and Location 2 at Matapouri.

	Location 1			Location 2		
	Site 1 (Raupo)	Site 2 (Forest-fringe)	Site 3 (Forest)	Site 1 (Raupo)	Site 2 (Forest-fringe)	Site 3 (Forest)
Stream depth (cm)	N/A	3–14	2–11	N/A	3–11	4–10
Stream width (m)	26.0–31.3	1.1–2.2	1.2–1.8	28.2–42.1	0.8–2.4	0.6–1.7
Mean water velocity (m/s)	<0.08	0.10–0.28	0.09–0.18	<0.08	0.14–0.31	0.11–0.24

2.4.2 Substrate analysis

Core samples (150mm internal diameter; 120mm depth where possible) were taken from streambeds at each of the hard-bottomed habitats (Sites 2 and 3) on 20th March 2005 to characterise the physical nature of the underlying substrata. Large sediments (>16mm) were removed from the streambed core area prior to cores being collected. The occurrence of pebbles (4–64mm), cobbles (64–256mm), and boulders (>256mm) was recorded to characterise the physical nature of the larger surface sediment constituents. Sediment cores were dried for 20–32 hours in a laboratory oven at 42° C then mechanically sorted for 10 minutes with an Endecotts EFL 20000/2 test sieve

[6] This site is situated on the boarder of two differing land environments.

shaker at 50 Hz (vibration speed: 1,425 per minute). Sediments were separated into size classes using a series of Endecotts sieves (16, 8, 4, 2, 1 and 0.5mm and 250, 125 & 63µm), and classified using the Udden-Wentworth (Udden 1914, Wentworth 1922) size classes and terms. All sediments <63µm were pooled and termed silt/clay. Sediment fractions were weighed using a calibrated Mettler balance (model B502; accuracy ±0.05g), and presented as a percentage of total core weight.

In general, the streambeds consisted of hard greywacke bed-rock, boulders, cobbles, and pebbles positioned on a stable substrate of granule gravels. The upper layer of loose material ranged from 50–150mm depth and particle size composition of the smaller (<4mm) substrate fractions were predominately granule gravels and course sand types (Figure 13). Clay loams were also noted within the lower reaches of Location 1. Larger (>4mm) streambed sediments at Location 2 hard-bottomed habitats (Sites 2 and 3) tended to consist of isolated bedrock patches, boulders, and cobbles while Location 1 tended to be dominated by pebbles, with sporadic cobbles.

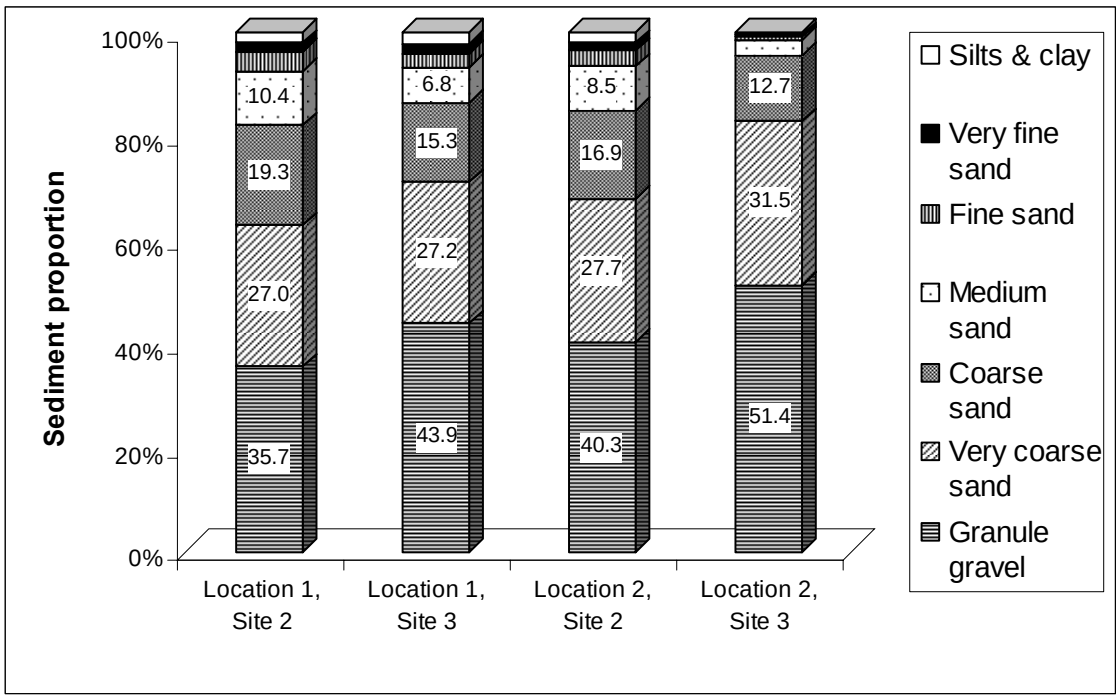

Figure 13. Mean particle size composition of streambed substrate (including organic components) after removal of larger sediments as indicated by core sampling. Sediment fractions are percentages of total dry weights. Size classes follow the Udden-Wentworth classification; silts & clay = <63µm, very fine sand = 63–124µm, fine sand = 125–249µm, medium sand = 250–499µm, coarse sand = 0.50–0.99mm, very coarse sand = 1.00–1.99mm, and granule gravel = 2.00–3.99mm). Small (<63µm) sediments were not rinsed from larger constituents, prior to analysis. Proportions <5% not labelled.

2.4.3 Physical and physico-chemical measurements

A NIWA rainfall gauge was located in the catchment (35° 46.03′ S, 174° 21.85′ E; 10m a.s.l.) and daily rainfall data were provided by the NIWA Climate Data Centre. Rainfall recorded in the Matapouri catchment during most months of 2005 was well below mean historical records (Figure 14). However, July recorded considerably more rainfall than mean historical records with 219.1mm (historical mean was 145.6mm).

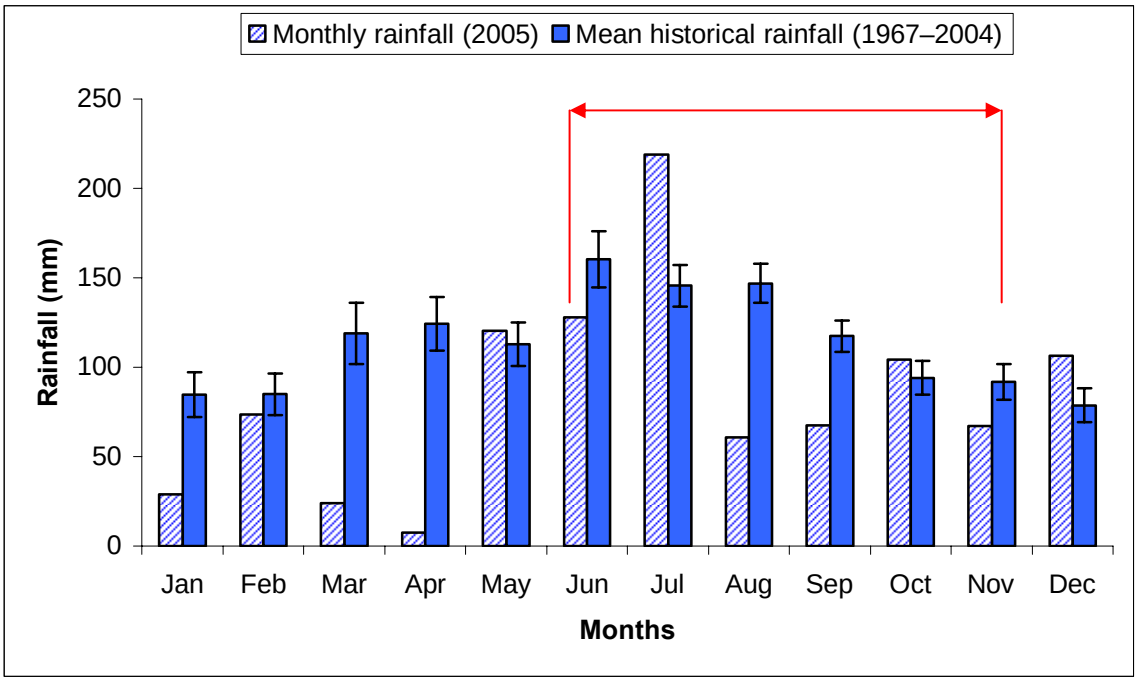

Figure 14. Monthly rainfall for the Matapouri catchment during 2005 and historical records (1967–2004) (error bars represent SEM). Red line indicates period of study.

Replicated (three) *in-situ* physico-chemical water 'spot readings' temperature (°C), pH, and TDS (ppm) were recorded from each site each month concurrently with benthic kick-samples, using a portable Extech EC500 Waterproof ExStik II pH/Conductivity Meter. TDS (ppm) values were standardized for water temperature by the meter and converted to conductivity (µS/cm) using a conversion table on return to the laboratory.

Dissolved oxygen (mg/L) was initially collected with a YSI-55 Dissolved Oxygen Meter. However, the meter was damaged so dissolved oxygen readings were discontinued as no other meter was available. All meters were calibrated in the laboratory before each dataset collection (or in the field in the case of the YSI-55).

Mean pH readings over the study period were relatively more acidic at Site 1 at both locations than all other sites, ranging from 6.2–6.9 for Location 1 and 6.8–7.6 for Location 2 (Figure 15). For Sites 2 and 3, at both locations, pH readings ranged from 7.2–7.9 during the study with mean pH values recorded just above neutral (~7.4).

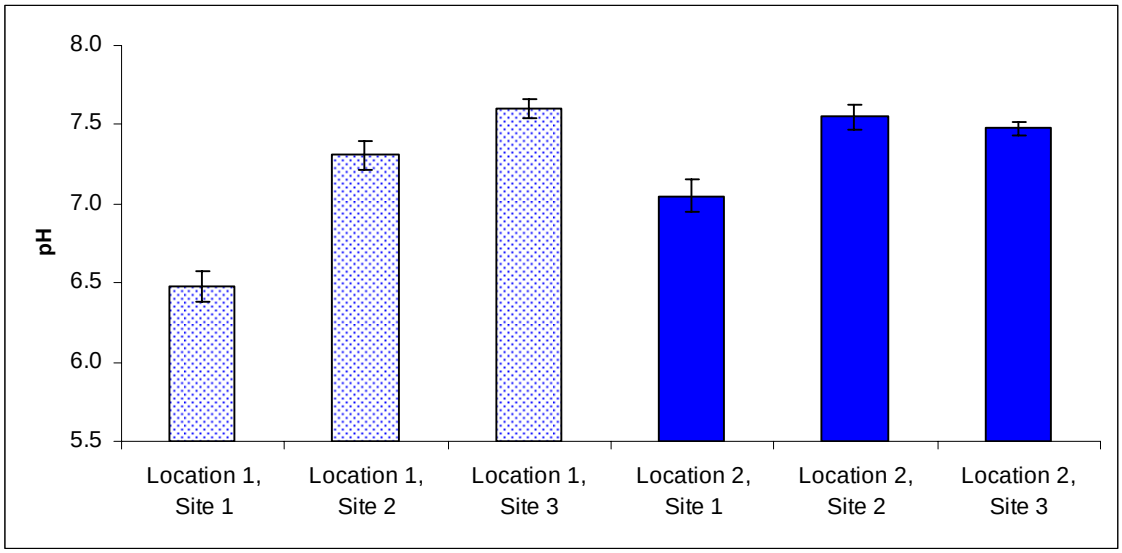

Figure 15. Mean *in-situ* pH readings of stream water from all sites within Locations 1 and 2.

Mean conductivity readings over the study period were relatively stable with little variation between sites or months, and little difference between locations (Figure 16). Location 2 recorded slightly higher conductivity readings ranging from 161–201 µS/cm (mean: 183 ± 2.7 µS/cm) while Location 1 readings ranged from 144–181 µS/cm (mean: 162 ± 2.5 µS/cm).

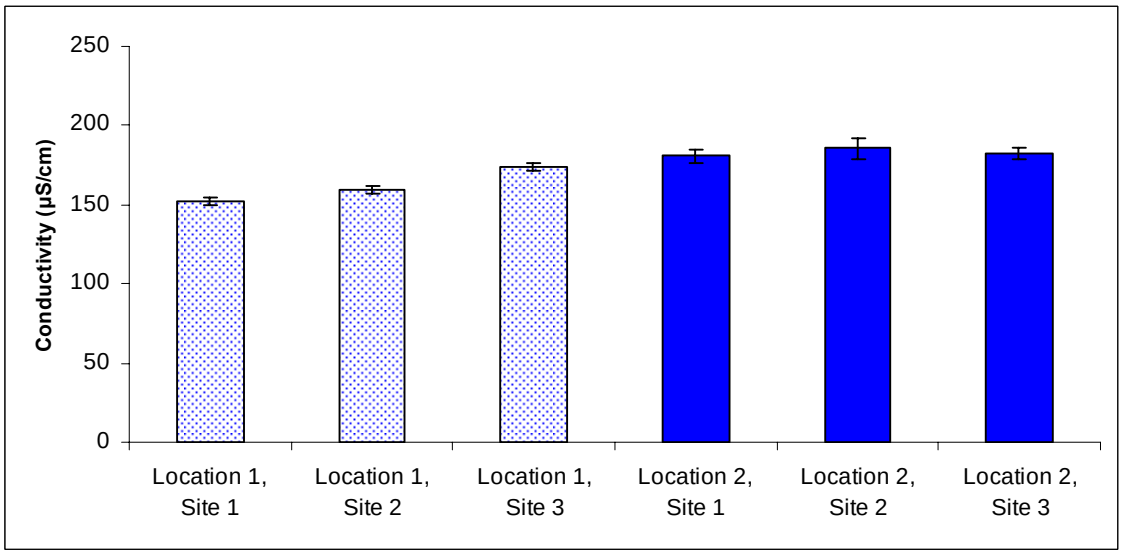

Figure 16. Mean *in-situ* conductivity readings (µS/cm) of stream water from all sites within Locations 1 and 2.

2.5 Conclusions

The catchment of Matapouri is reasonably representative of many of Northland's east coast catchments. Like the Matapouri catchment, most Northland catchments are small with rolling hills dominated by the same parent rock type, receive a moderate to high rainfall, and have an almost sub-tropical climate. Land use frequently consists of pockets of native forest in the headwaters, changing to pasture in the mid to lower catchments. Small coastal towns or rural communities are often present in the lower catchments.

Many of Northland's coastal townships have recently received a dramatic period of semi-urban development, and Matapouri is no exception. The lower catchment and township have undergone extensive land and infrastructure development in recent years, and the mid-catchment has been increasingly subjected to more intensive agricultural practices and exotic monoculture plantings. All these increasing pressures will be influencing the natural ecology of the resident flora and fauna.

In the case of Matapouri, only the headwaters of the upper catchment are currently free of the pressures of development, being protected by crown agency management and kaitiakitanga values of tangata whenua. These guardianship roles are expected to be upheld well into the future.

Chapter 3 – *An investigation of benthic invertebrate community compositions by kick-sampling*

3.1 Introduction

Analysing samples of aquatic invertebrates from the benthos of streams is an effective means of describing various ecological interactions of freshwater ecosystems. There are therefore many reasons why sampling of invertebrate communities would be undertaken. For example, aquatic invertebrates serve as good biological indicators of water quality (Rosenberg & Resh 1993) which can in-turn reflect ecosystem health, and direct future land use management. However, understanding a complete picture of ecosystem function through entire aquatic communities, and considering all known receiving pressures, is vital but often unachievable (Boothroyd & Stark 2000). The response is to focus on particular components of an ecosystem, or the factors that influence it.

The most important factors that may shape freshwater invertebrate communities include stream gradients, which influence water velocity and substrate particle size (Winterbourn 2004a), stream width which governs the potential of stream shading, and type and density of riparian vegetation, which controls the scale of shading, water temperatures, allochthonous input in forested streams, and light energy inputs in non-forested streams (Reeves *et al*. 2004). Other central factors that can affect community composition include climate and season (Hynes 1970a), water chemistry (e.g. pH, dissolved oxygen, suspended loads) (Davies-Colley & Wilcock 2004) and biological factors like predation or competition (McIntosh 2000, Winterbourn 2004a).

Three methods are commonly used for collecting benthic invertebrates (Winterbourn 1985b); Surber sampling (Surber 1937), kick-sampling (Frost *et al*. 1971), and individual stone sampling (Macan 1958). Surber sampling and individual stone sampling are used for collecting quantitative data, while kick-sampling is widely considered a convenient and effective semi-quantitative method. It is also one of the few methods available for sampling rocky and irregular sediments (Winterbourn 1985b).

Little research into invertebrate communities has been conducted in Northland streams (see Quinn & Hickey 1990a & b, Collier 1995, and Collier 2004) and there is no published research on freshwater invertebrate communities within Matapouri. In addition, no work has been conducted on seasonality patterns of invertebrate communities within Northland streams. Therefore, the aim of this study was to identify

the benthic freshwater invertebrate community composition, within two second order streams of the Matapouri. It was envisaged that the ecological information from this work would help local community to develop land management strategies within the catchment and provide important baseline data of the aquatic fauna.

3.2 Methods

3.2.1 Preliminary trials

On 20th March 2005 three replicate benthic core samples (150mm internal diameter; 120mm depth) were collected from three raupo habitats within the Matapouri catchment to test the logistics of the method. In the laboratory the samples were gently rinsed sequentially through a combination stack of 8mm, 2mm, and 0.5mm Endecotts sieves with water. The procedure was time consuming (up to 6 hours per replicate sample) and produced very few macroinvertebrates (1–12 individuals).

In addition, between 22–23 March 2005 collection of two samples were attempted to test the logistics of the method in three raupo habitats (n=6) by sweeping a D-net (Cuffney *et al*. 1993) through the water following the C2 protocol of Stark *et al*. (2001). This protocol was designed for sampling invertebrates of soft-bottomed streams and rivers, but was difficult to undertake in the raupo environment, and was destructive to the habitat. Consequently it was decided not to sample the raupo habitat for benthic invertebrates.

3.2.2 Sampling procedure

The kick-sampling technique of Frost *et al*. (1971) was selected as the preferred sampling method (as apposed to Surber or individual stone sampling) as:

- it required less equipment in the field
- it was easier to carry out in the headwater study locations
- it collected from a larger area of streambed
- composite samples from multiple microhabitats were easily collected and pooled, and
- fewer samples were required to produce accurate data

Three replicate benthic invertebrate kick-samples (each $1m^2$) were collected each month from June–November 2005, from two habitat types (Forest and Forest-fringe) at two separate locations (Figure 6). Raupo habitats were not sampled for benthic invertebrates for logistical reasons discussed in the preliminary trials section of this chapter. A minimum number of replicate kick-samples were collected to minimise time constraints associated with invertebrate processing and identification. However, each replicate was pooled from sub-replicates taken from a range of riffle microhabitats, to increase the area of streambed sampled; effectively increasing the fauna catch, without excessive replication.

Frequent sampling at a particular site is reported to alter habitat to a point where the community structure differs from the surrounding habitats (Frost *et al*. 1971). To minimise this possibility a monthly data collection schedule was formulated, so impact would be low, but frequent enough to record community changes throughout the study period. In addition, monthly collection would increase the accuracy of faunal records through temporal replication. A complete list of sampling dates is tabled in Appendix 5.

Benthic invertebrate kick-samples were collected following the protocols of Stark *et al*. (2001) from riffle stream sections using a handheld D-net, 400mm at the base, with 250µm mesh (500mm deep). Five ten-second $0.2m^2$ (0.4m x 0.5m) sub-replicate kick-samples were pooled to produce each replicate. Kicking of consistent effort (by the same collector each time) was used to disrupt the substrate to a depth of 60–100mm displacing epigean and hypogean taxa from a range of spatial microhabitats within 50–60m reaches. Invertebrates gently washed into the D-net with natural stream flow. Each sub-sample was taken while moving progressively upstream to avoid unnecessary sampling error.

Specimens were collected under special permit 307 issued by the Ministry of Fisheries (Client Number 9791209) and pursuant to section 97(1)(a)(i) and (ii) of the New Zealand Fisheries Act (1996).

Samples were anaesthetised in the field with 30% ethanol overnight, and then preserved with 75% ethanol on return to the laboratory while awaiting processing.

3.2.3 Processing and identification

In the laboratory samples were processed following the P3 protocol of Stark *et al*. (2001). Specifically, samples were gently rinsed through a combination stack of 4mm and 250µm Endecotts sieves to remove ethanol preservative, FPOM, and fine sediments. Samples were placed on a white sorting tray (with 50mm grid) and invertebrates systematically picked from the CPOM and remaining sediments under a Superlux LSX magnifier (3 dioptre magnification, T9 22 watt circular fluorescent lamp), and preserved in 75% ethanol ready for identification. Adult specimens, pupae, exuviae, empty shells (Mollusca), and empty cases (Trichoptera) were not recorded.

Invertebrates were identified under a Saxon dissecting microscope (10–40x) using descriptions and/or keys of Winterbourn *et al*. (2006), McFarlane (1990), Cowley (1978), Rowe (1987), Smith & Ward (in prep), Towns & Peters (1996), Winterbourn (1973), Ordish (1984), Chapman & Lewis (1976), and Anderson (2005). Gordh & Headrick (2005) was used for assistance with entomological terms. Owing to taxonomic difficulties and limited financial resources, not all specimens were identified to species.

All taxa were allocated functional feeding groups after Cowie (1980) and Rounick *et al*. (1982) to allow evaluation of functional attributes (based on food acquisition) within the community (Cummins & Klug 1979). Designations were assigned following cited literature i.e. Cowley (1978), Cowie (1980), Rounick *et al*. (1982), Winterbourn *et al*. (1984), Linklater (1995), Winterbourn (2000b), Thompson & Townsend (2003), and Winterbourn *et al*. (2006) and approximations were made for the few taxa that no reported feeding group could be found. For taxa that were acknowledged to be opportunistic feeders (Anderson & Sedell 1979) resulting from food availability, or a change in feeding mode with increased size, the principal feeding group was identified.

It was observed that there were several species of some taxa present (i.e. *Deleatidium*, *Zephlebia* and *Hydrobiosis*). However, these were not differentiated owing to time constraints and inexperience. Early instars and damaged specimens that were unable to be identified were either omitted or placed into the most germane taxon.

3.2.4 Specimen vouchers

A voucher specimen collection was constructed to facilitate identification efforts, and to aid future taxonomic studies. Benthic voucher specimens were confirmed by Brian Smith (NIWA, Hamilton), Dr Ian Boothroyd (Kingett Mitchell), Stephen Moore (Landcare Research, Auckland), Paul Lambert (NIWA, Greymouth), Dr Richard Leschen (Landcare Research, Auckland), and Dr Gary Barker (Landcare Research, Hamilton), and were preserved (75% ethanol) and catalogued following Walker & Crosby (1988), and stored at NorthTec Environmental Sciences in Whangarei.

3.2.5 Statistical analysis

Taxonomic richness and total abundance were measured as the total number of taxa and total number individuals recorded/m^2, from each replicate, at each site. All invertebrate records were entered into Microsoft Office Excel 2003 and analysed using the statistical software SigmaStat 3.5.

To compare overall benthic invertebrate abundance between the two locations, a Kruskal-Wallis One-way Analysis of Variance on Ranks was preformed, while *F*-tests, normality tests, and Student *t*-tests were used to test for sample variance, normality, and significance. Data that were found to violate the assumptions of normality were analysed using non-parametric Mann-Whitney Rank Sum *U*-tests. Alpha limits of significance for Mann-Whitney Rank Sum *U*-tests were set at <0.033 after allowing for correction of alpha using the false discovery rate control for m independent tests.

The Shannon-Weiner Diversity Index (H') (Shannon & Weaver 1949), which takes into account the numbers of organisms of each taxon, was used to calculate community diversity; the value being calculated from the equation:

$$H' = - \sum p_i \ln p_i$$

where H' is the diversity index and p_i is the proportion of the i-th taxon in the population. In addition, the Shannon-Weiner Equitability Index (E_H), which measures evenness of taxa in the population, was calculated from the equation:

$$E_H = H' / H_{max} = H' / \ln S$$

3.3 Results

3.3.1 Occurrence and abundance of taxa

A total of 7,814 aquatic invertebrates, comprising 71 taxa, were recorded from the benthos of streams draining the Matapouri catchment (Appendix 6). A Kruskal-Wallis One-way Analysis of Variance on Ranks resulted in no significant difference in the mean abundances of all taxa between Locations 1 and 2.

Abundances of all individual taxa were compared between sites and between locations using Mann-Whitney Rank Sum *U*-tests (Table 3). Platyhelminthes were present in moderate[7] numbers and Oligochaeta and Acari in low numbers at all sites, at both locations, but no differences were statistically significant. A single Collembola (Arthropleona) was recorded from Location 2 at Site 2.

Three gastropod taxa were recorded during the study. *Ferrissia dohrnianus* (Ancylidae) was present in low numbers at all sites at both locations, and was significantly (P = 0.015) more abundant in Location 2. *Potamopyrgus antipodarum* (Hydrobiidae) was present in moderate numbers at all sites at both locations, and was significantly (P = 0.026) more abundant at Site 3 than Site 2 in Location 1. Although there were considerably more individuals recorded in Location 2 than Location 1, this difference was not significant. A single individual *Lymnaea* sp. (Lymnaeidae) was recorded from Location 1 at Site 2.

Four crustacean taxa were recorded during the study; all in very low numbers. *Paratya curvirostris* (Atyidae) was present at all sites at both locations, while taxa from Amphipoda and Ostracoda were present only at some sites, at both locations. *Paranephrops planifrons* (Parastacidae) was present at both locations, but were only recorded at Site 2.

Of the ten ephemeropteran taxa recorded during the study, *Ameletopsis perscitus* (Ameletopsidae) was only recorded in low numbers at Site 2, Location 1, while *Isothraulus abditus* (Leptophlebiidae) was only recorded at both sites at Location 2, in very low numbers. *Coloburiscus humeralis* (Coloburiscidae) was more common at Site

[7] Very low numbers were considered <3, low numbers were considered 3–24, moderate numbers were considered ~25–150, high numbers were considered >150.

3 than Site 2 at both locations though these differences were not significant. *Ichthybotus hudsoni* (Ichthybotidae) was present in low numbers at all sites at both locations. The Leptophlebiidae species *Acanthophlebia cruentata*, *Atalophlebioides cromwelli*, *Deleatidium* spp., *Mauiulus luma*, *Neozephlebia scita*, and *Zephlebia* spp. were all recorded in moderate to high abundances. For all these taxa, there was a trend of greater abundance at Site 2 at Location 1 and Site 3 at Location 2, but the differences were only significant for *Neozephlebia scita* and *Zephlebia* spp. between Sites 2 and 3 at Location 2 ($P = 0.015$ and $P = 0.002$ respectively). Furthermore, for all these taxa there was a trend of greater abundance at Location 2 than Location 1, though only *Mauiulus luma*, *Neozephlebia scita*, and *Zephlebia* spp. were significant ($P = 0.015$, $P = 0.015$, and $P = 0.009$ respectively).

Five plecopteran genera from all four New Zealand families were recorded. *Austroperla cyrene* (Austroperlidae) and *Zelandoperla* sp. (Gripopterygidae) were recorded in moderate numbers, and *Stenoperla prasina* (Eustheniidae) in low numbers, at both sites at both locations. There were no significant differences in abundance between sites for these taxa, however there were significantly more *A. cyrene* recorded at Location 2 ($P = 0.009$). *Spaniocerca zelandica* (Notonemouridae) were recorded in low numbers in Site 3 of both Locations, in moderate numbers at Site 2 of Location 2, but were absent from Site 2 of Location 1. Considerably more *S. zelandica* were recorded from Location 2 than Location 1 however this difference was not statistically significant. *Spaniocercoides watti* (Notonemouridae) was only recorded at Site 2 at Location 2, in very low numbers.

One species of Odonata, *Antipodochlora braueri* (Corduliidae), was recorded in low numbers from both sites at Location 1, but absent from Location 2, and a single species, *Microvelia macgregori* (Veliidae), from the order Hemiptera was recorded in very low numbers, and only from Site 2 at Location 2. The megalopteran *Archichauliodes diversus* (Corydalidae) was recorded in moderate to high numbers at all sites at both locations, though there were no significant differences in abundance between sites or betweens locations.

Taxa from six aquatic families of the order Coleoptera were recorded. Adults and larvae of *Hydora* sp. (Elmidae) were recorded in moderate numbers from sites within Location 1 and low numbers from sites within Location 2. There were no significant differences

in abundances between sites however there were significantly more recorded at Location 1 than Location 2 ($P = 0.004$). Adults of *Homalaena* sp. (Hydraenidae) and larvae of *Byrrhocryptus urquharti* (Ptilodactylidae) were recorded in low numbers from all sites at both locations while Hydrophilidae and Scirtidae larvae and Staphylinidae adults were recorded in very low numbers at most sites at both locations. For all Hydraenidae, Hydrophilidae, Ptilodactylidae, Scirtidae, and Staphylinidae taxa there appeared to be a trend of higher abundance in Location 1 than Location 2, though no differences were significant. Furthermore, an unidentified larva, suspected to be a terrestrial addition from the family Elateridae, was recorded from Site 3 at Location 2.

Sixteen dipteran taxa from eleven families were recorded. Taxa from Chironominae, Orthocladiinae, and Tanypodinae (all Chironomidae), together with *Austrosimulium* sp. (Simuliidae), were recorded at all sites at both locations in moderate numbers. Ceratopogonidae, *Nothodixa* sp. and *Paradixa* sp. (both Dixidae), Tabanidae, and Eriopterini (Tipulidae) were recorded at all sites at both locations in low numbers. Hexatomini (Tipulidae) was recorded in low numbers in Location 1 but not recorded in Location 2, while Empididae was recorded in very low numbers at both locations. Single individuals of *Harrisius pallidus* (Chironomidae), Muscidae, and Psychodidae were recorded at Location 2, while single individuals of Stratiomyidae and *Mischoderus* sp. (Tanyderidae) were recorded at Location 1. No significant differences in abundances were recorded for any dipteran taxa between sites or between locations although there were trends of greater abundance at Location 2 than Location 1 for the Chironomidae taxa Chironominae, Orthocladiinae, and Tanypodinae, and the Dixidae taxa *Nothodixa* sp. and *Paradixa* sp..

Nineteen trichopteran taxa from ten families were also recorded. *Olinga* spp. (Conoesucidae) were recorded at all sites at both locations in high numbers, and were the most numerically dominant invertebrate in the study. *Pycnocentria evecta* (Conoesucidae), *Helicopsyche* spp. (Helicopsychidae), *Hydrobiosis* spp., *Hydrochorema crassicaudatum*, and *Psilochorema macroharpax* (all Hydrobiosidae), *Orthopsyche fimbriata* and *Orthopsyche thomasi* (both Hydropsychidae), and *Hydrobiosella mixta* (Philopotamidae) were recorded at all sites at both locations in moderate numbers. *Psilochorema mimicum* (Hydrobiosidae), *Hudsonema amabile* (Leptoceridae), and *Oeconesus maori* (Oeconesidae) were recorded at most sites at both locations in low numbers while single individuals of *Pycnocentria sylvestris*

(Conoesucidae) were recorded at both locations. *Pycnocentrodes aureolus* (Conoesucidae), *Psilochorema donaldsoni* (Hydrobiosidae), an early-instar Hydroptilidae, and *Zelandoptila moselyi* (Psychomyiidae) were recorded in very low numbers and at Location 1 only, while a single individual of *Triplectides* sp. (Leptoceridae) and low numbers of *Polyplectropus altera* (Polycentropodidae) were recorded from Location 2 only. No significant differences in abundances were recorded for any trichopteran taxa between sites or between locations although there were trends of greater abundance at Location 1 than Location 2 for *Olinga* spp., *Helicopsyche* spp., *Orthopsyche fimbriata*, and *Hydrobiosella mixta*.

When looking at mean abundance of individual taxa throughout the study, the majority of taxa were recorded in low numbers and temporal trends were meaningless. For those taxa which were present in reasonable numbers, very few temporal trends were apparent (Figure 17). Orthocladiinae, *Austrosimulium* sp., *Hydrobiosis* spp., *Psilochorema macroharpax*, and *Olinga* spp. appeared to increase in numbers throughout the study, at both locations (particularly in November). Platyhelminthes appeared to increase in Location 2 only, and *Helicopsyche* spp. and *Orthopsyche fimbriata* in Location 1 only. *Mauiulus luma* was the only taxon to display an obvious decrease in numbers; this decrease was observed at both locations.

Table 3. Abundances of taxa recorded from June–November 2005 from Sites 2 and 3 at Locations 1 and 2, with P-values of differences in abundance between sites, and between locations and the principal functional feeding groups Predators (P), Collector-Browsers (C-B), Shredders (S), and Filterers (F). Abundances were pooled from three replicates over six (monthly) sampling events. Significant values are indicated in **bold**.

				Location 1			Location 2					
Phylum/Class/Order	**Family**	**Most specific taxon[8]**	**Functional feeding group (FFG)[9]**	**Site 2 (Forest-fringe) n=3**	**Site 3 (Forest) n=3**	**P-value[10]**	**Site 2 (Forest-fringe) n=3**	**Site 3 (Forest) n=3**	**P-value[10]**	**Location 1 n=6**	**Location 2 n=6**	**P-value[10]**
PLATYHELMINTHES			C-B	13	18	0.589	33	11	0.180	31	44	0.818
ANNELIDA												
OLIGOCHAETA			C-B	3	2	0.699	11	8	0.485	5	19	0.699
MOLLUSCA												
GASTROPODA	Ancylidae	*Ferrissia dohrnianus*	C-B	1	5	0.310	8	17	0.093	6	25	**0.015**
	Hydrobiidae	*Potamopyrgus antipodarum*	C-B	13	64	**0.026**	80	97	0.589	77	177	0.180
	Lymnaeidae	*Lymnaea* sp.	C-B	1	0	0.699	0	0	1.000	1	0	0.699
ARTHROPODA												
CRUSTACEA: Amphipoda			C-B	0	0	1.000	0	2	0.394	0	2	0.394
CRUSTACEA: Decapoda	Atyidae	*Paratya curvirostris*	S	1	7	0.937	2	8	0.937	8	10	0.937
	Parastacidae	*Paranephrops planifrons*	C-B	1	0	0.699	1	0	0.699	1	1	1.000
CRUSTACEA: OSTRACODA			C-B	0	1	0.699	1	2	0.937	1	3	0.589
ARACHNIDA: Acari			P	11	5	0.394	3	6	0.699	16	9	0.240
COLLEMBOLA: Arthropleona			C-B	0	0	1.000	1	0	0.699	0	1	0.699
INSECTA: Ephemeroptera	Ameletopsidae	*Ameletopsis perscitus*	P	13	0	0.180	0	0	1.000	13	0	0.180
	Coloburiscidae	*Coloburiscus humeralis*	F	77	129	0.065	49	129	0.093	206	178	0.485
	Ichthybotidae	*Ichthybotus hudsoni*	F	3	4	0.937	4	9	0.180	7	13	0.240
	Leptophlebiidae	*Acanthophlebia cruentata*	C-B	63	48	0.394	68	143	0.394	111	211	0.699
		Atalophlebioides cromwelli	C-B	43	26	0.699	58	105	0.310	69	163	0.065
		Deleatidium spp.	C-B	91	19	0.041	78	85	0.699	110	163	0.240
		Isothraulus abditus	C-B	0	0	1.000	2	1	0.937	0	3	0.699
		Mauiulus luma	C-B	178	178	0.937	253	683	0.065	356	936	**0.015**
		Neozephlebia scita	C-B	6	5	0.818	9	49	**0.015**	11	58	**0.015**
		Zephlebia spp.	C-B	105	75	0.485	73	297	**0.002**	180	370	**0.009**
INSECTA: Odonata	Corduliidae	*Antipodochlora braueri*	P	5	4	0.818	0	0	1.000	9	0	0.394
INSECTA: Plecoptera	Austroperlidae	*Austroperla cyrene*	S	10	22	0.485	46	45	0.818	32	91	**0.009**
	Eustheniidae	*Stenoperla prasina*	P	10	6	0.310	9	8	0.699	16	17	0.937
	Gripopterygidae	*Zelandoperla* sp.	S	13	9	0.394	26	19	0.818	22	45	0.180
	Notonemouridae	*Spaniocerca zelandica*	C-B	0	2	0.394	23	8	0.485	2	31	0.132
		Spaniocercoides watti	C-B	0	0	1.000	2	0	0.699	0	2	0.699
INSECTA: Hemiptera	Veliidae	*Microvelia macgregori*	P	0	0	1.000	2	0	0.394	0	2	0.394
INSECTA: Megaloptera	Corydalidae	*Archichauliodes diversus*	P	140	81	0.093	94	95	0.818	221	189	0.699
INSECTA: Coleoptera	Elmidae	*Hydora* sp. (adults & larvae)	C-B	100	54	0.310	12	7	0.818	154	19	**0.004**
	Hydraenidae	*Homalaena* sp.(adults)	C-B	14	7	0.589	4	1	0.310	21	5	0.065
	Hydrophilidae		C-B	2	1	0.699	0	1	0.699	3	1	0.394
	Ptilodactylidae	*Byrrhocryptus urquharti*	C-B	10	13	0.937	9	7	0.818	23	16	0.485
	Scirtidae		S	7	0	0.394	1	1	1.000	7	2	0.937
	Staphylinidae (adults)		P	0	2	0.699	1	3	0.589	2	4	0.699
	Unidentified larva 1		C-B	0	0	1.000	0	1	0.699	0	1	1.000
INSECTA: Diptera	Ceratopogonidae		P	0	2	0.394	1	4	0.310	2	5	0.485
	Chironomidae	Chironominae	C-B	16	28	1.000	58	17	0.818	44	75	0.699
		Harrisius pallidus	C-B	0	0	1.000	0	1	0.699	0	1	0.699
		Orthocladiinae	C-B	66	73	0.589	121	64	0.485	139	185	0.485
		Tanypodinae	C-B	14	21	0.699	26	21	0.589	35	47	0.485
	Dixidae	*Nothodixa* sp.	F	2	4	0.589	7	10	0.485	6	17	0.180
		Paradixa sp.	F	1	5	0.589	14	9	0.937	6	23	0.818
	Empididae		P	2	0	0.699	1	0	0.699	2	1	0.937
	Muscidae		C-B	0	0	1.000	1	0	0.699	0	1	0.699
	Psychodidae		C-B	0	0	1.000	0	1	0.699	0	1	0.699
	Simuliidae	*Austrosimulium* sp.	F	23	22	0.818	32	18	0.394	45	50	0.937
	Stratiomyidae		C-B	0	1	0.699	0	0	1.000	1	0	0.699
	Tabanidae		P	3	1	0.589	1	3	0.589	4	4	0.818
	Tanyderidae	*Mischoderus* sp.	C-B	0	1	0.699	0	0	1.000	1	0	0.699
	Tipulidae	Eriopterini	C-B	6	2	0.818	7	4	0.485	8	11	0.589
		Hexatomini	P	4	1	0.589	0	0	1.000	5	0	0.394
INSECTA: Trichoptera	Conoesucidae	*Olinga* spp.	S	530	352	0.485	281	403	0.394	882	684	0.485
		Pycnocentria evecta	S	20	53	0.041	42	40	0.937	73	82	0.818
		Pycnocentria sylvestris	S	0	1	0.699	1	0	0.699	1	1	1.000
		Pycnocentrodes aureolus	C-B	2	0	0.699	0	0	1.000	2	0	0.699
	Helicopsychidae	*Helicopsyche* spp.	C-B	53	43	0.485	35	16	0.132	96	51	0.065
	Hydrobiosidae	*Hydrobiosis* spp.	P	13	10	0.818	13	20	0.240	23	33	0.240
		Hydrochorema crassicaudatum	P	3	2	0.485	3	4	0.937	5	7	0.818
		Psilochorema donaldsoni	P	3	0	0.699	0	0	1.000	3	0	0.699
		Psilochorema macroharpax	P	17	22	1.000	33	26	0.699	39	59	0.818
		Psilochorema mimicum	P	2	1	0.699	0	9	0.180	3	9	0.699
	Hydropsychidae	*Orthopsyche fimbriata*	C-B	48	62	0.818	31	28	0.699	110	59	0.240
		Orthopsyche thomasi	C-B	49	62	0.699	49	63	0.937	111	112	0.589
	Hydroptilidae	Early instar	C-B	1	0	0.699	0	0	1.000	1	0	0.699
	Leptoceridae	*Hudsonema amabile*	P	1	0	0.699	0	1	0.699	1	1	1.000
		Triplectides sp.	S	0	0	1.000	0	1	0.699	0	1	0.699
	Oeconesidae	*Oeconesus maori*	S	2	0	0.394	1	1	1.000	2	2	1.000
	Philopotamidae	*Hydrobiosella mixta*	C-B	19	43	0.485	9	29	0.093	62	38	0.589
	Polycentropodidae	*Polyplectropus altera*	P	0	0	1.000	2	7	0.485	0	9	0.180
	Psychomyiidae[11]	*Zelandoptila moselyi*	P	0	1	0.699	0	0	1.000	1	0	0.699

[8] All individuals were larvae or nymphs unless otherwise stated.
[9] It is acknowledged that many of New Zealand's invertebrates are opportunists or generalists depending on the size or type of individual, food item availability, and locality, thus can be classified in multiple FFG's. For the purposes of this study the principal FFG is recorded.
[10] Probability values calculated using Mann-Whitney Rank Sum *U*-tests. Probability values <0.033 were treated as significant after allowing for correction of alpha adjusted for m independent tests using the false discovery rate control.
[11] *Zelandoptila moselyi* is currently placed in the family Psychomyiidae however based on a current revision of the species it is believed to belong in the family Ecnomidae (Brian Smith, NIWA Hamilton, pers. comm. 11/06/07).

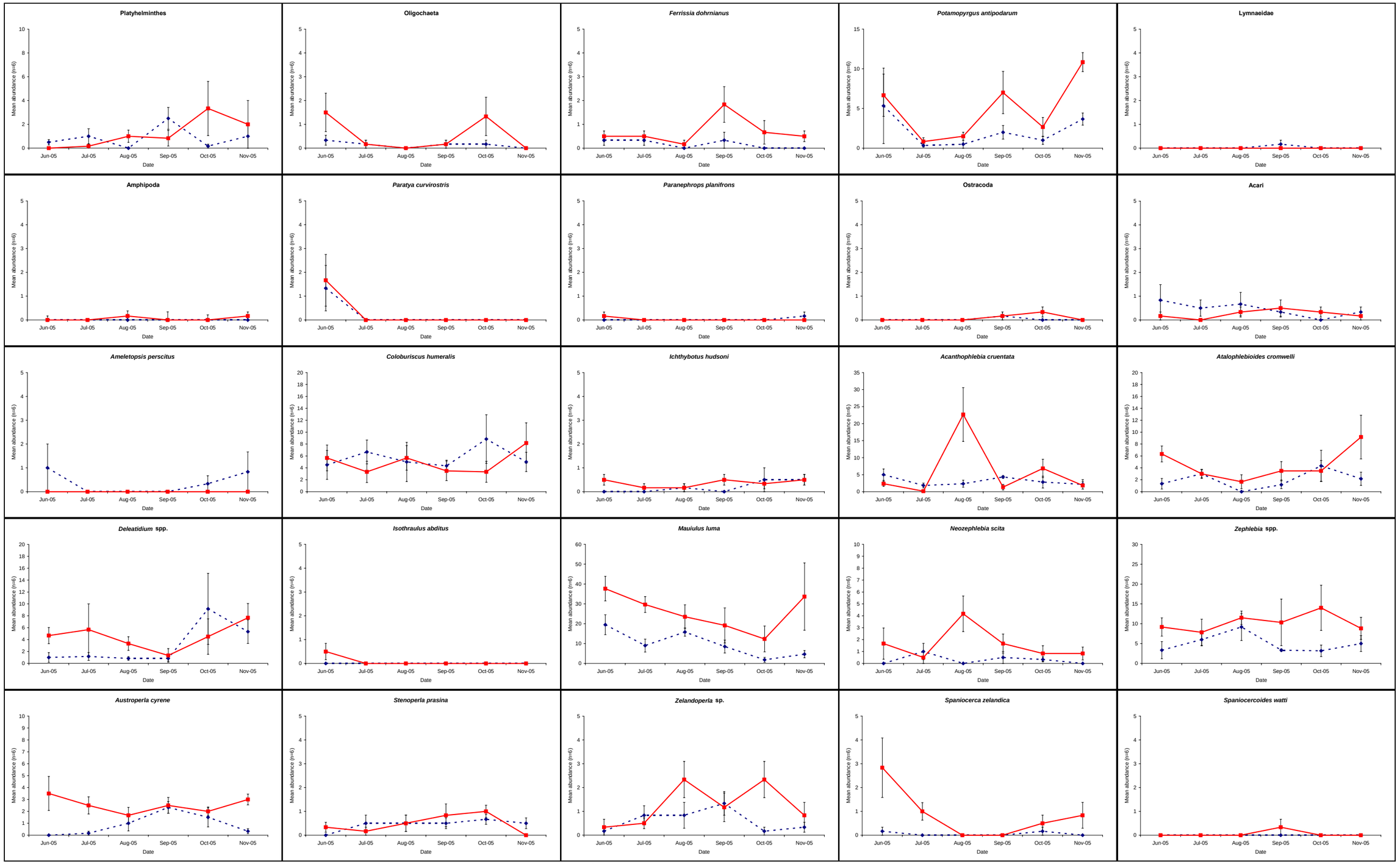

Figure 17. Mean abundance of taxa over time (error bars represent SEM). Blue dashed lines indicate Location 1 and orange solid lines indicate Location 2.

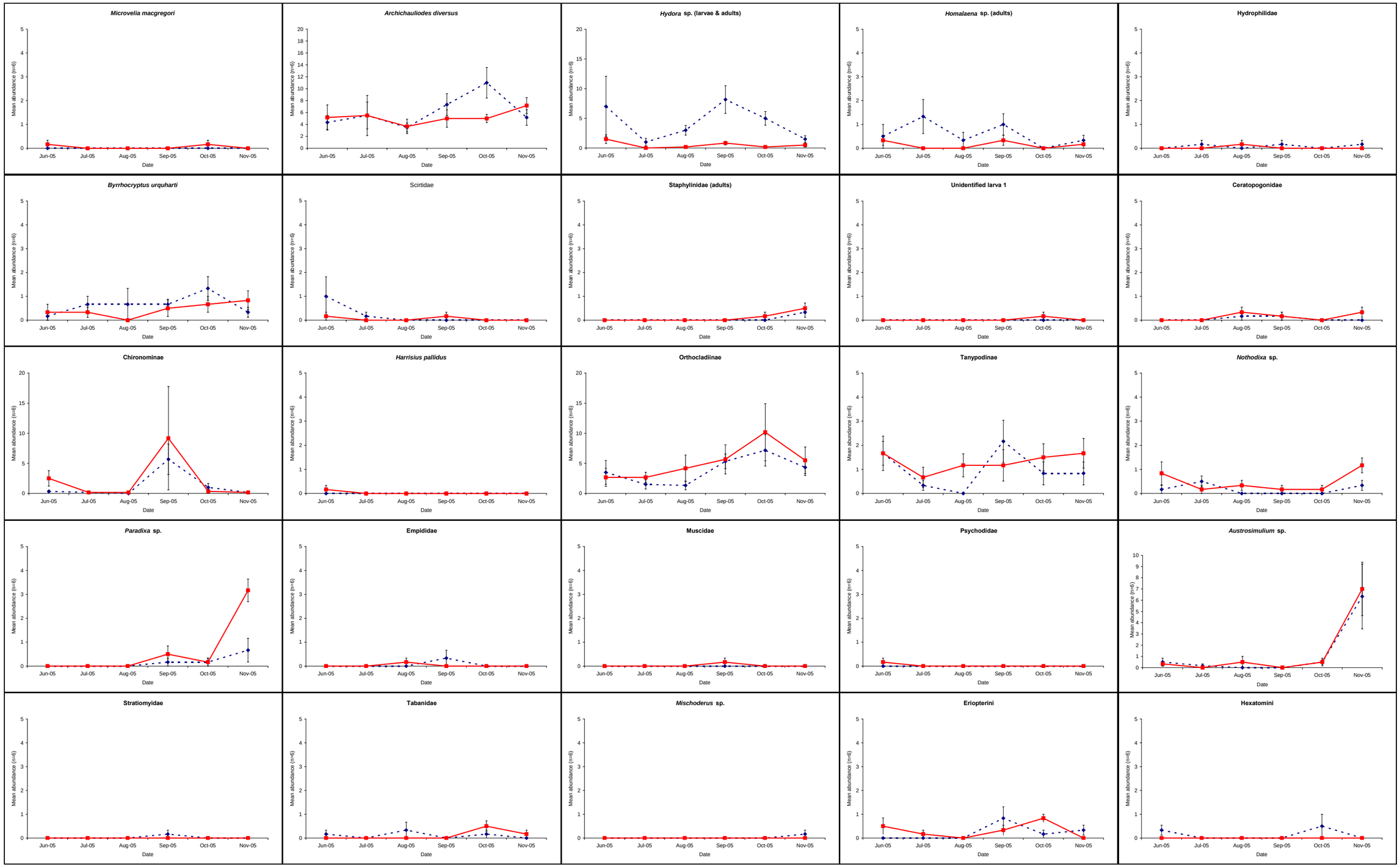

Figure 17 continued. Mean abundance of taxa over time (error bars represent SEM). Blue dashed lines indicate Location 1 and orange solid lines indicate Location 2.

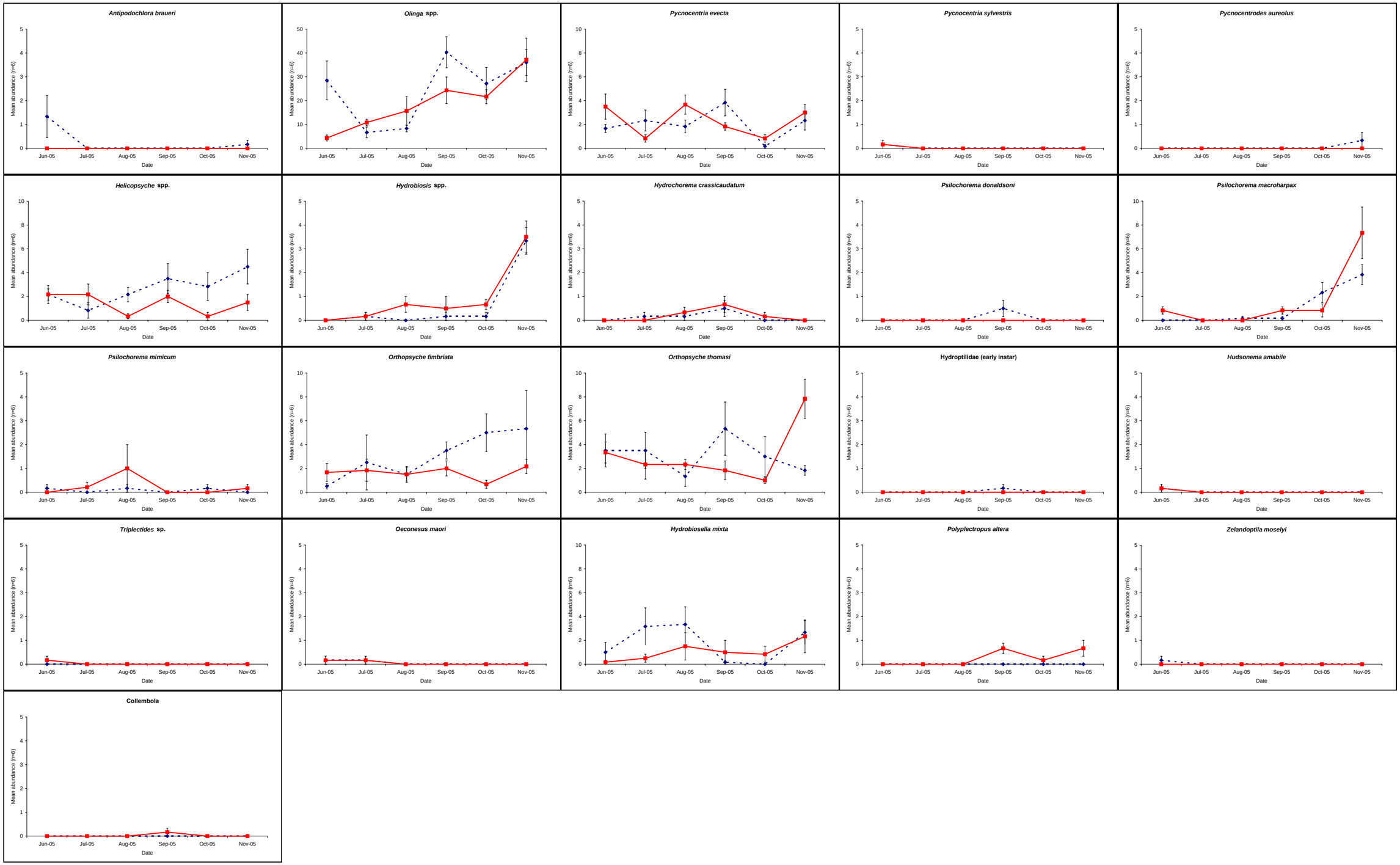

Figure 17 continued. Mean abundance of taxa over time (error bars represent SEM). Blue dashed lines indicate Location 1 and orange solid lines indicate Location 2.

3.3.2 Differences in taxonomic richness

At all sites per month throughout the sampling period taxonomic richness ranged from 22–40 taxa (Table 4). When sites within the locations were combined, taxonomic richness ranged from 27–44 taxa per month.

At Location 1, mean taxonomic richness for the six month period was 29.2 at Site 2 and 28.3 at Site 3. A *t*-test showed no significant difference in taxonomic richness between the 2 habitats ($t = 0.312$, d.f. = 10, $P = 0.762$). At Location 2, mean taxonomic richness for the six month period was 30.3 at the Site 2 and 33.0 at Site 3. A *t*-test showed no significant difference in taxonomic richness between the two habitats ($t = -0.847$, d.f. = 10, $P = 0.417$). There was a mean of 36 taxa at Location 1 and 39 at Location 2 however this difference was also not significant ($t = -1.074$, d.f. = 10, $P = 0.308$).

When looking at temporal taxonomic richness (June–November 2005) there appeared to be a decline at most sites, and subsequently both locations, during July and August. In addition, Site 2 at both locations also recorded a decline in taxa during October.

Table 4. Taxonomic richness recorded from sites and locations between June–November 2005.

	Location 1		**Location 2**			
2005	**Site 2 (Forest-fringe) (n=3)**	**Site 3 (Forest) (n=3)**	**Site 2 (Forest-fringe) (n=3)**	**Site 3 (Forest) (n=3)**	**Location 1 (n=6)**	**Location 2 (n=6)**
June	32	31	34	38	39	44
July	32	23	29	22	35	32
Aug	22	22	25	31	27	35
Sep	33	32	36	33	41	42
Oct	25	29	26	40	35	42
Nov	31	33	32	34	39	39
Mean (SE)	29.2 (1.9)	28.3 (1.9)	30.3 (1.8)	33.0 (2.6)	36.0 (2.0)	39.0 (1.9)

3.3.3 Differences in invertebrate abundance

Within each month, abundances of all invertebrate taxa at both Sites 2 and 3 within Location 1 ranged from 171–387 and at Location 2 from 193–688 (Table 5). When sites within the locations were combined, abundances ranged from 378–1098 individuals per month.

Mean monthly abundances over the sampling period were 305.7 and 266.7 at Sites 2 and 3 respectively in Location 1 and 288.7 and 441.3 at Sites 2 and 3 respectively at Location 2. There was no significant difference in taxonomic abundance between sites at Location 1 (t = 0.824, d.f. = 10, P = 0.429), but there was a significant difference between sites at Location 2 (t = -2.317, d.f. = 10, P = 0.043). When the sites within each location (1 and 2) were combined, a mean of 572.3 and 730.0 individuals were recorded respectively, the difference not being significant (t = -1.558, d.f. = 10, P = 0.150).

When looking at temporal abundances (June–November 2005) there appeared to be a decline at all sites, and subsequently both locations, during July. Relatively lower abundances were also recorded during August at Location 1, and Site 2 of Location 2.

Table 5. Abundances of benthic invertebrates recorded from sites and locations between June–November 2005.

	Location 1		**Location 2**			
2005	**Site 2 (Forest-fringe) (n=3)**	**Site 3 (Forest) (n=3)**	**Site 2 (Forest-fringe) (n=3)**	**Site 3 (Forest) (n=3)**	**Location 1 (n=6)**	**Location 2 (n=6)**
June	335	288	368	348	623	716
July	207	171	229	281	378	510
Aug	179	212	265	444	391	709
Sept	385	354	267	433	739	700
Oct	387	236	193	454	623	647
Nov	341	339	410	688	680	1098
Mean (SE)	305.7 (36.9)	266.7 (29.7)	288.7 (34.0)	441.3 (56.4)	572.3 (62.0)	730.0 (80.1)

3.3.4 Shannon-Weiner Diversity indices

Monthly Shannon-Weiner Diversity indices at individual sites ranged from 2.387–2.911 at Location 1 and from 2.234–2.838 at Location 2 (Table 6). When sites within the two locations were combined, indices ranged from 2.407–2.926.

Mean index values over the sampling period were 2.572 and 2.665 at Sites 2 and 3 respectively at Location 1 and 2.588 and 2.559 at Sites 2 and 3 respectively at Location 2. There were no significant differences in index values between the sites at either location (t = -1.028, d.f. = 10, P = 0.328 and t = 0.276, d.f. = 10, P = 0.788 respectively). When the two sites within each location were combined, mean index values of 2.719 and 2.725 were recorded, the differences not being significant (t = 0.276, d.f. = 10, P = 0.952).

No discernable temporal patterns in Shannon-Weiner Diversity indices were observed over the study period, though high outliers in Location 1 and low outliers in Location 2 were recorded in July 2005.

Table 6. Shannon-Weiner diversity indices recorded from sites and locations between June–November 2005.

	Location 1		**Location 2**			
2005	**Site 2 (Forest-fringe) (n=3)**	**Site 3 (Forest) (n=3)**	**Site 2 (Forest-fringe) (n=3)**	**Site 3 (Forest) (n=3)**	**Location 1 (n=6)**	**Location 2 (n=6)**
June	2.387	2.606	2.709	2.668	2.635	2.810
July	2.911	2.636	2.416	2.234	2.926	2.407
Aug	2.416	2.557	2.579	2.557	2.584	2.621
Sept	2.501	2.813	2.661	2.552	2.711	2.845
Oct	2.494	2.692	2.329	2.789	2.679	2.841
Nov	2.721	2.683	2.838	2.553	2.781	2.823
Mean (SE)	2.572 (0.083)	2.665 (0.036)	2.588 (0.077)	2.559 (0.075)	2.719 (0.050)	2.725 (0.072)

3.3.5 Shannon-Weiner Equitability indices

Monthly equitability indices at individual sites ranged from 0.075–0.116 at Location 1 and from 0.070–0.103 at Location 2 (Table 7). When sites within the locations were combined, equitability values ranged from 0.064–0.096.

Mean equitability values over the sampling period were 0.090 and 0.096 at Sites 2 and 3 respectively at Location 1 and 0.086 and 0.079 at Sites 2 and 3 respectively at Location 2. There were no significant differences in equitability values between the sites at either Location (t = -0.759, d.f. = 10, P = 0.466 and t = 1.102, d.f. = 10, P = 0.296 respectively). When the two sites within each location were combined, mean equitability values of 0.077 and 0.070 were recorded, the difference by t-test not being significant (t = 1.313, d.f. = 10, P = 0.218).

Like the Shannon-Weiner diversity indices, no discernable temporal patterns in Shannon-Weiner Equitability indices were observed over the study period, though several high outliers were observed in July and August 2005.

Table 7. Equitability values recorded from sites and locations between June–November 2005.

	Location 1		Location 2			
2005	Site 2 (Forest-fringe) (n=3)	Site 3 (Forest) (n=3)	Site 2 (Forest-fringe) (n=3)	Site 3 (Forest) (n=3)	Location 1 (n=6)	Location 2 (n=6)
June	0.075	0.084	0.080	0.070	0.068	0.064
July	0.091	0.115	0.083	0.102	0.084	0.075
Aug	0.110	0.116	0.103	0.082	0.096	0.075
Sept	0.076	0.088	0.074	0.077	0.066	0.068
Oct	0.100	0.093	0.090	0.070	0.077	0.068
Nov	0.088	0.081	0.089	0.075	0.071	0.072
Mean (SE)	0.090 (0.006)	0.096 (0.006)	0.086 (0.004)	0.079 (0.005)	0.077 (0.005)	0.070 (0.002)

3.3.6 Overall community compositions

Trichoptera, Diptera, and Ephemeroptera were the most speciose taxonomic groups recorded at all sites at both locations (Table 8). Trichoptera ranged from 12–15 taxa per site, with Diptera and Ephemeroptera ranging from 10–11 and 8–9 taxa respectively per site. When sites within the locations were combined, Location 1 recorded 17 trichopteran taxa and Location 2 recorded 15, while Diptera and Ephemeroptera recorded 13 and 9 respectively at both locations.

Total taxa counts per site ranged from 49–53 and when sites within the locations were combined, Location 1 recorded 60 taxa and Location 2 recorded 61.

Table 8. Number of sub-taxa within major taxonomic groupings recorded from sites and locations between June–November 2005.

	Location 1		Location 2			
Taxon	Site 2 (Forest-fringe) (n=3)	Site 3 (Forest) (n=3)	Site 2 (Forest-fringe) (n=3)	Site 3 (Forest) (n=3)	Location 1 (n=6)	Location 2 (n=6)
Platyhelminthes	1	1	1	1	1	1
Oligochaeta	1	1	1	1	1	1
Gastropoda	3	2	2	2	3	2
Amphipoda	0	0	0	1	0	1
Decapoda	2	1	2	1	2	2
Ostracoda	0	1	1	1	1	1
Acari	1	1	1	1	1	1
Arthropleona	0	0	1	0	0	1
Ephemeroptera	9	8	9	8	9	9
Odonata	1	1	0	0	1	0
Plecoptera	3	4	5	4	4	5
Hemiptera	0	0	1	0	0	1
Megaloptera	1	1	1	1	1	1
Coleoptera	5	5	5	7	6	7
Diptera	10	11	11	11	13	13
Trichoptera	15	12	12	14	17	15
TOTALS	**52**	**49**	**53**	**53**	**60**	**61**

A number of major taxonomic groups were recorded with significant differences in abundance between locations using Mann-Whitney Rank Sum *U*-tests (Table 9). Gastropoda, Ephemeroptera, and Plecoptera were significantly ($P = 0.027$, $P = 0.003$, and $P = 0.023$ respectively) more abundant at Location 2, while Coleoptera were significantly ($P = 0.018$) more abundant at Location 1. No significant differences in abundance of major taxa were recorded between sites with the exception of Gastropoda which were significantly ($P = 0.017$) more abundant at Site 3 of Location 1.

Temporal community compositions, as observed by major taxonomic groups, resulted in few conclusive changes in abundance at individual sites. However, Trichoptera taxa appeared to increase in abundance throughout the study period, while Ephemeroptera decreased and Diptera increased from September–November. These patterns became somewhat more obvious when both sites within each location were combined (Figure 18).

Table 9. Abundances of sub-taxa within major taxonomic groupings for Sites 2 and 3 at Locations 1 and 2, with P-values of differences in abundance between sites, and between locations. Abundances were pooled from three replicates over six (monthly) sampling events.

	Location 1			Location 2					
Taxon	Site 2 (Forest-fringe) (n=3)	Site 3 (Forest) (n=3)	P-value[12]	Site 2 (Forest-fringe) (n=3)	Site 3 (Forest) (n=3)	P-value [12]	Location 1 (n=6)	Location 2 (n=6)	P-value [12]
Platyhelminthes	13	18	0.589	33	11	0.180	31	44	0.818
Oligochaeta	3	2	0.699	11	8	0.485	5	19	0.699
Gastropoda [13]	14	65	**0.017**	88	114	0.232	79	202	**0.027**
Amphipoda	0	0	1.000	0	2	0.394	0	2	0.394
Decapoda	2	7	0.651	3	8	0.651	9	11	1.000
Ostracoda	0	1	0.699	1	2	0.937	1	3	0.589
Acari	11	5	0.394	3	6	0.699	16	9	0.240
Arthropleona	0	0	1.000	1	0	0.699	0	1	0.699
Ephemeroptera	579	484	0.374	594	1501	0.097	1063	2095	**0.003**
Odonata	5	4	0.818	0	0	1.000	9	0	0.394
Plecoptera	33	39	0.878	106	80	0.438	72	186	**0.023**
Hemiptera	0	0	1.000	2	0	0.394	0	2	0.394
Megaloptera	140	81	0.093	94	95	0.818	221	189	0.699
Coleoptera [14]	133	75	0.285	26	17	0.652	208	43	**0.018**
Diptera	137	161	0.772	269	152	0.438	298	421	0.397
Trichoptera	763	652	0.699	500	648	0.246	1415	1148	0.941

[12] Probability values calculated using Mann-Whitney Rank Sum *U*-tests. Probability values <0.033 were treated as significant after allowing for correction of alpha adjusted for m independent tests using the false discovery rate control.
[13] Analysis excludes a single *Lymnaea* sp. individual.
[14] Analysis excludes terrestrial individuals.

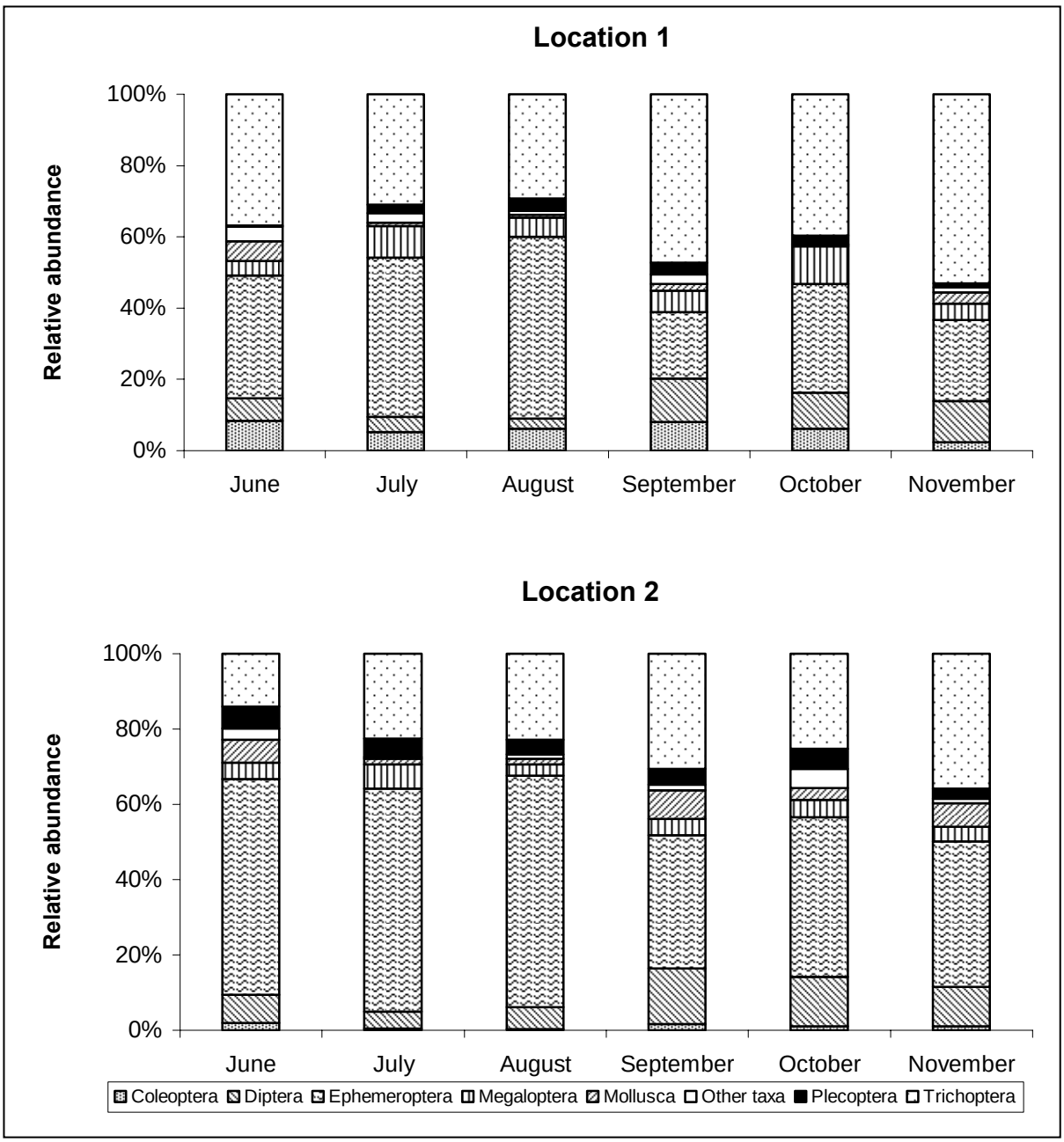

Figure 18. Temporal abundances of invertebrate taxa recorded from Location 1 and Location 2 between June–November 2005. 'Other taxa' group consisted of Acari, Crustacea, Collembola, Hemiptera, Odonata, Oligochaeta, and Platyhelminthes.

3.3.7 Functional feeding group compositions

Abundances of major functional feeding groups were compared between sites and between locations using Mann-Whitney Rank Sum *U*-tests (Table 10). Collector-browsers were recorded in very high numbers, relative to other feeding groups, in all sites at both locations. No significant differences in abundances existed between the sites in either location, and although there were considerably more individuals recorded

in Location 2 than Location 1, this difference was not significant. Filterers and Predators were recorded in low numbers and Shredders in moderate numbers, relative to other feeding groups, in all sites at both locations. However, no differences in abundances between sites or between locations were significant.

Temporal community compositions, as observed by functional feeding groups, recorded a decrease in Collector-browsers and an increase in Shredders in both locations over the period of study, though this was more noticeable for Location 2 (Figure 19). Filterers and Predators both recorded no noticeable changes in temporal abundance, in either Location 1 or 2.

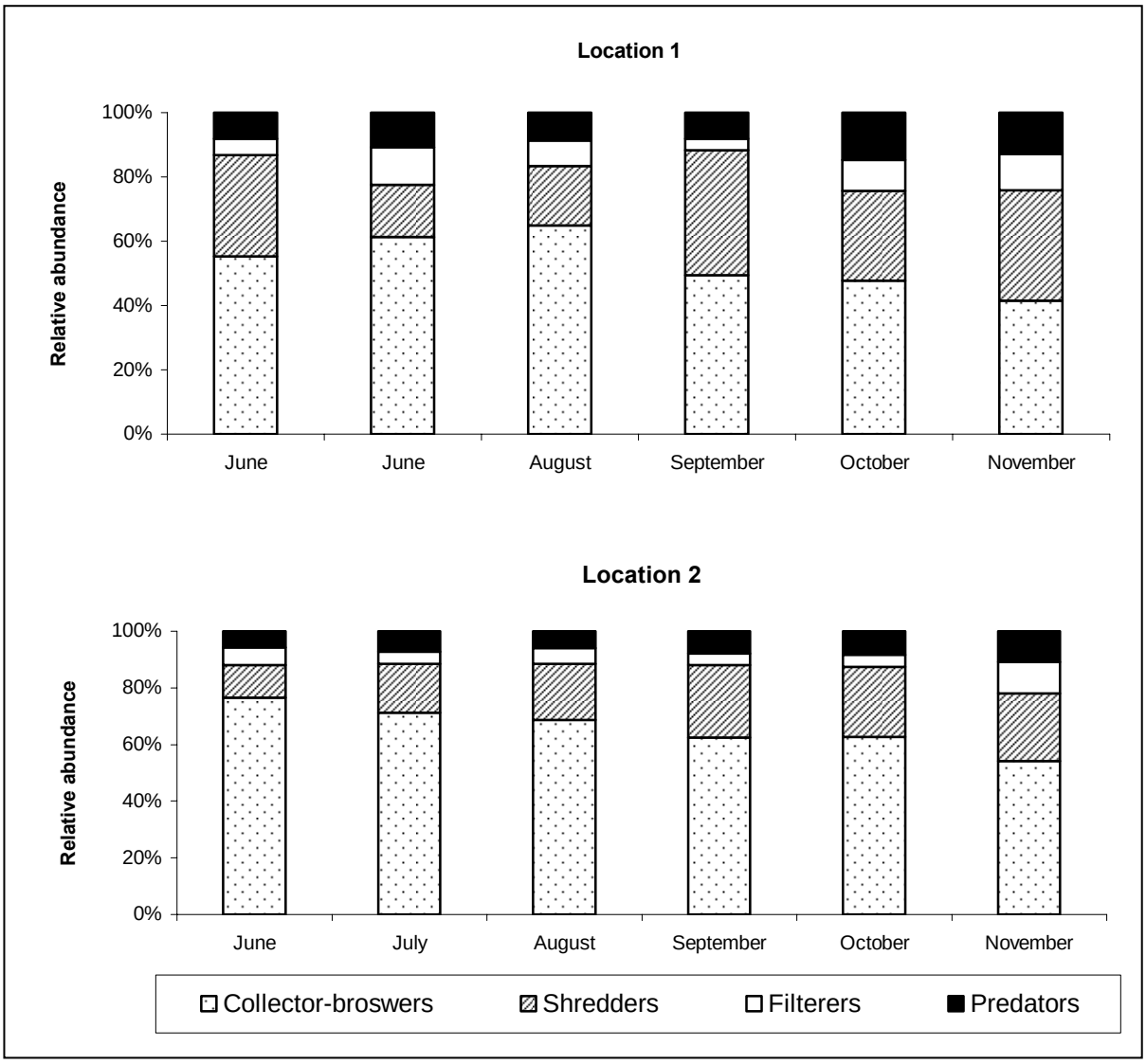

Figure 19. Temporal abundances major functional feeding groups of invertebrate taxa recorded from Location 1 and Location 2 between June–November 2005.

Table 10. Abundances of taxa within principal functional feeding groups for Sites 2 and 3 at Locations 1 and 2, with P-values of differences in abundance between sites, and between locations. Abundances were pooled from three replicates over six (monthly) sampling events.

	Location 1			Location 2					
Functional feeding group	**Site 2 (Forest-fringe)**	**Site 3 (Forest)**	**P-value[15]**	**Site 2 (Forest-fringe)**	**Site 3 (Forest)**	**P-value [15]**	**Location 1**	**Location 2**	**P-value [15]**
Collector-browsers	920	854	0.993	1064	1770	0.430	1774	2834	0.284
Filterers	106	164	0.521	106	175	0.093	270	281	0.263
Predators	227	138	0.203	163	186	0.217	365	349	0.920
Shredders	581	444	0.874	399	517	0.935	1025	916	0.435

[15] Probability values calculated using Mann-Whitney Rank Sum *U*-tests. Probability values <0.033 were treated as significant after allowing for correction of alpha adjusted for m independent tests using the false discovery rate control.

3.4 Discussion

3.4.1 Invertebrate taxonomic richness

A total of 71 taxa were recorded between June and November 2005 from the stream benthos of the four study sites within the Matapouri catchment headwaters. This appears to be a relatively moderate taxonomic richness compared to those reported by authors of other New Zealand studies (i.e. Winterbourn & Collier 1987, Collier *et al*. 1989, Collier 1995, Collier 2004). However, studies exceeding 71 taxa were collected from 4.5–8.5 times more sites, and often with greater temporal (seasonal and/or annual) and spatial (eco-region, catchment, and/or stream reach) replication. Furthermore, directly comparing taxonomic richness with other studies is difficult as, although often similar, collection methods and resolution of taxonomic identification used by other authors do differ to varying degrees. Winterbourn (1981), in a review of the use of invertebrates for assessing stream water quality suggested that riffle habitats are likely to produce 10–30 species per sample, and Cook (2002) recorded a mean of 11–24 taxa per site in a study of Northland forest stream invertebrates. Mean taxonomic richness (pooled from three replicates) in the Matapouri catchment headwaters ranged from 28.3–33.0 per site for June–November 2005, which is at the high end of Winterbourn's suggestion. Seventy-one taxa (approximately 30 per sample) from four sites, of limited spatial separation and temporal replication, and a singular sampling method, may in fact be quite high. This is no surprise as species richness tends to be high in forested headwaters due to relatively more stable and heterogeneous habitats (Cowie 1985). It is highly likely that additional sampling of other benthic habitats (i.e. the hyporheic zone, leaf-packs, pools, seepages, submerged bryophytes, and wetted rock crevices) as in Collier *et al*. (2000), and other diversity studies, would increase the taxa count considerably.

3.4.2 Community invertebrate structure and composition

The invertebrate community in this study was dominated by Trichoptera (19 taxa), Diptera (16 taxa), and Ephemeroptera (10 taxa). Additional species of some reported genera were also observed (i.e. *Olinga* spp., *Helicopsyche* spp., *Hydrobiosis* spp., *Zephlebia* spp., and *Deleatidium* spp.), both as larvae and/or as adults[16], but not

[16] Adult investigations reported in Chapters 4 and 5.

differentiated due to lack of experience and time constraints. Trichoptera and Diptera respectively are commonly reported as the taxonomically dominant orders of New Zealand benthic stream communities (e.g. Collier 1995, Harding *et al*. 1997, Collier *et al*. 1998). Cook (2002) in a study of Northland forest invertebrate communities also reported Trichoptera (26 taxa), Diptera (23 taxa), and Ephemeroptera (15 taxa) as the taxonomically dominant orders.

Relatively fewer Plecoptera (5 taxa) were recorded in this study compared to other New Zealand studies and is most likely due to Northland's temperate climate and a predominance of runoff dominated streams that lack thermal stability and cooler temperature regimes exhibited by the likes of spring- (Baillie *et al*. 2005) or snow-fed rivers.

Relatively high numbers of mayfly taxa, in particular the Leptophlebiidae, were recorded compared to other studies (ten ephemeropteran taxa were recorded but both *Zephlebia* and *Deleatidium* were only recorded to generic level. More that one species of each was observed, but not differentiated). Winterbourn (2004b) noted that more Ephemeroptera are known from the North than South Islands of New Zealand. Summerhays (1983), Towns (1987), and Cook (2002) reported diverse mayfly faunas (10–28 species) occurring in several mainland and offshore island streams in northern New Zealand. This is possibly the result of hydrological or bio-geographical characteristics of the region (Towns 1987). Collier (1995), in a study of lowland macroinvertebrate communities of Northland, recorded the mayfly fauna being dominated by Leptophlebiidae (67% of taxa); *Zephlebia dentata* being the most widely distributed. In contrast, *Deleatidium* spp. has frequently been found to be the most abundant and widely distributed mayfly in most other New Zealand regions (Winterbourn 2000a).

The occurrence, distribution, and abundance of some taxa varied considerably both within sites (habitats) and between locations (spatial component), while others had a cosmopolitan catchment distributions, and were present in similar densities, at all sites, at both locations. In general, it is acknowledged that unmodified New Zealand stream invertebrate communities consist of a core of common genera (i.e. *Deleatidium*, *Coloburiscus*, *Nesameletus*, *Stenoperla*, *Zelandoperla*, *Zelandobius*, *Hydrobiosis*, *Psilochorema*, *Pycnocentria*, *Olinga*, *Aoteapsyche*, *Archichauliodes*, and *Potamopyrgus*

(Winterbourn *et al*. 1981, Rounick & Winterbourn 1982, Quinn & Hickey 1990a)) with a few numerically dominant taxa and a large number of rare ones (Winterbourn 1985b) which is unusual by global standards (Thompson & Townsend 2000).

Most of New Zealand's common core taxa, as listed by other authors (Winterbourn *et al*. 1981, Rounick & Winterbourn 1982, Quinn & Hickey 1990a) were indeed common in this study though there were several differences. Both the mayfly *Nesameletus* and the stonefly *Zelandobius* were absent from this study, but have been recorded from other Northland localities (McLellan 1993, Hitchings & Staniczek 2003), and at least in the case of *Nesameletus*, which is commonly found on the edges of small forest streams with moderate to slow flows (Hitchings & Staniczek 2003), the physical characteristics of the study site match reported habitat preferences. Phillips (1930) described *Nesameletus* (then *Ameletus*) as the best example of a swimming-type of mayfly nymph in New Zealand. It is possible that *Nesameletus* was able to avoid being collected by kick-sample, though this is unlikely. The free-living caddisfly *Aoteapsyche* was also absent, though the niche appeared to be utilised by another hydropsychid caddisfly, *Orthopsyche*. This is not surprising as most species of *Aoteapsyche* are reported as common in sizable, stony, open streams and rivers while *Orthopsyche* are best known from small, stony, forested streams (Cowley 1978, Winterbourn *et al*. 2006). The four stream reaches from which the samples were collected were all small (~1.5m ±0.9m) and the catchment forested (to varying degree but forested nonetheless). Furthermore, the leptophlebiid mayfly *Deleatidium*, although present in moderate numbers, was not as dominant as reported in other New Zealand studies (e.g. Rounick & Winterbourn (1982), Collier *et al*. (1989), Quinn & Hickey 1990a, and Harding *et al*. (1997)). However, a number of taxa not reported as core New Zealand taxa were also recorded in large numbers at all sites. These included the leptophlebiid mayflies *Acanthophlebia cruentata*, *Atalophlebioides cromwelli*, *Mauiulus luma*, and *Zephlebia* spp., thus it appears that *Deleatidium* may be sharing, or even competing for, the niche with these other leptophlebiids. Other taxa not reported as core New Zealand taxa, but present in large numbers at all sites were the cased-caddisfly *Helicopsyche* spp. and the chironomid midge Orthocladiinae.

Community compositions are influenced by several major physical factors (Winterbourn 1985a, Richards *et al*. 1993, Arab *et al*. 2004). The structure of a community is dynamic, changing both temporally and spatially (Hynes 1970a) at

differing scales (Frissell *et al*. 1986, Tate & Heiny 1995). Those factors deemed of highest importance are stream gradients influencing water velocity and substrate size (Richards *et al*. 1993, Winterbourn 2004a), stream width governing the potential of stream shading, and density and type of riparian vegetation, controlling the scale of shading, water temperatures, allochthonous input in forested streams (Reeves *et al*. 2004), and light energy inputs in non-forested streams. The degree of catchment development to improved pasture, and level of enrichment as indicated by increased nutrients and periphyton biomass, have also been suggested as being important (Quinn & Hickey 1990a). However, which combination of these factors is most important varies from one community to another (Winterbourn 2004a).

3.4.3 Site and location differences in invertebrate communities

Although the two locations appeared similar in both physical and physico-chemical characteristics, a number of taxa were significantly more abundant at Location 2 than Location 1 (i.e. *Ferrissia dohrnianus*, *Mauiulus luma*, *Neozephlebia scita*, *Zephlebia* spp., and *Austroperla cyrene*) while others, although not statistically significant, were recorded with trends of greater abundance at Location 2 (i.e. *Potamopyrgus antipodarum*, *Acanthophlebia cruentata*, *Atalophlebioides cromwelli*, *Deleatidium* spp., *Zelandoperla* sp., *Spaniocerca zelandica*, Chironominae, Orthocladiinae, *Nothodixa* sp., and *Paradixa* sp.). In contrast, *Hydora* sp. was significantly more abundant at Location 1, while *Helicopsyche* spp. and *Hydrobiosella mixta*, although not statistically significant, were recorded with trends of greater abundance at Location 1. There were also a number of taxa only recorded at one location or the other (10 taxa solely recorded at Location 1 and 11 taxa solely recorded Location 2).

Of the two study locations, Location 2 sites were positioned on average, approximately 10m higher in elevation and identified as having slightly higher gradients than Location 1 sites. All other physical and physico-chemical variables appeared to be comparable between the two locations. It is reported that gradient, which influences substrate particle size, is one of the most important factors influencing invertebrate structure (Winterbourn 2004a). The substrate at Location 2 tended to be larger and more heterogeneous than Location 1, which may account for the distribution and abundance of some taxa. For example, the elmid beetle *Hydora* sp. was significantly more abundant at Location 1, which tended to have smaller substrate constituents. Elmid

beetle larvae are often found in streams where fine sediments are present (Winterbourn 2004b). Studies by Jowett & Richardson (1990) and Quinn & Hickey (1990b) indicate that some shredder (*Olinga feredayi*) and filterer (*Aoteapsyche colonica* and *Coloburiscus humeralis*) taxa show preference for larger substrates and may be attributed to higher retention of allochthonous organic matter being trapped by in-stream cover and larger inorganic substrates.

The majority of 'more abundant taxa' were recorded at Location 2, where stream conditions may have been more stable (yet still influenced by moderate freshes), and in-stream habitat more desirable, possibly providing Collector-browser (e.g. *Ferrissia dohrnianus*, *Potamopyrgus antipodarum*, and leptophlebiid taxa) and Shredder (e.g. *Austroperla cyrene*) taxa optimum feeding conditions. This may also explain why some taxa (i.e. *Potamopyrgus antipodarum*, *Coloburiscus humeralis*, *Acanthophlebia cruentata*, *Atalophlebioides cromwelli*, *Mauiulus luma*, *Neozephlebia scita*, *Zephlebia* spp., and *Hydrobiosella mixta*) were more common (though not statistically significant) at Site 3 than Site 2 at either one or both locations. The intermediate disturbance hypothesis (Connell 1978) which proposes that biodiversity is highest when disturbance is neither too rare nor too frequent, and the harsh-benign hypothesis (Peckarsky 1983) which predicts that abiotic factors predominate stream community structure in harsh environments, and biotic factors become increasingly more influential in more benign environments, may also partially explain the higher diversity pattern of Location 2 taxa.

3.4.4 Temporal invertebrate community changes

Both invertebrate taxonomic richness and abundance considerably decreased during the July and August 2005 sampling periods. This distinct change in community composition was also noted by outliers in the Shannon-Weiner diversity and equitability indices. These reductions are most likely to be the result of flood disturbance, caused by extreme rainfall recorded in July 2005, as apposed to other ecological events e.g. mass pupation.

3.4.5 Taxonomic resolution of identification

In this study resolution of identification was moderate and although almost half (48%) of the taxa were recorded to species, many others were recorded to broader taxonomic levels (i.e. genera, tribe, sub-family, family, order, or even phylum). This is common practice for many specimens though it is feasible for experienced workers to identify most specimens of some groups i.e. Trichoptera and Ephemeroptera to the species level. An example of this taxonomic resolution issue is the genus *Orthopsyche*, where both species, *O. fimbriata* and *O. thomasi*, were recorded at both sites at both locations in similar densities. However, the two species were not confirmed by a taxonomist; *O. fimbriata* was distinguished by the anterior margin of the frontoclypeus having a shallow concavity on the left side, and the head pigmentation uniformly dark brown. *O. thomasi* was distinguished by the anterior margin of the frontoclypeus lacking the concavity, the head pigmentation golden brown, and smaller in size than *O. fimbriata.* It is possible that only *O. fimbriata* is actually present in the Matapouri catchment, and that those recorded as *O. thomasi* are all mid-instars of *O. fimbriata* in which the concavity has not yet developed, or is inconspicuous, and the head pigmentation still to darken. Adult specimens of *O. fimbriata* (confirmed by a taxonomist) were collected in abundance by light and sticky trap catches from all study sites (study reported in Chapter 4) during the same collection dates as the benthic study, but no adult *O. thomasi* were recorded.

3.4.6 Records of potential conservation interest

The mayfly fauna included three individuals of *Isothraulus abditus*. This is a new locality record for one of New Zealand's rarest mayflies (Towns & Peters 1996). It is listed as a taxonomically determinate (data poor) freshwater invertebrate by Hitchmough *et al*. (2007), and was considered of potential conservation interest by Collier (1992, 1993) due to its known distribution being restricted to only two Ecological Regions[17]. Towns & Peters (1996) also reported that *Isothraulus abditus* has only been confirmed from two localities. It was first recorded (as *Zephlebia* sp. A) as occasional from one site in the Waitakere Ranges near Auckland (Towns 1976, 1978, Towns & Peters 1979), and again by Towns (1987) from Great Barrier Island

[17] Ecological Regions framework of McEwen (1987) (cited Collier 1992).

(Coromandel Ecological Region) who reported considerable numbers in an isolated pool filled with large quantities of leaves and twigs, connected to others by subterranean flow. Towns (1987) also recorded others, in lesser densities in first order tributaries with little discernible surface flow. In addition to Towns & Peters (1996) confirmed records, Summerhays (1983) also recorded an *Isothraulus*-like sp. from the Pirongia Mountain in the Waikato Ecological Region. Since Collier (1992, 1993) noted the potential conservation interest of *I. abditus*, scattered reports of its occurrence have been noted, though most were in difficult to obtain records. Along with an additional record from the Auckland Ecological Region (Maxted *et al*. 2003) and four additional records from the Northland Ecological Region i.e. Pukenui Forest (Collier 1995), Puketi Forest (Seitzer 1995), Glenbervie Forest (NTB 1999), and Omahuta Forest (Cook 2002), three recent publications have recorded the occurrence of *I. abditus* in the Waikato Ecological Region (Collier *et al*. 2000, Scarsbrook & Halliday 2002, Parkyn *et al*. 2006). Based on the details available in the literature, with the exception of Towns (1987), most authors allude to very low numbers of *I. abditus*, often only single individuals, being present. Furthermore, there is a recurring theme of the habitat being forested headwater streams, low or no surface flows, pool dwelling, with high leaf-pack assemblages. The only contradiction to this were the specimens recorded by Summerhays (1983) which were both from sites in the main Rangitukia Stream, though he noted litter and wood accumulation at the sites. The sites in the Matapouri catchment where *I. abditus* was recorded consisted of forested shallow riffle/run sections with considerable backwaters and abundant leaf-packs and woody debris. It isn't surprising that so few occurrences have been recorded, as most benthic sampling targets riffle habitats, in moderately flowing waters and *I. abditus* appears to prefer low-flow habitats.

Two other species recorded in the catchment were considered of potential interest by Collier (1992). *Spaniocercoides watti*, known only from the Northland Ecological Region (Collier 1993), was recorded in very low numbers (two individuals), though these specimens were small, and not confirmed by a taxonomist. McLellan (1991) noted that *S. watti* had quite different genitalia from other members of the genus and could be considered to be a new genus, though its proper position must await discovery and description of the adult male. *Olinga jeanae* was also present; adult[18] specimens being

[18] Adult investigations reported in Chapters 4 and 5.

positively identified by a taxonomist. However, larval specimens were not able to be separated and subsequently reported as *Olinga* spp. in this chapter.

3.4.7 Study limitations

The temporal data collected for this study (June–November) were dictated by the duration of enrolment for a MAppSc thesis at the Auckland University of Technology. It is acknowledged that examining a full annual dataset would have been far more valuable. However, the data collection period was reduced to allow for preliminary studies and writing up.

A monthly data collection schedule was devised to record any temporal (June–November) changes in community compositions. Although striving to maintain regular sample collection periods, difficult site access, accentuated by adverse weather conditions, resulted in schedule fluctuations of ± eight days. In addition, attempting to follow a schedule meant that sampling was sometimes conducted after freshes (and one flood event) which were reflected in the community compositions recorded. This was an important limitation as anomalies in the data from such events have almost certainly influenced the statistical results.

Damaged specimens and early instars of a number of taxa (especially mayflies) were unable to be identified to species, and were placed into the most germane taxon. It is now acknowledged that these specimens should have been recorded as apparent morphospecies (i.e. Leptophlebiidae).

A low number (three) of replicate samples were collected from each site throughout the study to minimise the time spent on sample processing and identification (the final design still collected 72 benthic samples, which required a significant amount of time to analyse). This limited the number of statistical tests that could be carried out, and discriminated the power of the analyses. In addition, it is possible that low replication may have reduced the accuracy of the faunal inventories somewhat.

It was proposed to investigate life histories of select genera by size class analysis using head width measurements. However, because processing and identification were so time-consuming, life history investigations were not undertaken.

Ideally water velocity and substrate datasets would have been collected concurrently with the spot water quality measurements and benthic samples. However, the additional equipment and personnel required to collect these data from rough terrain meant that these factors were omitted from the study. It is acknowledged that water chemistry, water velocity, and the nature of the substrate are all important factors which characterise invertebrate community structure (Winterbourn 2004a). Collier (1995), in a study of Northland streams, found that substrate size was a secondary factor affecting community composition and taxonomic richness in Northland, after water temperature, shade ratio, and riffle depth. However, Death (2000) noted that Collier's study was one of the few which had actually identified substrate size as a determinant of community structure. A single set of substrate core samples and stream velocity readings were collected, from each location, during base-flow, to describe the physical environment of the study sites.

Chapter 4 – *Investigation of winged stages by sticky trapping*

4.1 Introduction

The final stage of aquatic insects is a terrestrial stage; the sole purpose being to reproduce. The adults leave the stream, which is known as emergence, and take flight. Dispersal of the adult females upstream, prior to oviposition, is suggested to be a behaviour that compensates for possible downstream drift by larvae, allowing completion of the colonisation cycle (Muller 1982). Oviposition behaviour can strongly influence between-stream and within-stream distributions of larvae (Winterbourn & Crowe 2001), however prior to oviposition, females must find a suitable habitat. This preference varies between species, but most mayfly (Ephemeroptera), stonefly (Plecoptera) and caddisfly (Trichoptera) adults favour stream-side riparian vegetation, and a suitable gravel substrate (Jackson & Resh 1991).

Sticky traps have been used in studies to sample or collect adult aquatic insects. Sticky traps provide a convenient and passive collection method that avoids some bias involved in other more active methods.

Little research into aquatic adult stages has been conducted in Northland streams and there has been no research into aquatic adult stages at Matapouri. The aim of this study was to gather presence, abundance, and life-history data on aquatic adult stage insects, during the months of June–November from Matapouri, and to support the results of the benthic study.

4.2 Methods

4.2.1 Preliminary trials

Several designs, materials, and product applications were tested for performance and suitability. Initial sticky traps were constructed of white 100% polyester voile curtain netting (dimensions 1m x 1m ($1m^2$ per side)) stretched across the stream between two wooden stakes and driven into the substrate until stable (Figure 20).

Figure 20. Early sticky trap design erected in the field.

The netting was coated on both sides with a spray-on formula of tangle-trap; a clear, odourless, all-weather, insect adhesive compound, produced by Tanglefoot (The Tanglefoot Company, Grand Rapids, Michigan. U.S.A.). The design resulted in very low catches of adult insects (during March/April 2005) which may have been due to the colour of the traps (bright white), the poor adhesive quality of the trap surfaces, or some other factor (e.g. time of year).

The netting was replaced with 200 micron (thickness) clear acetate sheets (eight A4 sheets joined with clear 40mm 3M Sellotape) (dimensions 0.840m x 0.592m (~0.5m^2 per side)). The spray-on tangle-trap adhesive was changed to the tangle-trap paste formula (also Tanglefoot product), which was a superior adhesive but very time-consuming and difficult to work with. These modifications produced higher catches, even though the trapping surface area was reduced. It was then decided to further reduce the catching area to ~0.25m^2 per side (four A4 sheets; total dimensions 0.840m x 0.296m) (Figure 21).

Figure 21. An improved version of the sticky trap system set in the field.

However, during the fourth set of trials a period of wet weather descended over the study site and it was quickly apparent that erecting stakes in unstable substrata was less than desirable, as increased water velocities quickly washed away the stakes. The stakes that remained standing were removed and the acetate sheets were hung on 1mm braided cord, initially with small bulldog clips, but eventually by threading the cord through multiple holes punched into the acetate sheets. The sheets tended to flap in windy conditions, and the braided cord stretched, causing the sticky traps to sag. A final improvement was made, exchanging the 1mm cord for 3mm synthetic rope, which was threaded through both the top and bottom of the acetate sheets.

4.2.2 Trap deployment

Two contrasting habitats were sampled; each requiring a different system to deploy the sticky traps.

At Sites 2 and 3 (Forest and Forest-fringe habitats) the final version of the piloted sticky traps was able to be utilised. This involved hanging four 200 micron clear acetate A4 sheets joined with clear 40mm 3M sellotape, (dimensions 0.840m x 0.296m (~0.25m^2 per side)) on 3mm synthetic rope, which was threaded through both the top and bottom

of the acetate sheets. The ropes were tied to trees on opposite stream banks so the traps were positioned perpendicular to the stream. The top of the sticky traps hung at head-height (~1.7m) (Figure 22).

Figure 22. Final sticky design for Sites 2 and 3 (Forest and Forest-fringe habitats).

At the Site 1 locations (Raupo habitats) accessing the centre of the sites was difficult, and it was noted that moving through the raupo was a highly destructive process. Also, there were no suitable natural points to tie the sticky trap ropes to. It was therefore decided to construct a system that allowed the traps to be set from the banks, so avoiding damage the raupo habitat. Sites were selected where two large trees were positioned on either side of the Raupo habitat, but the total span did not exceed 50m (distances over 50m would have required additional equipment and incurred other logistical problems). A platform was constructed in the manuka (*Leptospermum scoparium*) canopy, to work from. Rope systems were devised that allowed the sticky traps to be tied to a main rope line and be drawn out, one after the other, using a pulley system (Figure 23). The main rope line and attached sticky traps were suspended just above the Raupo habitat (Figure 24), and traps could be set and retrieved as required.

Figure 23. Pulley system used to deploy the sticky traps above Site 1 (Raupo habitat).

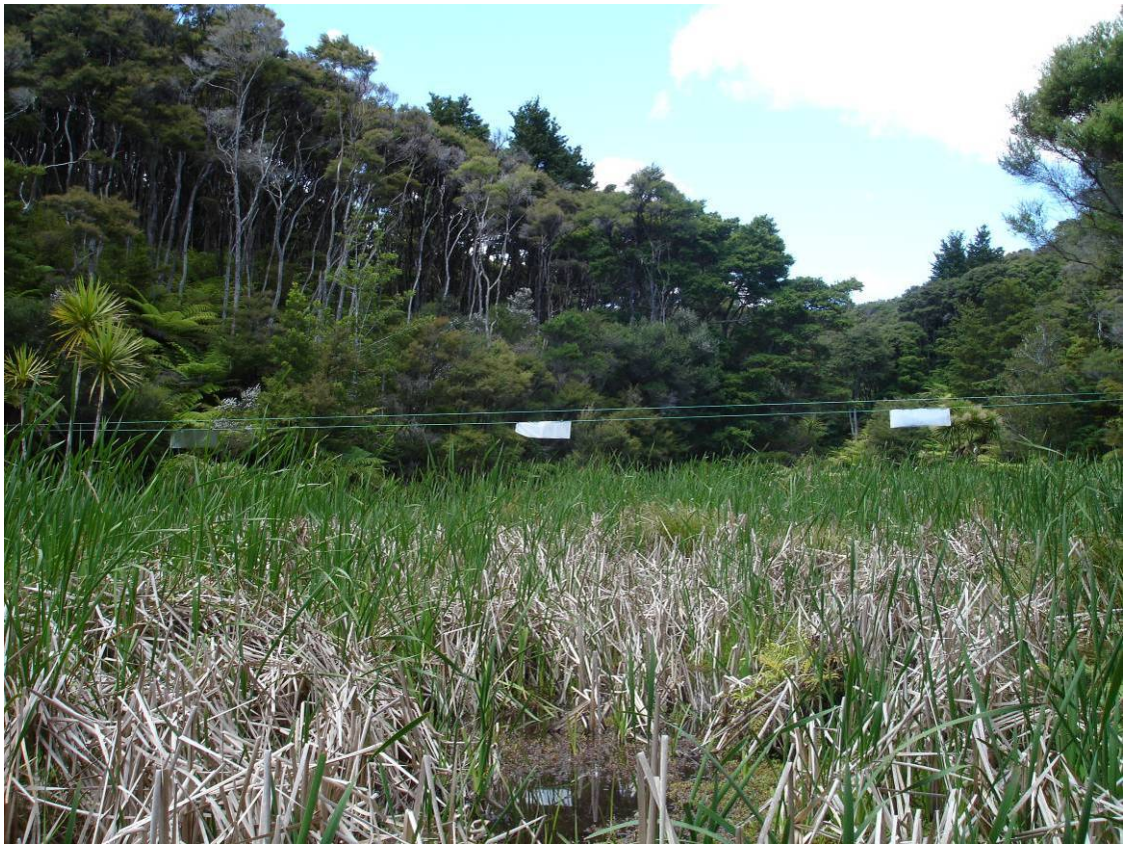

Figure 24. Sticky traps deployed at Site 1 (Raupo habitat).

4.2.3 Sampling procedure

Sticky traps were set each month between June and November 2005. The traps were due to be in place continuously for 14 days every month, however unfavourable weather conditions sometimes meant that this period was extended (see Appendix 5 for details). Replicate (3) sticky traps were located within each of three sites (Forest, Forest-fringe and Raupo habitats) at two separate locations (Locations 1 and 2) (Figure 25).

All acetate sheets were constructed, and insect adhesive applied (to both sides), prior to heading into the field. Each 'loaded trap' was placed one on top of the other; the first and last were covered with greaseproof paper and placed between two 4mm hardboard sheets (hardboard dimensions slightly larger than the traps) for transportation.

In the field, at Site 1 of both locations, loaded replicate (3) traps were tied to the main rope line with 1mm braided cord, and sprayed with a tetramethrin based, long-lasting (~ 90 days) insecticide product by Mortein (barrier outdoor) to kill insects quickly (following Collier & Smith 1995). The centre replicate trap was placed about centre of the site, and there was a ~3m separation between replicates. For Sites 2 and 3, three replicate traps were hung individually at ~50m intervals along the stream reach.

When collecting the sticky traps, each acetate sheet was removed and marked with waterproof labels written in pencil, and transported and stored between sheets of greaseproof paper. The rope hangers were refastened and left ready for subsequent data collections.

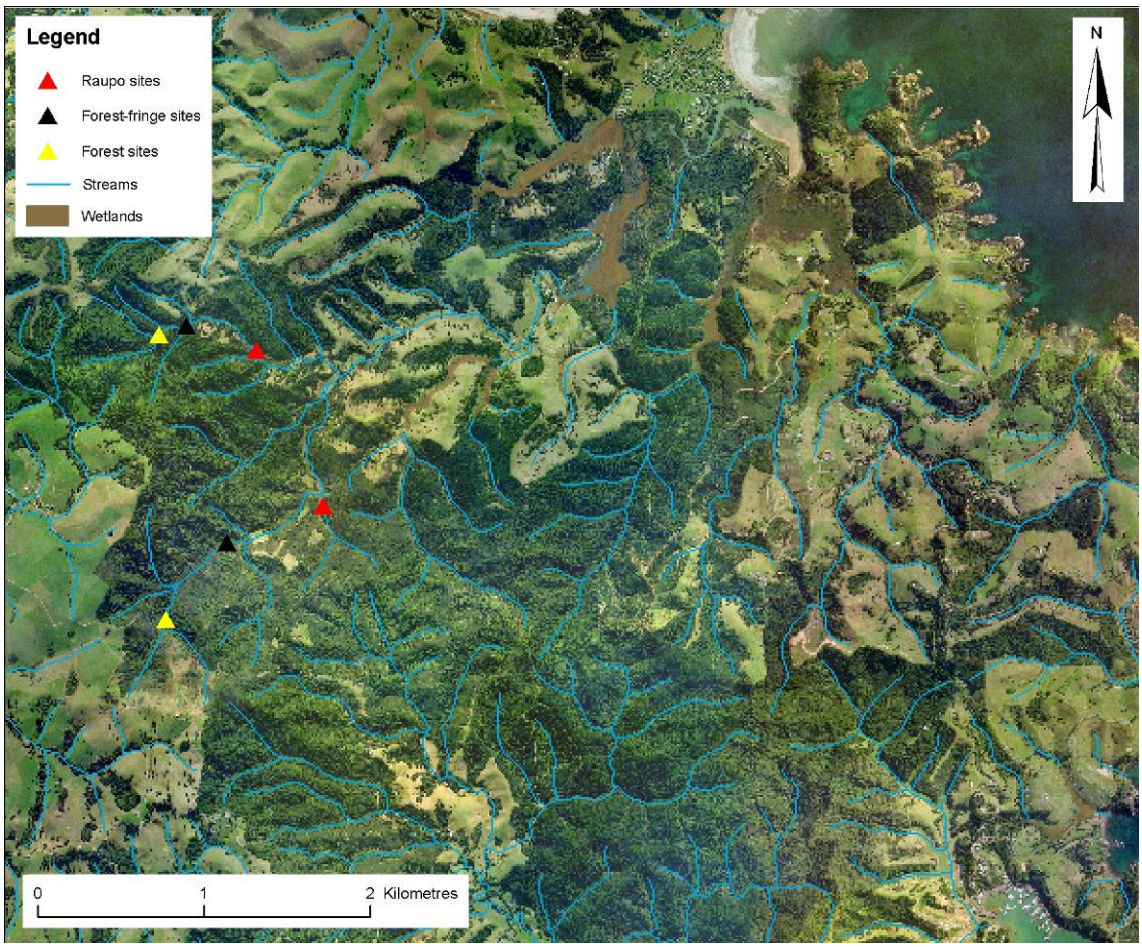

Figure 25. The three sampling sites situated within Location 1 in the south and Location 2 in the north. Aerial imagery provided by Northland Regional Council (NRC).

Back in the laboratory, the acetate sheets loaded with the catch (Figure 26 and Figure 27) were stored out of the light, in a dry cupboard, awaiting processing.

Figure 26. Example of a sticky trap sheet with large catch. The image appears blurry as there are four transparent traps placed one on top of the other.

Figure 27. Close up example of a sticky trap catch.

4.2.4 Processing and identification

In the laboratory an attempt was made to separate the insects from the sticky traps by soaking in tubs of mineral turpentine to break down the glue allowing the catch to float free (as per the Tangle-trap instructions). However, because of the size and large number of traps per month (18), vast quantities of mineral turpentine would have been required. This was the desired technique as the catches could then be stored in pottles of ethanol for future investigation. However, it became evident that the traps would need to be processed 'as is' (i.e. without separating the insects from the acetate sheets). Therefore, each A4 sheet was carefully separated and systematically scanned under a Superlux LSX magnifier (3 dioptre magnification, T9 22 watt circular fluorescent lamp).

Most taxa present were identified, numerated and recorded to order using Naumann *et al*. (1996). An exception was the dipteran family Tipulidae, which were recorded separately. Also, some individuals were recorded at higher taxonomic levels (Arachnida, Nematoda, and Mollusca). Gordh & Headrick (2005) was used for assistance with entomological terms. For completeness all raw data are tabled in Appendix 7.

Many different types of invertebrates were collected by sticky trap during this study (including Mollusca!), however only the aquatic representatives will be reported.

4.2.5 Statistical analysis

All invertebrate records (type and number) were entered into Microsoft Office Excel 2003 and analysed using the statistical software SigmaStat 3.5. To compare select order/family, and total combined flighted insect abundance, between sites, between locations, and between sites across locations, *F*-tests, normality tests, and Student *t*-tests were used to test for sample variance, normality, and significance. Data that were found to violate the assumptions of normality were analysed using non-parametric Mann-Whitney Rank Sum *U*-tests. Alpha limits of significance for Mann-Whitney Rank Sum *U*-tests were set at <0.033 after allowing for correction of alpha using the false discovery rate control for m independent tests.

4.3 Results

4.3.1 Occurrence and abundance of taxa

A total of 20,390 invertebrates, comprising of 17 orders, were recorded by sticky trapping from the Matapouri catchment between June–November 2005 (Appendix 7). Of these orders, 11 were considered to be substantially of terrestrial origin, with another (Diptera) comprising few aquatic (i.e. Tipulidae and Chironomidae), but mostly terrestrial fauna. Five aquatic orders (Ephemeroptera, Plecoptera, Trichoptera, Megaloptera, and Odonata) of insects were also recorded.

Abundances of most[19] aquatic orders (and one family) were compared individually between sites, between locations, and between sites across locations using Mann-Whitney Rank Sum *U*-tests. Within Location 1 there was an obvious trend of higher abundance at both Site 2 and Site 3 than at Site 1, for all aquatic taxa, though not all were statistically significant (Table 11). There appeared to be few differences in abundance between Sites 2 and 3.

Table 11. Mann-Whitney P-values of taxa differences in abundance between sites within Location 1. Sites with significantly greater abundances are indicated in cells (S2 = Site 2, S3 = Site 3) and values are **bold**.

	Ephemeroptera	Plecoptera	Trichoptera	Megaloptera	Tipulidae
Site 1– Site 2	***P* = 0.016** (S2)	*P* = 1.000	***P* = 0.004** (S2)	*P* = 0.080	*P* = 0.051
Site 1– Site 3	***P* = <0.001** (S3)	***P* = 0.019** (S3)	***P* = 0.015** (S3)	*P* = 0.163	*P* = 0.074
Site 2– Site 3	*P* = 0.278	***P* = 0.019** (S3)	*P* = 0.787	*P* = 0.580	*P* = 0.739

Within Location 2 there was also an obvious trend of higher abundance at both Site 2 and Site 3 than at Site 1, for all aquatic taxa; Ephemeroptera, Plecoptera, and Trichoptera were statistically significant (Table 12). There appeared to be no differences in abundance between Sites 2 and 3.

[19] The odonate group have been excluded from the results as only 4 individuals were recorded during the study.

Table 12. Mann-Whitney P-values of taxa differences in abundance between sites within Location 2. Sites with significantly greater abundances are indicated in cells (S2 = Site 2, S3 = Site 3) and values are **bold**.

	Ephemeroptera	Plecoptera	Trichoptera	Megaloptera	Tipulidae
Site 1– Site 2	***P* = <0.001**(S2)	***P* = 0.009**(S2)	***P* = <0.001**(S2)	*P* = 0.283	*P* = 0.124
Site 1– Site 3	***P* = <0.001**(S3)	***P* = <0.001**(S3)	***P* = <0.001**(S3)	*P* = 0.531	*P* = 0.105
Site 2– Site 3	*P* = 0.962	*P* = 0.098	*P* = 0.358	*P* = 0.655	*P* = 0.739

When looking at abundances of groups of taxa i.e. to order or family, at specific sites between Location 1 and Location 2, there was no evidence of any differences between the Site 1 sites. However, Location 2 recorded higher trends of abundance for most taxa groups between both the Site 2 and Site 3 sites; in particular, the Ephemeroptera and Plecoptera were statistically significant between the Site 2 sites ($P = 0.027$ and $P = 0.009$ respectively).

When sites within the locations were combined, abundances were significantly greater in Location 2 for Ephemeroptera, Plecoptera, and Tipulidae ($P = 0.027$, $P = 0.008$, and $P = 0.039$ respectively). There appeared to be no differences in abundance for Megaloptera and Trichoptera orders between locations.

4.3.2 Compositions and temporal abundance of taxa

When looking at compositions of individual taxa groups, Trichoptera and Tipulidae were dominant within both locations (Figure 28). Ephemeroptera were also reasonably well represented, though more-so in Location 2.

Temporal abundances of individual taxa groups all steadily increased post August, though there was a marked decline during November (Figure 29). Plecoptera and Megaloptera only began to become active, in very low numbers, during October and November.

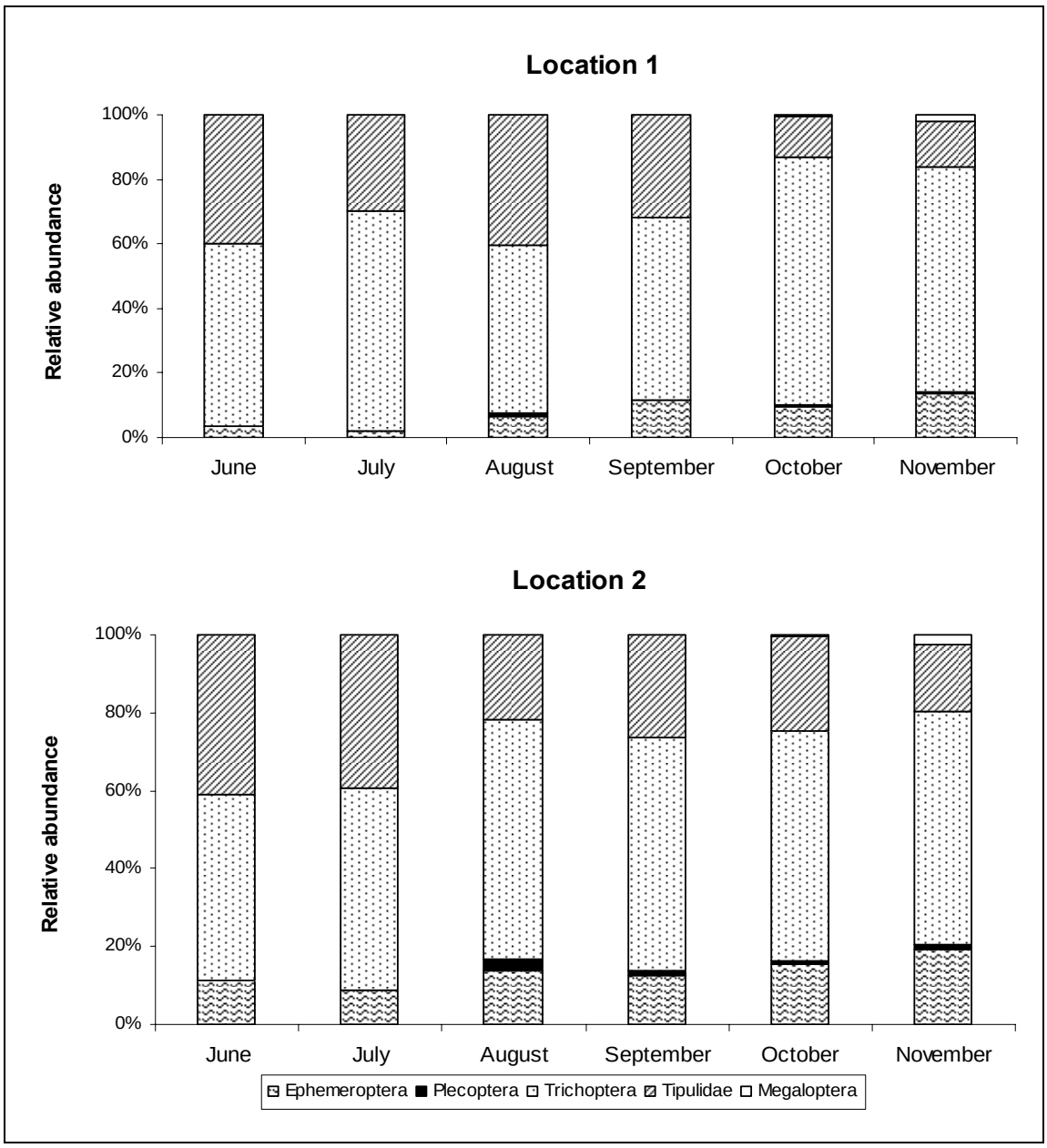

Figure 28. Composition of aquatic invertebrate taxa recorded by sticky trap from Location 1 and Location 2 between June–November 2005.

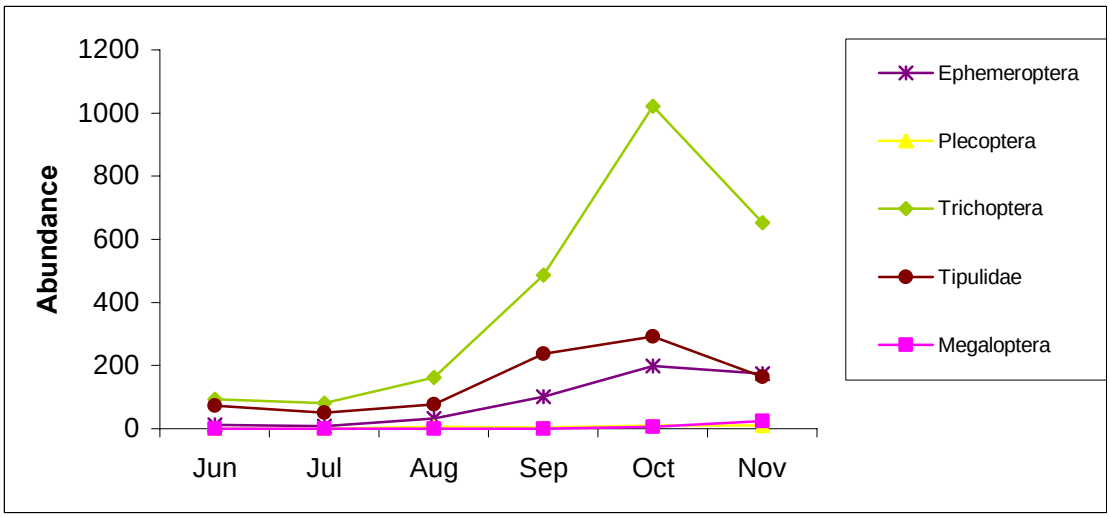

Figure 29. Abundances of aquatic invertebrate taxa recorded by sticky trap from the Matapouri catchment (Location 1 and 2 combined) between June–November 2005.

4.4 Discussion

4.4.1 Invertebrate abundances

The data suggest that there was trend for higher abundance in both locations at Site 2 and Site 3 than in Site 1, for all aquatic taxa. However, there appeared to be little difference in abundance between Sites 2 and 3 at either location. In addition, Location 2 recorded larger trends of abundance for most taxa groups between both the Site 2 and Site 3 sites. Sites 2 and 3 at each location were both positioned under a canopy of native vegetation, where as Site 1 was open and exposed. Furthermore, Location 2 had a denser canopy and riparian vegetation than Location 1. All of the aquatic groups recorded in this study by sticky trap have a high proportion of representatives that are acknowledged as preferring streams with a 'healthy' and diverse composition of riparian vegetation (Collier & Scarsbrook 2000) which may explain the higher abundances at Location 2 and the lower abundances within the Site 1 sites. In fact, the statistics would probably have been even more definitive if it had not been for a family of Trichoptera (Hydroptilidae) that commonly occur in large numbers in slow-flowing open or degraded environments (Scarsbrook *et al*. 2000), and made up a large proportion of the recorded catch from both Site 1 locations.

Odonata were recorded in low numbers during the study and were excluded from analysis. However, this by no means infers that odonate representatives were inactive within the Matapouri catchment during the study period. In fact large numbers of Odonata (i.e. Zygoptera, and to a lesser extent Anisoptera) were observed; particularly from late August. Members of the odonate order are strong fliers (Rowe 1987) and, not unlike some other aquatic insects e.g. Trichoptera (Bird & Hynes 1981), probably exercise a high degree of trap avoidance.

4.4.2 Study limitations

This study utilising stick trapping (and the following study using light trapping) was intended to provide a vastly more detailed description of the community compositions, life-histories, and seasonality of adult stage aquatic invertebrates. However, it wasn't until after all fieldwork was complete that it was realised how difficult the identification was going to be to provide a meaningful level of resolution. There was not enough time or expertise to complete the identification to the desired level, within the required

timeframe, thus only an overview has been provided, as supporting data to the benthic chapter.

Malaise traps (Malaise 1937) are accepted as superior to other trapping methods for collecting many groups of flying insects (Hosking 1979) and Muller (1982) demonstrated in a comparative study that Malaise traps are the most suitable device for studies on flighted freshwater insects. However, Malaise traps were not available for this study and consequently, combinations of sticky traps and light traps, which are also frequently used in entomological studies, were substituted to sample for adult stages.

The isolated and unexplored nature of the study location was an attraction of the research; it did however present a number of issues. Difficult access to the study sites severely restricted the design of, and type of, equipment that could be used. All equipment needed to be lightweight to be carried, for several kilometres at times, through steep native forest lacking walking tracks. Equipment-intensive sampling designs were unrealistic; the final designs were a compromise between the ideal, and the logistically achievable.

It was identified early in the design that sticky traps blowing in the wind may accentuate insect avoidance and measures were taken to prevent excessive sticky trap movement. However, the system deployed in the Site 1 locations (Raupo habitat) could not be secured, thus traps set in Sites 2 and 3 of each location differ slightly from those set in the Site 1 locations.

An omission in this study was the failure to collect site specific physical parameters e.g. temperature and humidity data. An application for funding for data loggers was lodged, however this unfortunately did not eventuate.

Chapter 5 – *Investigation of winged stages by light trapping*

5.1 Introduction

Light traps are an active collection method, used regularly in aquatic insect studies. As stated in the previous chapter, little research into aquatic adult stages has been conducted in Northland streams and there has been no research into aquatic adult stages at Matapouri. The aim of this study was to gather presence, abundance, and life-history data on aquatic adult stage insects, using light traps during the months of June–November from Matapouri, to support the benthic and sticky trapping studies.

5.2 Methods

5.2.1 Preliminary trials

Light trap design followed that of Collier *et al*. (2000), with minor modifications made due to cost constraints, and equipment availability.

Initial light traps consisted of a 'cheap' white plastic bin (dimensions 460 x 290 x 120 mm) half-filled with water. An 8 watt fluorescent lamp (model F8W/33) was housed within a Thorn lamp enclosure (Type BBO10812V), with diffuser cover. The diffuser cut down the level of ultraviolet light emitted, but was retained to protect the lamp and circuitry from moisture. The light unit was taped to the top centre of the bin (Figure 30), ensuring that the light would be detectable by insects in a 360° arc. The lights were powered by Powergard 12 volt (7 a/h) sealed lead-acid batteries (make HGL7-12; float charging voltage 13.6–13.8 v @ 25°). Approximately 10mls of biodegradable dishwashing liquid (Sunlight) was added, and mixed, to the water of three traps to break the surface tension of the water, and washed around the upper edges of the tray to increase surface 'slipperiness'. Three more traps were set without dishwashing liquid. Traps set without dishwashing liquid caught very few insects whereas traps with dishwashing liquid caught numerous insects. The six traps were reset (all with dishwashing liquid), and three fluorescent lamps were replaced with blacklight lamps (model TL 8W/05). Numerous insects were caught in traps with fluorescent and blacklight lamps.

Two types of plastic bin were trialled, as it was suspected that the amount of light that was being reflected from the 'cheap' white plastic bins could be improved, thus improving the catch. Six blacklight light traps were set (all with dishwashing liquid),

three with ‘cheap’ white plastic bins, and three more reflective white ‘fridge’ bins (dimensions 410 x 290 x 110mm); the resulting catches favoured the ‘fridge’ bins, based on numbers and diversity of insects.

The final light trap design was a white ‘fridge’ bin (dimensions 410 x 290 x 110mm), half-filled with water and 10mls of biodegradable dishwashing liquid. A blacklight lamp (model TL 8W/05) was housed within a lamp enclosure, and diffuser cover. The light unit was taped to the top centre of the bin, and powered by the12 volt (7 a/h) sealed lead-acid battery.

Figure 30. Light trap design deployed in the study.

5.2.2 Sampling procedure

Six light traps were set one night each month between June and November 2005 on fine still evenings. These were located within each of the three sites (Forest, Forest-fringe, and Raupo) at two separate locations (Locations 1 and 2) (see Figure 6). Sampling dates are tabled in Appendix 5.

Prior to sampling all batteries were charged simultaneously using Electronic & Transformer Engineering Ltd. sealed lead-acid battery chargers (Type LAC750, Sec: 13.8 nominal 0.65 amp DC), until fully charged. All batteries were new at the start of the study, and used and charged for the same periods of time, thus were deemed to charge/discharge at the same rate, and last approximately the same period of time. This was important because the traps needed to be catching for the same period of time.

Timing units, used to activate and deactivate electrical units simultaneously, were investigated but were beyond the means of the project's budget. Consequently, the traps were activated manually, in sequence; the time between the first and last was 60–80 minutes but all traps were activated just before, or during, the dusk period. Once activated, the lights remained on until the battery voltage ran low, and the lights switched off (~7 hours[20]).

At Sites 2 and 3 the light trap units were placed on a rock, or gravel bank, near centre stream (Figure 31). For the Site 1 sites, planks were placed on the swampy ground out to the centre of the habitat ~50m downstream of the permanently constructed sticky trap lines. Traps were set on a flat site at the end of the plank walkway.

[20] Sealed lead-acid batteries only operate at ~70% efficiency (G. Forrest pers.com, NorthTec electrical technician) thus a 0.666 amp draw (8 watt / 12 volt) on a 7 a/h battery at 70% theoretically provides 7 hours 21 minutes of light opperation.

Figure 31. Light trap positioned during preliminary trials midway between Sites 2 and 3. A trial sticky trap can also be seen in the background.

The next morning, the light traps were cleared by carefully decanting off most of the water and transferring the catch into labelled 500ml containers. The planks in the Raupo habitats were removed and stored above the floodplain, and the light traps disassembled and removed.

On return to the laboratory, more water was decanted from the samples, and replaced with 75% ethanol.

5.2.3 Processing and identification

In the laboratory invertebrates were systematically identified to order following Naumann *et al*. (1996) under a Superlux LSX magnifier (3 dioptre magnification, T9 22 watt circular fluorescent lamp). The invertebrate samples were then numerated, recorded, and stored in 75% ethanol. Raw data are tabled in Appendix 8.

Further identification of the Ephemeroptera, Plecoptera, Trichoptera, and Megaloptera orders, from three replicate samples, was carried out using descriptions and/or keys of Phillips (1930), Towns & Peters (1996), McLellan (1991, 1996, 1999), Smith & Ward

(in prep), Mosely & Kimmins (1953), Ward (unknown, 2000), Neboiss (1986), Ward & Henderson (2004), and Johanson (1999) to give an indication of the species present within the catchment, and to aid in identification of benthic taxa through association. A list of species recorded is tabled in Appendix 9.

Trichoptera voucher specimens were confirmed by Brian Smith (NIWA, Hamilton), while several Ephemeroptera vouchers were confirmed by Dr David Towns (Department of Conservation, Auckland) and Stephen Moore (Landcare Research, Auckland). Voucher specimens were preserved (75% ethanol), catalogued following Walker & Crosby (1988), and stored at NorthTec Environmental Sciences in Whangarei. Gordh & Headrick (2005) was used for assistance with entomological terms. Many different types of invertebrates were collected by light trap during this study, however only the aquatic representatives will be reported.

5.2.4 Statistical analysis

All invertebrate records (type and number) were entered into Microsoft Office Excel 2003 and analysed using the statistical software SigmaStat 3.5. To compare select order/family, and total combined flighted insect abundance, between sites, between locations, and between sites across locations, *F*-tests, normality tests, and Student *t*-tests were used to test for sample variance, normality, and significance. Data that were found to violate the assumptions of normality were analysed using non-parametric Mann-Whitney Rank Sum *U*-tests. Alpha limits of significance for Mann-Whitney Rank Sum *U*-tests were set at <0.033 after allowing for correction of alpha using the false discovery rate control for m independent tests.

5.3 Results

5.3.1 Occurrence and abundance of taxa

A total of 4,854 invertebrates, comprising 17 orders, were recorded by light trapping from the Matapouri catchment between June–November 2005 (Appendix 8). These were the same 17 orders recorded by sticky trapping. Of the orders, 10 were considered to be substantially of terrestrial origin, with another (Diptera) comprising few aquatic (i.e. Tipulidae family), but mostly terrestrial fauna. Five aquatic orders (Ephemeroptera, Plecoptera, Trichoptera, Megaloptera, and Odonata) of insects were also recorded.

Abundances of most[21] orders (and one family) were compared individually between sites, between locations, and between sites across locations using Mann-Whitney Rank Sum *U*-tests. The data collected by light traps indicated that no differences in abundance existed between any sites within Location 1 or within Location 2, either as individual orders/family or combined as total abundance per site. In addition, when the abundances at specific sites (i.e. Site 1 vs Site 1, Site 2 vs Site 2, Site 3 vs Site 3) were compared between Location 1 and Location 2, for groups of taxa (i.e. to order or family), or combined total abundances of taxa, there was also no evidence of any differences between the sites. Furthermore, abundances of all aquatic orders were compared separately between locations and no statistically significant differences were detected.

5.3.2 Compositions and temporal abundance of taxa

When looking at compositions of individual taxa groups, Trichoptera and Tipulidae were dominant within both locations (Figure 32).

[21] The odonate group have been excluded from the results as only 1 individual was recorded during the study.

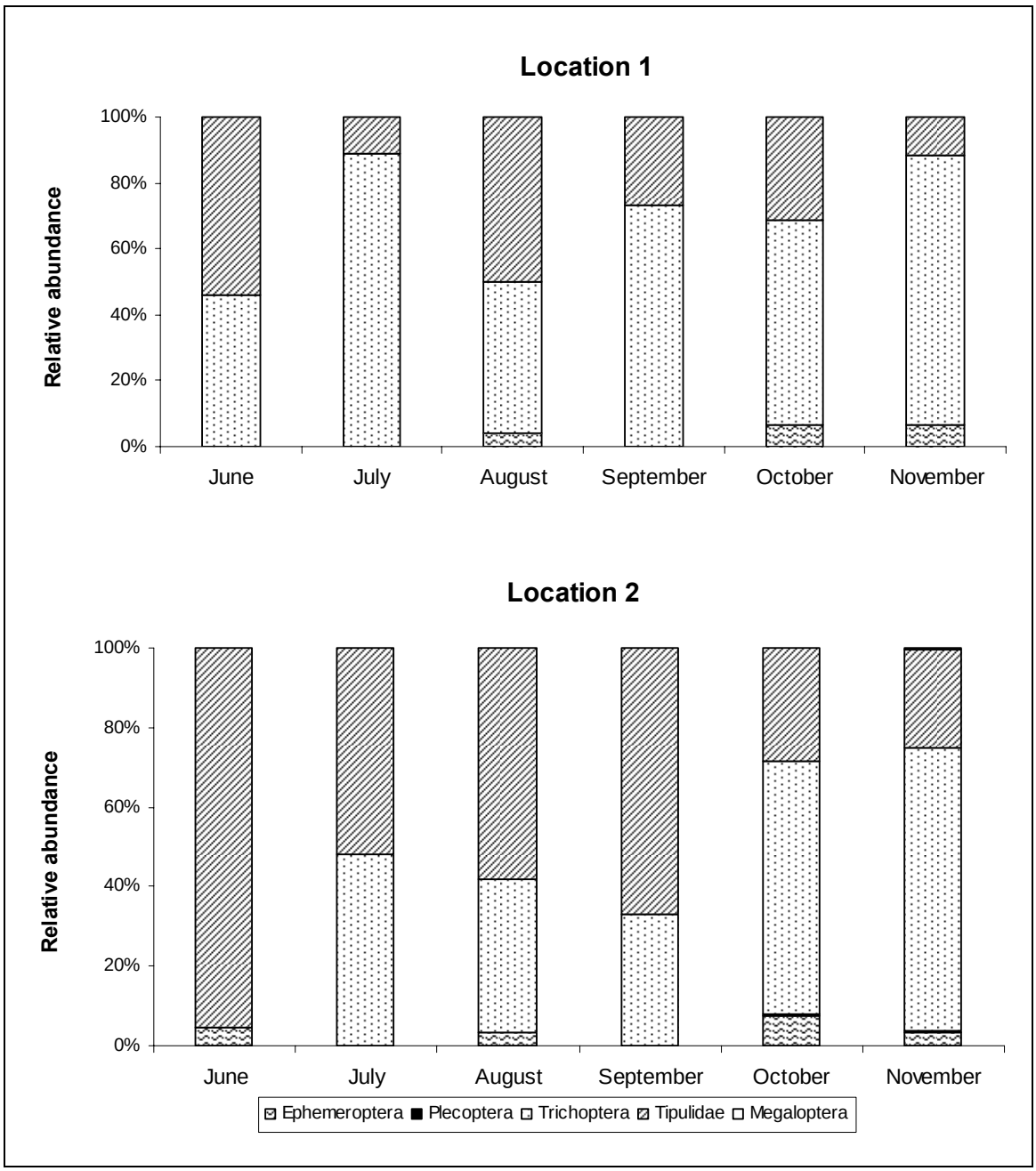

Figure 32. Composition of aquatic invertebrate taxa recorded by light trap from Location 1 and Location 2 between June–November 2005.

Temporal abundances of the aquatic taxa recorded a steady increase of Trichoptera and Tipulidae throughout the study period, with a sharp increase in Trichoptera during November (Figure 33). Ephemeroptera, Plecoptera, and Megaloptera only began to become active, in low numbers, during October and November.

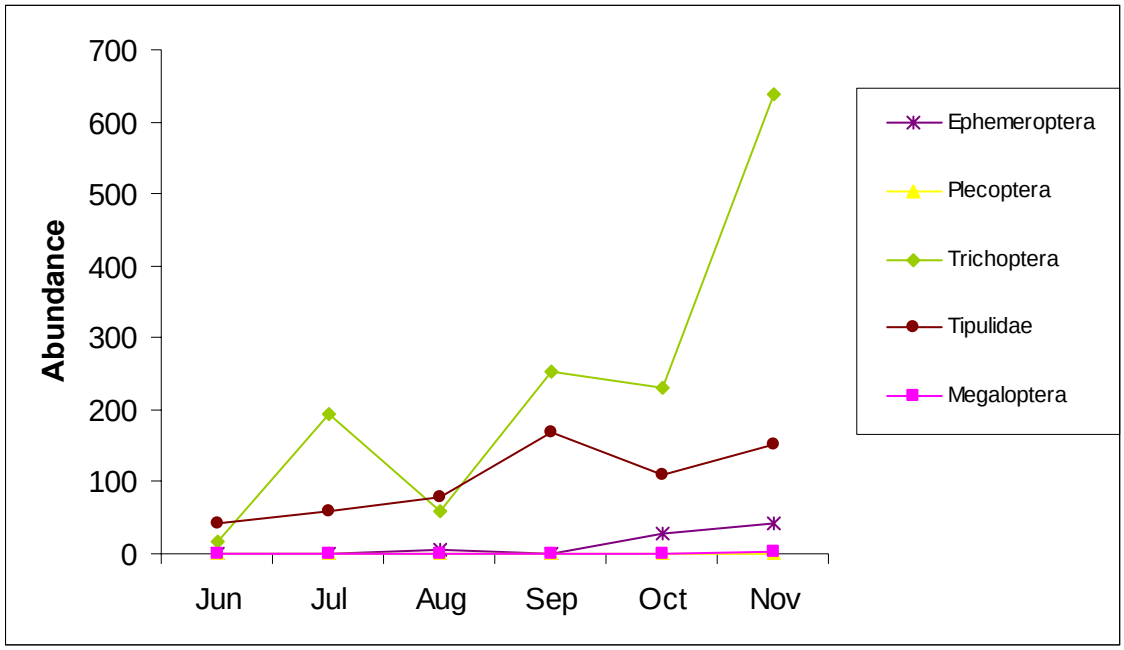

Figure 33. Abundances of aquatic invertebrate taxa recorded by light trap from the Matapouri catchment (Location 1 and 2 combined) between June–November 2005.

5.4 Discussion

5.4.1 Invertebrate abundances

Although light trapping recorded identical results to the sticky trapping in terms of orders of taxa present in the catchment, the abundances recorded were markedly different. As light traps are an active rather than passive collection method, one could predict large abundances in the catch, if insects are present. However, in contrast to both the benthic and sticky trap investigations, the light traps recorded no statistical differences between sites, between locations, or between sites across locations. Although it seems feasible that as winged adults appear reasonably motile their presence should not be overly restricted and be capable to journey the short distances involved between sites, and even locations. However, a number of authors have suggested the majority of aquatic orders display limited lateral dispersal, with suggestions that the main region of activity being 15–30m (Jackson & Resh 1989, Kovats *et al*. 1996, Collier & Smith 1998, Griffith *et al*. 1998). This is particularly noted for Trichoptera and Plecoptera, which are acknowledged as poor fliers (Petersen *et al*. 1999).

This being said, it is unlikely that this is the reason for the abundance differences between light trap results and the results of the other collection methods. The differences are most likely to be a result of the light trap method design or sampling procedure itself. Two possibilities seem to be most likely; limited trap replication, thus

sampling effort, and the bias of the light trapping method. Light traps are acknowledged to bias toward catching particular species and not others. Brown (1987) stated that riffle beetles are often absent from light trap collections because they fly during the day. Kovats *et al*. (1996) reported sex ratios of some groups tend to be female biased, further limiting the catch. Finally, sampling effort of the light trapping procedure may not have been intensive enough as sampling was only carried out at night (restricting the catch to nocturnal fauna), and sampling was restricted to one trap night per site per month.

5.4.2 Study limitations

As mentioned in the previous chapter discussion regarding study limitations, the sticky trapping and light trapping studies were intended to provide a vastly more detailed description of community compositions, life-histories, and seasonality of adult stage aquatic invertebrates. However, it wasn't until after all fieldwork was complete that it was realised how difficult the identification was going to be to provide a meaningful level of resolution. There was not enough time or expertise to complete the identification to the desired level, within the required timeframe, thus only an overview has been provided, as supporting data to the benthic chapter. In addition, it is acknowledged that data collection was only for a six-month period, however monthly light trapping has continued and a paper looking at a full season of data, with finer resolution of identification, will be completed in the near future.

The lights traps were activated manually in sequence and operated from dusk till the time the battery voltage dropped and the light switched off, approximately seven hours later. The time between the first and last activation was 60–80 minutes. However timing units, following Collier & Smith (1996), would have enabled all traps to be switched on and off simultaneously. Timing units were investigated but were beyond the project budget.

Chapter 6 *– Concluding remarks*

6.1 Significant results and implications

A study of the aquatic invertebrates from three differing local-scale habitats, native forest, native forest-fringe, and raupo wetland, from two locations within the Matapouri catchment was conducted to assess community structure. Four data collection methods were undertaken; benthic kick-sampling, sticky trapping, light trapping, and emergence trapping. Emergence trapping was discontinued after two months, due to successive flooding events. 33,058 adult or larval invertebrates were recorded over the six-month data collection period (June–November).

Investigations of aquatic larvae from the stream benthos recorded 71 taxa by kick-sampling over the six month period, with a mean of approximately 30 taxa per site per month. In comparison with similar studies elsewhere in New Zealand, a figure of around 30 taxa per sample was high. The benthic macroinvertebrate fauna at all sites was dominated by Trichoptera, Diptera, and Ephemeroptera. This pattern of diversity is similar to that reported in other New Zealand studies. In contrast to previous studies, the leptophlebiid mayfly genus *Deleatidium* was not numerically dominant over the rest of the community, and other leptophlebiid genera (*Acanthophlebia*, *Atalophlebioides*, *Mauiulus* and *Zephlebia*) were equally represented, possibly reflecting niche partitioning between the groups. The rare mayfly *Isothraulus abditus* was recorded at one of the forest locations. There are no published records of this species from Northland.

In contrast to the Trichoptera, Diptera, and Ephemeroptera, the Plecoptera fauna was relatively depauperate at Matapouri, probably reflecting the near sub-tropical climate of the region and lack of temperature-buffered streams. Interestingly, *Zelandobius* spp., a core New Zealand genus, was absent but is regularly recorded in Northland. A species of conservation interest, *Spaniocercoides watti*, currently recognised as a Northland endemic, was recorded in low numbers.

There were no apparent trends in diversity or abundance of benthic invertebrates over time. Also, there were no significant differences in species diversity between the two locations. However, in many cases, taxa were more abundant at Location 2. This may have been due to steeper gradients at Location 2, and the consequent effects on substrate size and streambed stability, as all other physical factors appeared similar between

locations. Although several significant differences of individual benthic taxa were recorded, no broad effect of habitat (sites) on species diversity was observable. However, at Location 2, abundances were significantly higher at Site 3 (Forest) compared to Site 2 (Forest-fringe). The reasons for this were unclear, but may be attributed to higher retention of allochthonous organic materials, trapped by in-stream cover and larger substrates.

Investigations of adult stages by sticky traps mirrored most benthic results recording community compositions and abundances dominated by Trichoptera and Diptera, while Plecoptera were poorly represented. Location 2 recorded higher abundances of taxa, particularly Ephemeroptera and Plecoptera.

Investigations of adult stages by light traps however did not produce any statistically significant differences in abundances between sites, between locations, or between sites across locations, and it is believed to be due to limited sampling replication combined with some biases of light trapping.

This study indicates that the aquatic invertebrate community at Matapouri is diverse but also reasonably representative. Several rare or uncommon insects inhabit the catchment. It is therefore important that Iwi and the local Landcare Group, who invited and supported this research, together with the Department of Conservation, continue their efforts in protecting these areas. The resident fauna have the capacity to restock areas downstream, which are intended for restoration through sediment controls and riparian management.

6.2 **Methodology** (study of the methods)

6.2.1 Emergence trapping

Emergence trapping was initially scheduled to be carried out monthly, and set for a 14 day period. Pilot studies during March–May 2005 successfully caught aquatic insect adult stages, however the traps were destroyed several times by repeated flooding events, and the sampling method was discontinued after only two months. No meaningful results were collected however the traps did prove to be a useful method of collection during trial runs. Diptera, Ephemeroptera, and Trichoptera specimens were all collected in low numbers and the method could be improved by setting the trap over

a sturdy frame made of plastic or lightweight metal. I would also recommend including in the trap design a killing/preserving jar with collection funnel. Not a lot can be done to avoid flooding situations when the study site is remote, and visited irregularly, and I would recommend avoiding this situation if at all possible by selecting study sites that can be readily accessed when heavy rainfall is forecast, and to clear the contents of the traps frequently e.g. weekly.

6.2.2 Benthic and adult studies

Benthic kick-sampling, sticky trapping, and light trapping studies were quite successful, in both the design and implementation, and produced a lot of useful data, however several improvements could be made, with better planning and resources. Firstly, and possibly most importantly, a six month study intending to collect life-history data, was always going to be of limited usefulness. This was acknowledged before commencement, but was not possible to undertake. It would certainly be more useful to be able to collect a 12 month dataset.

The light trapping results did not produce any statistically significant differences in abundances between sites, between locations, or between sites across locations, and was a surprising outcome. It is believed to be due to limited sampling replication combined with some biases of light trapping. Light traps are acknowledged to bias toward catching particular species and not others. Sex ratios of some groups tend to be female biased, further limiting the catch. Limitations of the method and can only be overcome by including other methods. However, sampling effort of the light trapping procedure may not have been intensive enough as sampling was only carried out at night (restricting the catch to nocturnal fauna), and sampling was restricted to one trap night per site per month. The light traps were activated manually in sequence and operated from dusk till the time the battery voltage dropped and the light switched off, approximately seven hours later. However timing units, following Collier & Smith (1996), would have enabled all traps to be switched on and off simultaneously, multiple times. Timing units were investigated but were beyond the project budget, but if they were available then traps could be set, as an example, for two hours each night for 7–10 days to increase sampling effort, without additional travel to the study site.

Sticky trapping and light trapping studies were intended to provide a vastly more detailed description of community compositions, life-histories, and seasonality of adult stage aquatic invertebrates. However, it wasn't until after all fieldwork was complete that it was realised how difficult the identification was going to be to provide a meaningful level of resolution. There was not enough time or expertise to complete the identification to the desired level, within the required timeframe, thus only an overview was provided, as supporting data to the benthic study.

6.3 Recommendations for future research

Improved taxonomic resolution of the winged stages, over a 12 month period, to investigate insect life-histories would certainly be recommended for future investigation. Also, a Northland-wide investigation into the habitat of *Isothraulus abditus*, which after a detailed literature search revealed, a reoccurring theme of the habitat being forested headwater streams, low or no surface flows, pool dwelling, with high leaf-pack assemblages. Finally, although few obvious physical differences were noted between the two locations, both the larval and adult communities tended to have larger abundances, and trends of more diverse benthic taxa. Investigations into stability, productivity, and allochthonous material input and retention rates would be valuable.

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Appendices –

Appendix 1 – Emergence trapping

Introduction

Emergence trapping was initially scheduled to be carried out monthly, being set for a 14 day period concurrently with sticky trapping, to provide data on site-specific emergence. Pilot studies during March–May 2005 successfully caught aquatic insect adult stages, however the traps were damaged by a moderate 'fresh' during June 2005 (the first month of sampling). The traps were repaired only to be destroyed beyond repair during July 2005 (the second month of sampling) by repeated flooding events, and the sampling method was discontinued.

Method

Twelve emergence nets were constructed using white 100% polyester voile curtain netting and polyester thread, adapted from the 'tent form' used by Norrie (1969), who reported that his design (terylene net 2.5m x 2m supported by a line tied to trees on either side of the stream) was "disadvantaged" as it was necessary to enter the trap to collect the catch. The emergence traps in this study were 1.3m long by 0.8m wide and were positioned over four corner pegs driven firmly into the substrate. The trap height rose from 0.4m at one end, up to 0.6m at the other, to encourage insect movement upwards to a collection point (Figure 34).

The collection point was accessed through a centrally located zip, and a false base was installed 0.3m from the streambed to collect falling specimens. The false base was loosely tacked inside the trap in such a way that emerging insects were able to climb up the inside of the trap. The trap's base was held to the substrate by rocks placed over canvas flaps (but did not restrict the movement of benthic invertebrates) and additional support to the trap's structure was included by way of polyester string running through the length of both sides of the trap, and tied to objects on the stream bank.

Three replicate emergence traps were operated at Sites 2 and 3 in both Location 1 and 2, and were subjectively positioned above riffle sections of stream.

Figure 34. Final emergence trap design erected in the field. Access to the catch is through the central zip on the top, and the false collection base is clearly visible half-way up the inside of the trap.

Results and conclusions

No meaningful results were collected due to the repeated intervention of unpleasant weather conditions, however the traps did prove to be a useful method of collection during trial runs. Diptera, Ephemeroptera, and Trichoptera specimens were all collected in low numbers and the method could be improved by setting the trap over a collapsible pole-type frame made of plastic or lightweight metal. The other improvement I would recommend is including in the trap design a killing/preserving jar with collection funnel.

Not a lot can be done to avoid flooding situations when the study site is remote, and visited irregularly, and I would recommend avoiding this situation if at all possible by selecting study sites that can be readily accessed when heavy rainfall is forecast, and to clear the contents of the trap frequently e.g. weekly.

Appendix 2 – Significant forest types of Matapouri

Survey date: 06/03/97–23/04/97 (Booth 2005)

- Totara-kanuka/manuka forest on hillslope
- Rimu-tanekaha-totara forest on hillslope
- Totara forest on hillslope
- Kauri-rimu-tanekaha forest on ridge
- Kanuka/manuka shrubland on hillslope
- Kanuka/manuka-kauri-rimu forest on hillslope
- Kauri-kawaka-rimu forest on ridge
- Kanuka/manuka-tanekaha-totara forest on hillslope
- Kanuka/manuka-rimu secondary forest on hillslope
- Totara-taraire forest in gully
- Taraire forest on hillslope
- Tanekaha-taraire forest on hillslope
- Kanuka/manuka-tanekaha-totara shrubland on hillslope
- Kauri-rimu forest on ridge
- Rimu-kauri-tanekaha forest on hillslope
- Mangrove-sea rush association on saltmarsh
- Mangrove forest on saltmarsh

Appendix 3 – Threatened flora and fauna of Matapouri

Data from Booth (2005); Threat classification following Hitchmough *et al*. (2007).

Nationally Endangered

- Australasian bittern (*Botaurus poiciloptilus*)
- Brown teal (*Anas chlorotis* "North Island")
- Fireweed (*Senecio scaberulus*)
- North Island kaka (*Nestor meridionalis septentrionalis*)

Nationally vulnerable

- Caspian tern (*Sterna caspia*)
- Northern New Zealand dotterel (*Charadrius obscurus aquilonius*)
- Reef heron (*Egretta sacra sacra*)

Serious Decline

- *Brachyglottis kirkii*
- North Island brown kiwi (*Apteryx mantelli*)
- Willow-leaved maire (*Mida salicifolia*)

Gradual Decline

- Freshwater crayfish (*Paranephrops planifrons*)
- Freshwater mussel (*Hyridella menziesii*)
- Longfin eel (*Anguilla dieffenbachia*)
- New Zealand pigeon (*Hemiphaga novaeseelandiae*)
- Northern little blue penguin (*Eudyptula minor iredalei*)
- Ornate skink (*Cyclodina ornata*)
- Pacific gecko (*Hoplodactylus pacificus*)
- White-fronted tern (*Sterna striata striata*)

Range Restricted

- Fringed gill mayfly (*Isothraulus abditus*)

Sparse

- *Adelopetalum tuberculatum*
- Banded rail (*Gallirallus philippensis assimilis*)
- Black shag (*Phalacrocorax carbo novaehollandiae*)
- *Fuchsia procumbens*
- Kawaka (*Libocedrus plumose*)
- Large-leaved milk tree (*Streblus banksii*)
- Monoao (*Halocarpus kirkii*)
- North Island fernbird (*Bowdleria punctata vealeae*)
- *Schizaea dichotoma*
- Spotless crake (*Porzana tabuensis plumbea*)

Appendix 4 – LENZ category explanations

(adapted from Leathwick *et al*. 2002)

Environment D1.1a

This environment consists of strongly rolling hills throughout Northland. The climate is warm with very high solar radiation and slight annual water deficits. Predominant soil parent materials are deeply weathered older basalts, andesites and rhyolites with greywacke, argillite and sandstone locally important. Soils are generally imperfectly drained and of moderate natural fertility.

Environment A6.1b

This environment consists of rolling hills north of Auckland. The largest of the A environments (nearly 50% of A's total area), it has warm temperatures, very high solar radiation and low annual water deficits. Sandstone is the most widespread soil parent material closely followed by greywacke – both are deeply weathered. Soils are imperfectly drained and are of low natural fertility.

Environment G3.1b

This environment is widely distributed along gently sloping floodplains of rivers and larger streams throughout Northland. The climate is warm with high solar radiation, high vapour pressure deficits and low annual water deficits. Soil parent materials are mostly fine-textured alluvium. Drainage is moderate and the natural soil fertility is moderate to low.

Appendix 5 – Sampling dates

Table 13. Sampling dates of benthic, light trapping, sticky trapping, and emergence trapping events.

Benthic Sampling	Light trapping	Sticky trapping	Emergence trapping
29/06/05	15–16/06/05	15–29/06/05	15–29/06/05
26/07/05	25–26/07/05	11–25/07/05	11–25/07/05
26/08/05	17–18/08/05	17/08/05–04/09/05	–
04/10/05	04–05/10/05	04–25/10/05	–
25/10/05	25–26/10/05	27/10/05–14/11/05	–
24/11/05	15–16/11/05	24/11/05–08/12/05	–

Appendix 6 – Raw benthic data

Table 14. Abundances of benthic taxa recorded in June 2005 from Sites 2 and 3 at Locations 1 and 2.

			Location 1						Location 2					
			Site 2			Site 3			Site 2			Site 3		
Phylum/Class/Order	**Family**	**Most specific taxon[22]**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**
PLATYHELMINTHES			0	1	1	0	0	0	0	0	0	0	0	0
ANNELIDA														
OLIGOCHAETA			0	0	1	1	0	0	0	0	4	4	0	1
MOLLUSCA														
GASTROPODA	Ancylidae	*Ferrissia dohrnianus*	1	0	0	1	0	0	0	0	1	1	1	0
	Hydrobiidae	*Potamopyrgus antipodarum*	0	0	1	0	2	29	0	3	5	6	7	19
	Lymnaeidae	*Lymnaea* sp.	0	0	0	0	0	0	0	0	0	0	0	0
ARTHROPODA														
CRUSTACEA: Amphipoda			0	0	0	0	0	0	0	0	0	0	0	0
CRUSTACEA: Decapoda	Atyidae	*Paratya curvirostris*	0	0	1	1	0	6	1	0	1	0	1	7
	Parastacidae	*Paranephrops planifrons*	0	0	0	0	0	0	0	1	0	0	0	0
CRUSTACEA: OSTRACODA			0	0	0	0	0	0	0	0	0	0	0	0
ARACHNIDA: Acari			0	1	4	0	0	0	1	0	0	0	0	0
COLLEMBOLA: Arthropleona			0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Ephemeroptera	Ameletopsidae	*Ameletopsis perscitus*	0	0	6	0	0	0	0	0	0	0	0	0
	Coloburiscidae	*Coloburiscus humeralis*	1	1	6	2	1	16	12	8	11	1	0	2
	Ichthybotidae	*Ichthybotus hudsoni*	0	0	0	0	0	0	1	0	0	1	1	0
	Leptophlebiidae	*Acanthophlebia cruentata*	0	2	9	2	9	8	0	5	4	2	2	1
		Atalophlebioides cromwelli	0	0	0	5	3	0	10	3	9	2	8	6
		Deleatidium spp.	0	0	5	0	0	1	3	10	6	6	2	1
		Isothraulus abditus	0	0	0	0	0	0	0	0	2	0	1	0
		Mauiulus luma	8	26	11	9	24	39	16	36	62	30	42	40
		Neozephlebia scita	0	0	0	0	0	0	0	0	0	0	2	8
		Zephlebia spp.	0	0	13	0	1	6	7	0	7	12	15	14
INSECTA: Odonata	Corduliidae	*Antipodochlora braueri*	0	0	5	3	0	0	0	0	0	0	0	0
INSECTA: Plecoptera	Austroperlidae	*Austroperla cyrene*	0	0	0	0	0	0	10	1	5	2	2	1
	Eustheniidae	*Stenoperla prasina*	0	0	0	0	0	0	0	1	0	0	1	0
	Gripopterygidae	*Zelandoperla* sp.	0	1	0	0	0	0	0	0	2	0	0	0
	Notonemouridae	*Spaniocerca zelandica*	0	0	0	0	0	1	1	8	5	0	1	2
		Spaniocercoides watti	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Hemiptera	Veliidae	*Microvelia macgregori*	0	0	0	0	0	0	0	1	0	0	0	0
INSECTA: Megaloptera	Corydalidae	*Archichauliodes diversus*	5	6	8	2	5	0	15	2	2	7	3	2
INSECTA: Coleoptera	Elmidae	*Hydora* sp. (adults & larvae)	3	0	32	2	5	0	0	1	5	1	1	1
	Hydraenidae	*Homalaena* sp.(adults)	3	0	0	3	0	0	1	1	0	0	0	0
	Hydrophilidae		0	0	0	0	0	0	0	0	0	0	0	0
	Ptilodactylidae	*Byrrhocryptus urquharti*	0	0	0	0	0	1	0	0	0	2	0	0
	Scirtidae		1	0	5	0	0	0	0	0	0	0	1	0
	Staphylinidae (adults)		0	0	0	0	0	0	0	0	0	0	0	0
	Unidentified larva 1		0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Diptera	Ceratopogonidae		0	0	0	0	0	0	0	0	0	0	0	0
	Chironomidae	Chironominae	1	0	0	0	0	1	0	0	1	1	6	7
		Harrisius pallidus	0	0	0	0	0	0	0	0	0	0	1	0
		Orthocladiinae	4	1	1	0	2	13	0	0	0	2	9	5
		Tanypodinae	0	1	3	2	1	3	2	1	5	1	1	0
	Dixidae	*Nothodixa* sp.	0	0	0	0	0	1	0	3	0	1	1	0
		Paradixa sp.	0	0	0	0	0	0	0	0	0	0	0	0
	Empididae		0	0	0	0	0	0	0	0	0	0	0	0
	Muscidae		0	0	0	0	0	0	0	0	0	0	0	0
	Psychodidae		0	0	0	0	0	0	0	0	0	0	1	0
	Simuliidae	*Austrosimulium* sp.	2	0	0	0	0	1	1	0	0	0	1	0
	Stratiomyidae		0	0	0	0	0	0	0	0	0	0	0	0
	Tabanidae		0	1	0	0	0	0	0	0	0	0	0	0
	Tanyderidae	*Mischoderus* sp.	0	0	0	0	0	0	0	0	0	0	0	0
	Tipulidae	Eriopterini	0	0	0	0	0	0	1	0	0	2	0	0
		Hexatomini	0	0	1	1	0	0	0	0	0	0	0	0
INSECTA: Trichoptera	Conoesucidae	*Olinga* spp.	65	23	37	12	21	13	5	9	1	5	5	1
		Pycnocentria evecta	1	2	1	1	2	3	2	7	6	1	1	4
		Pycnocentria sylvestris	0	0	0	0	0	1	1	0	0	0	0	0
		Pycnocentrodes aureolus	0	0	0	0	0	0	0	0	0	0	0	0
	Helicopsychidae	*Helicopsyche* spp.	4	2	3	0	0	4	4	1	2	3	2	1
	Hydrobiosidae	*Hydrobiosis* spp.	0	0	0	0	0	0	0	0	0	0	0	0
		Hydrochorema crassicaudatum	0	0	0	0	0	0	0	0	0	0	0	0
		Psilochorema donaldsoni	0	0	0	0	0	0	0	0	0	0	0	0
		Psilochorema macroharpax	0	0	0	0	0	0	2	1	1	0	0	1
		Psilochorema mimicum	0	0	0	0	0	1	0	0	0	0	0	0
	Hydropsychidae	*Orthopsyche fimbriata*	0	1	0	0	1	1	5	0	2	1	2	0
		Orthopsyche thomasi	6	1	3	0	2	9	6	3	6	1	2	2
	Hydroptilidae	Early instar	0	0	0	0	0	0	0	0	0	0	0	0
	Leptoceridae	*Hudsonema amabile*	0	0	1	0	0	0	0	0	0	0	1	0
		Triplectides sp.	0	0	0	0	0	0	0	0	0	0	0	1
	Oeconesidae	*Oeconesus maori*	0	0	1	0	0	0	0	0	0	1	0	0
	Philopotamidae	*Hydrobiosella mixta*	0	1	0	0	0	5	0	0	0	0	1	0
	Polycentropodidae	*Polyplectropus altera*	0	0	0	0	0	0	0	0	0	0	0	0
	Psychomyiidae[23]	*Zelandoptila moselyi*	0	0	0	0	0	1	0	0	0	0	0	0

[22] All individuals were larvae or nymphs unless otherwise stated.

[23] *Zelandoptila moselyi* is currently placed in the family Psychomyiidae however based on a current revision of the species it is believed to belong in the family Ecnomidae (Brian Smith, NIWA Hamilton, pers. comm. 11/06/07).

Table 15. Abundances of benthic taxa recorded in July 2005 from Sites 2 and 3 at Locations 1 and 2.

			Location 1						Location 2					
			Site 2			Site 3			Site 2			Site 3		
Phylum/Class/Order	**Family**	**Most specific taxon[24]**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**
PLATYHELMINTHES			4	0	0	1	0	1	0	1	0	0	0	0
ANNELIDA														
OLIGOCHAETA			0	1	0	0	0	0	0	1	0	0	0	0
MOLLUSCA														
GASTROPODA	Ancylidae	*Ferrissia dohrnianus*	0	0	0	1	0	1	1	0	0	1	0	1
	Hydrobiidae	*Potamopyrgus antipodarum*	0	0	0	1	1	0	1	0	0	0	1	3
	Lymnaeidae	*Lymnaea* sp.	0	0	0	0	0	0	0	0	0	0	0	0
ARTHROPODA														
CRUSTACEA: Amphipoda			0	0	0	0	0	0	0	0	0	0	0	0
CRUSTACEA: Decapoda	Atyidae	*Paratya curvirostris*	0	0	0	0	0	0	0	0	0	0	0	0
	Parastacidae	*Paranephrops planifrons*	0	0	0	0	0	0	0	0	0	0	0	0
CRUSTACEA: OSTRACODA			0	0	0	0	0	0	0	0	0	0	0	0
ARACHNIDA: Acari			2	1	0	0	0	0	0	0	0	0	0	0
COLLEMBOLA: Arthropleona			0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Ephemeroptera	Ameletopsidae	*Ameletopsis perscitus*	0	0	0	0	0	0	0	0	0	0	0	0
	Coloburiscidae	*Coloburiscus humeralis*	0	5	13	3	11	8	2	1	0	3	2	12
	Ichthybotidae	*Ichthybotus hudsoni*	0	0	0	0	0	0	0	0	1	0	0	0
	Leptophlebiidae	*Acanthophlebia cruentata*	0	0	3	4	1	3	1	0	0	0	0	0
		Atalophlebioides cromwelli	3	0	3	0	5	4	3	5	2	5	2	1
		Deleatidium spp.	2	4	0	0	0	1	0	27	0	1	1	5
		Isothraulus abditus	0	0	0	0	0	0	0	0	0	0	0	0
		Mauiulus luma	2	28	8	2	5	15	29	39	13	25	38	34
		Neozephlebia scita	4	2	0	0	0	0	0	0	0	0	0	0
		Zephlebia spp.	6	0	9	8	10	3	3	3	0	12	7	22
INSECTA: Odonata	Corduliidae	*Antipodochlora braueri*	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Plecoptera	Austroperlidae	*Austroperla cyrene*	0	0	1	0	0	0	2	4	4	4	1	0
	Eustheniidae	*Stenoperla prasina*	0	0	2	0	1	0	0	1	0	0	0	0
	Gripopterygidae	*Zelandoperla* sp.	2	0	2	0	1	0	1	1	0	0	1	0
	Notonemouridae	*Spaniocerca zelandica*	0	0	0	0	0	0	1	0	2	2	0	1
		Spaniocercoides watti	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Hemiptera	Veliidae	*Microvelia macgregori*	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Megaloptera	Corydalidae	*Archichauliodes diversus*	2	16	7	1	3	4	4	1	2	0	4	22
INSECTA: Coleoptera	Elmidae	*Hydora* sp. (adults & larvae)	4	1	1	0	0	0	0	0	0	0	0	0
	Hydraenidae	*Homalaena* sp.(adults)	4	0	3	0	0	1	0	0	0	0	0	0
	Hydrophilidae		0	1	0	0	0	0	0	0	0	0	0	0
	Ptilodactylidae	*Byrrhocryptus urquharti*	0	1	1	0	2	0	1	0	1	0	0	0
	Scirtidae		0	1	0	0	0	0	0	0	0	0	0	0
	Staphylinidae (adults)		0	0	0	0	0	0	0	0	0	0	0	0
	Unidentified larva 1		0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Diptera	Ceratopogonidae		0	0	0	0	0	0	0	0	0	0	0	0
	Chironomidae	Chironominae	0	0	1	0	0	0	0	0	1	0	0	0
		Harrisius pallidus	0	0	0	0	0	0	0	0	0	0	0	0
		Orthocladiinae	1	1	0	2	5	0	5	0	3	2	5	1
		Tanypodinae	0	0	1	0	0	1	0	0	2	0	2	0
	Dixidae	*Nothodixa* sp.	1	0	0	1	1	0	0	0	1	0	0	0
		Paradixa sp.	0	0	0	0	0	0	0	0	0	0	0	0
	Empididae		0	0	0	0	0	0	0	0	0	0	0	0
	Muscidae		0	0	0	0	0	0	0	0	0	0	0	0
	Psychodidae		0	0	0	0	0	0	0	0	0	0	0	0
	Simuliidae	*Austrosimulium* sp.	0	0	0	0	1	0	0	0	0	0	0	0
	Stratiomyidae		0	0	0	0	0	0	0	0	0	0	0	0
	Tabanidae		0	0	0	0	0	0	0	0	0	0	0	0
	Tanyderidae	*Mischoderus* sp.	0	0	0	0	0	0	0	0	0	0	0	0
	Tipulidae	Eriopterini	0	0	0	0	0	0	0	1	0	0	0	0
		Hexatomini	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Trichoptera	Conoesucidae	*Olinga* spp.	4	15	0	7	3	11	5	9	14	12	12	13
		Pycnocentria evecta	1	3	0	6	3	1	1	0	2	0	1	1
		Pycnocentria sylvestris	0	0	0	0	0	0	0	0	0	0	0	0
		Pycnocentrodes aureolus	0	0	0	0	0	0	0	0	0	0	0	0
	Helicopsychidae	*Helicopsyche* spp.	0	0	4	0	0	1	0	4	5	1	3	0
	Hydrobiosidae	*Hydrobiosis* spp.	0	0	1	0	0	0	0	0	0	0	1	0
		Hydrochorema crassicaudatum	0	1	0	0	0	0	0	0	0	0	0	0
		Psilochorema donaldsoni	0	0	0	0	0	0	0	0	0	0	0	0
		Psilochorema macroharpax	0	0	0	0	0	0	0	0	0	0	0	0
		Psilochorema mimicum	0	0	0	0	0	0	0	0	0	1	0	1
	Hydropsychidae	*Orthopsyche fimbriata*	1	0	14	0	0	0	6	0	0	1	1	3
		Orthopsyche thomasi	1	1	10	0	5	4	8	1	0	3	2	0
	Hydroptilidae	Early instar	0	0	0	0	0	0	0	0	0	0	0	0
	Leptoceridae	*Hudsonema amabile*	0	0	0	0	0	0	0	0	0	0	0	0
		Triplectides sp.	0	0	0	0	0	0	0	0	0	0	0	0
	Oeconesidae	*Oeconesus maori*	0	1	0	0	0	0	1	0	0	0	0	0
	Philopotamidae	*Hydrobiosella mixta*	1	0	1	1	9	7	2	0	0	1	0	0
	Polycentropodidae	*Polyplectropus altera*	0	0	0	0	0	0	0	0	0	0	0	0
	Psychomyiidae[25]	*Zelandoptila moselyi*	0	0	0	0	0	0	0	0	0	0	0	0

[24] All individuals were larvae or nymphs unless otherwise stated.

[25] *Zelandoptila moselyi* is currently placed in the family Psychomyiidae however based on a current revision of the species it is believed to belong in the family Ecnomidae (Brian Smith, NIWA Hamilton, pers. comm. 11/06/07).

Table 16. Abundances of benthic taxa recorded in August 2005 from Sites 2 and 3 at Locations 1 and 2.

			Location 1						Location 2					
			Site 2			Site 3			Site 2			Site 3		
Phylum/Class/Order	**Family**	**Most specific taxon[26]**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**
PLATYHELMINTHES			0	0	0	0	0	0	0	1	0	2	3	0
ANNELIDA														
OLIGOCHAETA			0	0	0	0	0	0	0	0	0	0	0	0
MOLLUSCA														
GASTROPODA	Ancylidae	*Ferrissia dohrnianus*	0	0	0	0	0	0	0	0	0	1	0	0
	Hydrobiidae	*Potamopyrgus antipodarum*	0	0	0	0	0	3	3	3	0	1	1	1
	Lymnaeidae	*Lymnaea* sp.	0	0	0	0	0	0	0	0	0	0	0	0
ARTHROPODA														
CRUSTACEA: Amphipoda			0	0	0	0	0	0	0	0	0	0	0	1
CRUSTACEA: Decapoda	Atyidae	*Paratya curvirostris*	0	0	0	0	0	0	0	0	0	0	0	0
	Parastacidae	*Paranephrops planifrons*	0	0	0	0	0	0	0	0	0	0	0	0
CRUSTACEA: OSTRACODA			0	0	0	0	0	0	0	0	0	0	0	0
ARACHNIDA: Acari			0	0	1	3	0	0	0	0	1	0	1	0
COLLEMBOLA: Arthropleona			0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Ephemeroptera	Ameletopsidae	*Ameletopsis perscitus*	0	0	0	0	0	0	0	0	0	0	0	0
	Coloburiscidae	*Coloburiscus humeralis*	2	0	0	5	2	21	5	3	0	5	6	15
	Ichthybotidae	*Ichthybotus hudsoni*	0	1	0	0	0	0	0	0	0	1	0	0
	Leptophlebiidae	*Acanthophlebia cruentata*	0	2	7	3	1	1	8	40	5	22	9	52
		Atalophlebioides cromwelli	0	0	0	0	0	0	0	0	0	0	7	3
		Deleatidium spp.	0	1	1	2	1	0	0	0	4	7	5	4
		Isothraulus abditus	0	0	0	0	0	0	0	0	0	0	0	0
		Mauiulus luma	9	22	13	22	15	14	15	22	6	36	46	16
		Neozephlebia scita	0	0	0	0	0	0	1	3	5	0	10	6
		Zephlebia spp.	6	26	6	6	4	7	5	10	16	16	11	11
INSECTA: Odonata	Corduliidae	*Antipodochlora braueri*	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Plecoptera	Austroperlidae	*Austroperla cyrene*	0	0	0	0	3	3	2	3	0	0	1	4
	Eustheniidae	*Stenoperla prasina*	2	0	0	0	1	0	1	0	2	0	0	0
	Gripopterygidae	*Zelandoperla* sp.	3	0	0	2	0	0	5	2	4	2	0	1
	Notonemouridae	*Spaniocerca zelandica*	0	0	0	0	0	0	0	0	0	0	0	0
		Spaniocercoides watti	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Hemiptera	Veliidae	*Microvelia macgregori*	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Megaloptera	Corydalidae	*Archichauliodes diversus*	3	4	2	7	3	2	5	8	1	3	0	5
INSECTA: Coleoptera	Elmidae	*Hydora* sp. (adults & larvae)	0	5	4	2	5	2	1	0	0	0	0	0
	Hydraenidae	*Homalaena* sp.(adults)	0	0	0	0	0	2	0	0	0	0	0	0
	Hydrophilidae		0	0	0	0	0	0	0	0	0	1	0	0
	Ptilodactylidae	*Byrrhocryptus urquharti*	0	4	0	0	0	0	0	0	0	0	0	0
	Scirtidae		0	0	0	0	0	0	0	0	0	0	0	0
	Staphylinidae (adults)		0	0	0	0	0	0	0	0	0	0	0	0
	Unidentified larva 1		0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Diptera	Ceratopogonidae		0	0	0	0	1	0	0	0	0	1	1	0
	Chironomidae	Chironominae	0	0	0	0	0	0	0	0	0	1	0	0
		Harrisius pallidus	0	0	0	0	0	0	0	0	0	0	0	0
		Orthocladiinae	4	0	0	1	0	3	3	2	3	15	2	0
		Tanypodinae	0	0	0	0	0	0	0	2	1	1	3	0
	Dixidae	*Nothodixa* sp.	0	0	0	0	0	0	0	0	0	1	0	1
		Paradixa sp.	0	0	0	0	0	0	0	0	0	0	0	0
	Empididae		0	0	0	0	0	0	0	1	0	0	0	0
	Muscidae		0	0	0	0	0	0	0	0	0	0	0	0
	Psychodidae		0	0	0	0	0	0	0	0	0	0	0	0
	Simuliidae	*Austrosimulium* sp.	0	0	0	0	0	0	0	0	0	3	0	0
	Stratiomyidae		0	0	0	0	0	0	0	0	0	0	0	0
	Tabanidae		0	2	0	0	0	0	0	0	0	0	0	0
	Tanyderidae	*Mischoderus* sp.	0	0	0	0	0	0	0	0	0	0	0	0
	Tipulidae	Eriopterini	0	0	0	0	0	0	0	0	0	0	0	0
		Hexatomini	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Trichoptera	Conoesucidae	*Olinga* spp.	4	6	13	10	11	6	10	19	5	43	2	15
		Pycnocentria evecta	2	0	1	2	4	2	6	4	0	4	4	4
		Pycnocentria sylvestris	0	0	0	0	0	0	0	0	0	0	0	0
		Pycnocentrodes aureolus	0	0	0	0	0	0	0	0	0	0	0	0
	Helicopsychidae	*Helicopsyche* spp.	0	3	2	1	3	4	1	0	0	0	0	1
	Hydrobiosidae	*Hydrobiosis* spp.	0	0	0	0	0	0	0	0	1	2	1	0
		Hydrochorema crassicaudatum	0	1	0	0	0	0	0	1	1	0	0	0
		Psilochorema donaldsoni	0	0	0	0	0	0	0	0	0	0	0	0
		Psilochorema macroharpax	0	0	0	1	0	0	0	0	0	0	0	0
		Psilochorema mimicum	1	0	0	0	0	0	0	0	0	6	0	0
	Hydropsychidae	*Orthopsyche fimbriata*	3	0	0	0	3	3	2	0	1	3	0	3
		Orthopsyche thomasi	0	4	0	0	0	4	2	1	2	3	2	4
	Hydroptilidae	Early instar	0	0	0	0	0	0	0	0	0	0	0	0
	Leptoceridae	*Hudsonema amabile*	0	0	0	0	0	0	0	0	0	0	0	0
		Triplectides sp.	0	0	0	0	0	0	0	0	0	0	0	0
	Oeconesidae	*Oeconesus maori*	0	0	0	0	0	0	0	0	0	0	0	0
	Philopotamidae	*Hydrobiosella mixta*	9	0	0	5	5	1	7	0	0	0	0	2
	Polycentropodidae	*Polyplectropus altera*	0	0	0	0	0	0	0	0	0	0	0	0
	Psychomyiidae[27]	*Zelandoptila moselyi*	0	0	0	0	0	0	0	0	0	0	0	0

[26] All individuals were larvae or nymphs unless otherwise stated.

[27] *Zelandoptila moselyi* is currently placed in the family Psychomyiidae however based on a current revision of the species it is believed to belong in the family Ecnomidae (Brian Smith, NIWA Hamilton, pers. comm. 11/06/07).

Table 17. Abundances of benthic taxa recorded in September 2005 from Sites 2 and 3 at Locations 1 and 2.

			Location 1						Location 2					
			Site 2			Site 3			Site 2			Site 3		
Phylum/Class/Order	**Family**	**Most specific taxon[28]**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**
PLATYHELMINTHES			5	0	2	0	3	5	4	1	0	0	0	0
ANNELIDA														
OLIGOCHAETA			0	0	0	1	0	0	1	0	0	0	0	0
MOLLUSCA														
GASTROPODA	Ancylidae	*Ferrissia dohrnianus*	0	0	0	0	0	2	3	1	0	1	1	5
	Hydrobiidae	*Potamopyrgus antipodarum*	1	0	0	2	4	5	14	3	6	0	3	16
	Lymnaeidae	*Lymnaea* sp.	1	0	0	0	0	0	0	0	0	0	0	0
ARTHROPODA														
CRUSTACEA: Amphipoda			0	0	0	0	0	0	0	0	0	0	0	0
CRUSTACEA: Decapoda	Atyidae	*Paratya curvirostris*	0	0	0	0	0	0	0	0	0	0	0	0
	Parastacidae	*Paranephrops planifrons*	0	0	0	0	0	0	0	0	0	0	0	0
CRUSTACEA: OSTRACODA			0	0	0	0	1	0	1	0	0	0	0	0
ARACHNIDA: Acari			1	0	1	0	0	0	0	0	0	2	0	1
COLLEMBOLA: Arthropleona			0	0	0	0	0	0	0	0	1	0	0	0
INSECTA: Ephemeroptera	Ameletopsidae	*Ameletopsis perscitus*	0	0	0	0	0	0	0	0	0	0	0	0
	Coloburiscidae	*Coloburiscus humeralis*	4	5	5	0	5	7	0	0	1	9	3	8
	Ichthybotidae	*Ichthybotus hudsoni*	0	0	0	0	0	0	1	1	0	0	1	0
	Leptophlebiidae	*Acanthophlebia cruentata*	6	3	5	4	4	4	1	0	0	5	2	0
		Atalophlebioides cromwelli	0	0	4	0	1	2	2	0	0	4	5	10
		Deleatidium spp.	3	0	1	1	0	0	0	0	1	0	0	7
		Isothraulus abditus	0	0	0	0	0	0	0	0	0	0	0	0
		Mauiulus luma	5	1	24	6	7	8	5	1	1	56	22	30
		Neozephlebia scita	0	0	0	0	0	3	0	0	0	2	4	4
		Zephlebia spp.	4	3	2	4	3	4	2	0	1	11	10	38
INSECTA: Odonata	Corduliidae	*Antipodochlora braueri*	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Plecoptera	Austroperlidae	*Austroperla cyrene*	3	2	1	3	1	4	2	0	3	5	2	3
	Eustheniidae	*Stenoperla prasina*	1	1	1	0	0	0	1	0	0	1	0	3
	Gripopterygidae	*Zelandoperla* sp.	1	0	2	0	2	3	3	0	1	3	0	0
	Notonemouridae	*Spaniocerca zelandica*	0	0	0	0	0	0	0	0	0	0	0	0
		Spaniocercoides watti	0	0	0	0	0	0	2	0	0	0	0	0
INSECTA: Hemiptera	Veliidae	*Microvelia macgregori*	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Megaloptera	Corydalidae	*Archichauliodes diversus*	15	10	3	5	4	7	10	5	2	0	7	6
INSECTA: Coleoptera	Elmidae	*Hydora* sp. (adults & larvae)	8	1	17	12	4	7	1	2	1	1	0	0
	Hydraenidae	*Homalaena* sp.(adults)	0	0	3	1	1	1	0	0	1	0	1	0
	Hydrophilidae		1	0	0	0	0	0	0	0	0	0	0	0
	Ptilodactylidae	*Byrrhocryptus urquharti*	0	1	1	1	0	1	0	2	0	0	1	0
	Scirtidae		0	0	0	0	0	0	0	1	0	0	0	0
	Staphylinidae (adults)		0	0	0	0	0	0	0	0	0	0	0	0
	Unidentified larva 1		0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Diptera	Ceratopogonidae		0	0	0	0	1	0	0	0	0	1	0	0
	Chironomidae	Chironominae	4	1	5	18	2	4	0	3	52	0	0	0
		Harrisius pallidus	0	0	0	0	0	0	0	0	0	0	0	0
		Orthocladiinae	6	4	8	0	6	8	15	4	11	2	1	1
		Tanypodinae	0	0	4	1	3	5	0	0	4	2	1	0
	Dixidae	*Nothodixa* sp.	0	0	0	0	0	0	0	0	0	0	0	1
		Paradixa sp.	0	0	0	0	1	0	0	2	0	1	0	0
	Empididae		0	2	0	0	0	0	0	0	0	0	0	0
	Muscidae		0	0	0	0	0	0	0	0	1	0	0	0
	Psychodidae		0	0	0	0	0	0	0	0	0	0	0	0
	Simuliidae	*Austrosimulium* sp.	0	0	0	0	0	0	0	0	0	0	0	0
	Stratiomyidae		0	0	0	0	1	0	0	0	0	0	0	0
	Tabanidae		0	0	0	0	0	0	0	0	0	0	0	0
	Tanyderidae	*Mischoderus* sp.	0	0	0	0	0	0	0	0	0	0	0	0
	Tipulidae	Eriopterini	1	0	3	1	0	0	0	1	1	0	0	0
		Hexatomini	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Trichoptera	Conoesucidae	*Olinga* spp.	67	30	52	27	37	29	26	17	14	51	17	21
		Pycnocentria evecta	5	1	0	5	7	5	3	1	1	2	2	2
		Pycnocentria sylvestris	0	0	0	0	0	0	0	0	0	0	0	0
		Pycnocentrodes aureolus	0	0	0	0	0	0	0	0	0	0	0	0
	Helicopsychidae	*Helicopsyche* spp.	4	0	2	1	6	8	3	3	3	1	0	2
	Hydrobiosidae	*Hydrobiosis* spp.	0	0	0	1	0	0	0	0	0	3	0	0
		Hydrochorema crassicaudatum	0	1	0	0	2	0	1	0	0	0	1	2
		Psilochorema donaldsoni	2	0	1	0	0	0	0	0	0	0	0	0
		Psilochorema macroharpax	0	1	0	0	0	0	0	0	1	2	1	1
		Psilochorema mimicum	0	0	0	0	0	0	0	0	0	0	0	0
	Hydropsychidae	*Orthopsyche fimbriata*	6	2	2	4	5	2	5	1	1	2	1	2
		Orthopsyche thomasi	2	8	1	1	15	5	3	0	0	5	1	2
	Hydroptilidae	Early instar	0	1	0	0	0	0	0	0	0	0	0	0
	Leptoceridae	*Hudsonema amabile*	0	0	0	0	0	0	0	0	0	0	0	0
		Triplectides sp.	0	0	0	0	0	0	0	0	0	0	0	0
	Oeconesidae	*Oeconesus maori*	0	0	0	0	0	0	0	0	0	0	0	0
	Philopotamidae	*Hydrobiosella mixta*	1	0	0	0	0	0	0	0	0	6	0	0
	Polycentropodidae	*Polyplectropus altera*	0	0	0	0	0	0	1	0	0	1	1	1
	Psychomyiidae[29]	*Zelandoptila moselyi*	0	0	0	0	0	0	0	0	0	0	0	0

[28] All individuals were larvae or nymphs unless otherwise stated.

[29] *Zelandoptila moselyi* is currently placed in the family Psychomyiidae however based on a current revision of the species it is believed to belong in the family Ecnomidae (Brian Smith, NIWA Hamilton, pers. comm. 11/06/07).

Table 18. Abundances of benthic taxa recorded in October 2005 from Sites 2 and 3 at Locations 1 and 2.

			Location 1						Location 2					
			Site 2			Site 3			Site 2			Site 3		
Phylum/Class/Order	**Family**	**Most specific taxon[30]**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**
PLATYHELMINTHES			0	0	0	0	1	0	0	14	0	5	1	0
ANNELIDA														
OLIGOCHAETA			0	0	1	0	0	0	0	5	0	1	2	0
MOLLUSCA														
GASTROPODA	Ancylidae	*Ferrissia dohrnianus*	0	0	0	0	0	0	1	0	0	3	0	0
	Hydrobiidae	*Potamopyrgus antipodarum*	0	0	0	3	1	2	1	0	2	1	8	4
	Lymnaeidae	*Lymnaea* sp.	0	0	0	0	0	0	0	0	0	0	0	0
ARTHROPODA														
CRUSTACEA: Amphipoda			0	0	0	0	0	0	0	0	0	0	0	0
CRUSTACEA: Decapoda	Atyidae	*Paratya curvirostris*	0	0	0	0	0	0	0	0	0	0	0	0
	Parastacidae	*Paranephrops planifrons*	0	0	0	0	0	0	0	0	0	0	0	0
CRUSTACEA: OSTRACODA			0	0	0	0	0	0	0	0	0	1	1	0
ARACHNIDA: Acari			0	0	0	0	0	0	0	0	0	1	1	0
COLLEMBOLA: Arthropleona			0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Ephemeroptera	Ameletopsidae	*Ameletopsis perscitus*	0	2	0	0	0	0	0	0	0	0	0	0
	Coloburiscidae	*Coloburiscus humeralis*	0	13	11	2	1	26	1	1	2	3	1	12
	Ichthybotidae	*Ichthybotus hudsoni*	0	0	0	0	0	3	0	0	0	0	1	1
	Leptophlebiidae	*Acanthophlebia cruentata*	4	0	11	1	0	1	1	2	0	14	10	14
		Atalophlebioides cromwelli	3	0	17	2	4	0	2	0	0	2	6	11
		Deleatidium spp.	14	3	37	1	0	0	0	0	1	3	4	19
		Isothraulus abditus	0	0	0	0	0	0	0	0	0	0	0	0
		Mauiulus luma	0	1	8	0	0	2	0	0	0	40	16	18
		Neozephlebia scita	0	0	0	1	1	0	0	0	0	0	1	4
		Zephlebia spp.	1	5	4	0	0	9	2	0	3	25	32	22
INSECTA: Odonata	Corduliidae	*Antipodochlora braueri*	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Plecoptera	Austroperlidae	*Austroperla cyrene*	2	0	0	2	0	5	2	1	1	2	3	3
	Eustheniidae	*Stenoperla prasina*	1	1	0	1	0	1	2	0	1	1	1	1
	Gripopterygidae	*Zelandoperla* sp.	0	0	0	1	0	0	5	0	2	1	4	2
	Notonemouridae	*Spaniocerca zelandica*	0	0	0	0	1	0	0	1	0	0	0	2
		Spaniocercoides watti	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Hemiptera	Veliidae	*Microvelia macgregori*	0	0	0	0	0	0	0	1	0	0	0	0
INSECTA: Megaloptera	Corydalidae	*Archichauliodes diversus*	5	12	23	8	9	9	5	5	5	4	3	8
INSECTA: Coleoptera	Elmidae	*Hydora* sp. (adults & larvae)	3	6	10	5	2	4	0	0	0	1	0	0
	Hydraenidae	*Homalaena* sp.(adults)	0	0	0	0	0	0	0	0	0	0	0	0
	Hydrophilidae		0	0	0	0	0	0	0	0	0	0	0	0
	Ptilodactylidae	*Byrrhocryptus urquharti*	0	0	1	3	2	2	0	1	0	2	0	1
	Scirtidae		0	0	0	0	0	0	0	0	0	0	0	0
	Staphylinidae (adults)		0	0	0	0	0	0	0	0	0	0	1	0
	Unidentified larva 1		0	0	0	0	0	0	0	0	0	1	0	0
INSECTA: Diptera	Ceratopogonidae		0	0	0	0	0	0	0	0	0	0	0	0
	Chironomidae	Chironominae	0	4	0	0	0	2	0	0	0	2	0	0
		Harrisius pallidus	0	0	0	0	0	0	0	0	0	0	0	0
		Orthocladiinae	3	18	3	12	3	4	10	2	33	2	8	6
		Tanypodinae	1	0	0	0	1	3	1	1	1	4	0	2
	Dixidae	*Nothodixa* sp.	0	0	0	0	0	0	0	0	0	1	0	0
		Paradixa sp.	0	0	1	0	0	0	0	0	0	0	1	0
	Empididae		0	0	0	0	0	0	0	0	0	0	0	0
	Muscidae		0	0	0	0	0	0	0	0	0	0	0	0
	Psychodidae		0	0	0	0	0	0	0	0	0	0	0	0
	Simuliidae	*Austrosimulium* sp.	1	1	1	0	0	0	0	0	0	1	2	0
	Stratiomyidae		0	0	0	0	0	0	0	0	0	0	0	0
	Tabanidae		0	0	0	0	1	0	1	0	0	1	1	0
	Tanyderidae	*Mischoderus* sp.	0	0	0	0	0	0	0	0	0	0	0	0
	Tipulidae	Eriopterini	0	0	0	1	0	0	1	1	1	1	0	1
		Hexatomini	0	0	3	0	0	0	0	0	0	0	0	0
INSECTA: Trichoptera	Conoesucidae	*Olinga* spp.	24	25	59	27	16	12	25	12	24	31	24	14
		Pycnocentria evecta	0	0	0	1	0	0	0	0	1	2	1	1
		Pycnocentria sylvestris	0	0	0	0	0	0	0	0	0	0	0	0
		Pycnocentrodes aureolus	0	0	0	0	0	0	0	0	0	0	0	0
	Helicopsychidae	*Helicopsyche* spp.	8	2	4	1	2	0	2	0	0	0	0	0
	Hydrobiosidae	*Hydrobiosis* spp.	0	0	0	0	1	0	0	1	0	1	1	1
		Hydrochorema crassicaudatum	0	0	0	0	0	0	0	0	0	0	1	0
		Psilochorema donaldsoni	0	0	0	0	0	0	0	0	0	0	0	0
		Psilochorema macroharpax	3	5	0	0	2	4	0	0	0	0	2	3
		Psilochorema mimicum	0	0	1	0	0	0	0	0	0	0	0	0
	Hydropsychidae	*Orthopsyche fimbriata*	2	11	1	8	3	5	2	0	1	1	0	0
		Orthopsyche thomasi	0	6	1	0	1	10	2	0	1	1	1	1
	Hydroptilidae	Early instar	0	0	0	0	0	0	0	0	0	0	0	0
	Leptoceridae	*Hudsonema amabile*	0	0	0	0	0	0	0	0	0	0	0	0
		Triplectides sp.	0	0	0	0	0	0	0	0	0	0	0	0
	Oeconesidae	*Oeconesus maori*	0	0	0	0	0	0	0	0	0	0	0	0
	Philopotamidae	*Hydrobiosella mixta*	0	0	0	0	0	0	0	0	0	4	1	0
	Polycentropodidae	*Polyplectropus altera*	0	0	0	0	0	0	0	0	0	1	0	0
	Psychomyiidae[31]	*Zelandoptila moselyi*	0	0	0	0	0	0	0	0	0	0	0	0

[30] All individuals were larvae or nymphs unless otherwise stated.

[31] *Zelandoptila moselyi* is currently placed in the family Psychomyiidae however based on a current revision of the species it is believed to belong in the family Ecnomidae (Brian Smith, NIWA Hamilton, pers. comm. 11/06/07).

Table 19. Abundances of benthic taxa recorded in November 2005 from Sites 2 and 3 at Locations 1 and 2.

			Location 1						Location 2					
			Site 2			Site 3			Site 2			Site 3		
Phylum/Class/Order	**Family**	**Most specific taxon**[32]	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Replicate 1**	**Replicate 2**	**Replicate 3**
PLATYHELMINTHES			0	0	0	0	6	0	12	0	0	0	0	0
ANNELIDA														
OLIGOCHAETA			0	0	0	0	0	0	0	0	0	0	0	0
MOLLUSCA														
GASTROPODA	Ancylidae	*Ferrissia dohrnianus*	0	0	0	0	0	0	0	0	1	0	1	1
	Hydrobiidae	*Potamopyrgus antipodarum*	3	6	2	2	6	3	12	12	15	7	8	11
	Lymnaeidae	*Lymnaea* sp.	0	0	0	0	0	0	0	0	0	0	0	0
ARTHROPODA														
CRUSTACEA: Amphipoda			0	0	0	0	0	0	0	0	0	0	1	0
CRUSTACEA: Decapoda	Atyidae	*Paratya curvirostris*	0	0	0	0	0	0	0	0	0	0	0	0
	Parastacidae	*Paranephrops planifrons*	0	0	1	0	0	0	0	0	0	0	0	0
CRUSTACEA: OSTRACODA			0	0	0	0	0	0	0	0	0	0	0	0
ARACHNIDA: Acari			0	0	0	0	1	1	0	1	0	0	0	0
COLLEMBOLA: Arthropleona			0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Ephemeroptera	Ameletopsidae	*Ameletopsis perscitus*	0	5	0	0	0	0	0	0	0	0	0	0
	Coloburiscidae	*Coloburiscus humeralis*	2	7	2	1	11	7	0	2	0	17	16	14
	Ichthybotidae	*Ichthybotus hudsoni*	0	1	1	0	0	1	0	0	0	1	1	1
	Leptophlebiidae	*Acanthophlebia cruentata*	0	2	9	0	1	1	0	1	0	1	2	7
		Atalophlebioides cromwelli	6	2	5	0	0	0	4	15	3	3	5	25
		Deleatidium spp.	6	11	3	1	11	0	16	4	6	4	2	14
		Isothraulus abditus	0	0	0	0	0	0	0	0	0	0	0	0
		Mauiulus luma	3	2	13	2	6	2	5	3	0	56	32	106
		Neozephlebia scita	0	0	0	0	0	0	0	0	0	0	0	0
		Zephlebia spp.	2	3	15	3	3	4	3	11	0	14	7	18
INSECTA: Odonata	Corduliidae	*Antipodochlora braueri*	0	0	0	0	0	1	0	0	0	0	0	0
INSECTA: Plecoptera	Austroperlidae	*Austroperla cyrene*	0	0	1	0	0	1	2	2	2	4	4	4
	Eustheniidae	*Stenoperla prasina*	0	1	0	0	1	1	0	0	0	0	0	0
	Gripopterygidae	*Zelandoperla* sp.	1	1	0	0	0	0	0	0	0	2	0	3
	Notonemouridae	*Spaniocerca zelandica*	0	0	0	0	0	0	3	0	2	0	0	0
		Spaniocercoides watti	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Hemiptera	Veliidae	*Microvelia macgregori*	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Megaloptera	Corydalidae	*Archichauliodes diversus*	10	6	3	1	4	7	12	8	2	7	6	8
INSECTA: Coleoptera	Elmidae	*Hydora* sp. (adults & larvae)	3	0	2	1	0	3	0	1	0	0	0	2
	Hydraenidae	*Homalaena* sp.(adults)	0	0	1	0	1	0	1	0	0	0	0	0
	Hydrophilidae		0	0	0	0	0	1	0	0	0	0	0	0
	Ptilodactylidae	*Byrrhocryptus urquharti*	0	1	0	1	0	0	2	2	0	1	0	0
	Scirtidae		0	0	0	0	0	0	0	0	0	0	0	0
	Staphylinidae (adults)		0	0	0	1	0	1	0	0	1	1	0	1
	Unidentified larva 1		0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Diptera	Ceratopogonidae		0	0	0	0	0	0	1	0	0	0	1	0
	Chironomidae	Chironominae	0	0	0	1	0	0	0	0	1	0	0	0
		Harrisius pallidus	0	0	0	0	0	0	0	0	0	0	0	0
		Orthocladiinae	5	4	3	10	4	0	12	6	12	1	0	2
		Tanypodinae	1	3	0	1	0	0	3	0	3	3	0	1
	Dixidae	*Nothodixa* sp.	0	0	1	0	0	1	2	1	0	1	1	2
		Paradixa sp.	0	0	0	0	3	1	3	5	4	2	3	2
	Empididae		0	0	0	0	0	0	0	0	0	0	0	0
	Muscidae		0	0	0	0	0	0	0	0	0	0	0	0
	Psychodidae		0	0	0	0	0	0	0	0	0	0	0	0
	Simuliidae	*Austrosimulium* sp.	3	12	3	18	2	0	17	4	10	3	7	1
	Stratiomyidae		0	0	0	0	0	0	0	0	0	0	0	0
	Tabanidae		0	0	0	0	0	0	0	0	0	0	1	0
	Tanyderidae	*Mischoderus* sp.	0	0	0	0	0	1	0	0	0	0	0	0
	Tipulidae	Eriopterini	1	1	0	0	0	0	0	0	0	0	0	0
		Hexatomini	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA: Trichoptera	Conoesucidae	*Olinga* spp.	19	34	53	40	23	47	51	20	15	75	29	33
		Pycnocentria evecta	1	1	1	3	6	2	5	2	1	2	3	5
		Pycnocentria sylvestris	0	0	0	0	0	0	0	0	0	0	0	0
		Pycnocentrodes aureolus	0	0	2	0	0	0	0	0	0	0	0	0
	Helicopsychidae	*Helicopsyche* spp.	2	3	10	2	8	2	0	3	4	1	0	1
	Hydrobiosidae	*Hydrobiosis* spp.	5	3	4	3	1	4	6	2	3	5	3	2
		Hydrochorema crassicaudatum	0	0	0	0	0	0	0	0	0	0	0	0
		Psilochorema donaldsoni	0	0	0	0	0	0	0	0	0	0	0	0
		Psilochorema macroharpax	1	4	3	7	3	5	16	3	9	10	3	3
		Psilochorema mimicum	0	0	0	0	0	0	0	0	0	0	1	0
	Hydropsychidae	*Orthopsyche fimbriata*	1	4	0	4	2	21	0	4	1	2	3	3
		Orthopsyche thomasi	2	3	0	2	2	2	2	7	5	11	13	9
	Hydroptilidae	Early instar	0	0	0	0	0	0	0	0	0	0	0	0
	Leptoceridae	*Hudsonema amabile*	0	0	0	0	0	0	0	0	0	0	0	0
		Triplectides sp.	0	0	0	0	0	0	0	0	0	0	0	0
	Oeconesidae	*Oeconesus maori*	0	0	0	0	0	0	0	0	0	0	0	0
	Philopotamidae	*Hydrobiosella mixta*	1	5	0	3	1	6	0	0	0	8	5	1
	Polycentropodidae	*Polyplectropus altera*	0	0	0	0	0	0	0	0	1	0	2	1
	Psychomyiidae[33]	*Zelandoptila moselyi*	0	0	0	0	0	0	0	0	0	0	0	0

[32] All individuals were larvae or nymphs unless otherwise stated.

[33] *Zelandoptila moselyi* is currently placed in the family Psychomyiidae however based on a current revision of the species it is believed to belong in the family Ecnomidae (Brian Smith, NIWA Hamilton, pers. comm. 11/06/07).

Appendix 7 – Raw sticky trap data

Table 20. Invertebrate abundances collected by sticky trap for all sites within Location 1 and Location 2 for June–July 2005. Terrestrial invertebrates are also reported for completeness.

R = Replicate	June																		July														
	Location 1									Location 2									Location 1									Location 2							
	Site 1			Site 2			Site 3			Site 1			Site 2			Site 3			Site 1			Site 2			Site 3			Site 1			Site 2			Site 3		
Taxon	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
Ephemeroptera	1	0	0	0	1	0	1	0	0	0	0	0	2	3	3	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	4	0	3
Plecoptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	5	10	6	0	14	4	1	4	7	1	2	3	5	9	5	1	9	7	2	3	2	3	10	4	1	1	8	1	1	1	2	11	4	14	5	9
Megaloptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-tipulid Diptera	40	68	52	59	31	546	12	30	23	17	19	46	27	24	14	35	22	49	40	50	64	745	2085	2900	702	61	312	70	34	21	34	33	38	37	141	89
Tipulidae	6	0	4	7	3	3	1	8	4	4	5	2	1	2	8	6	1	7	3	2	6	0	1	0	1	1	1	4	9	3	2	1	1	7	3	6
Odonata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemiptera	0	2	1	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0	3	1	2	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
Coleoptera	5	3	2	5	3	16	2	2	7	5	8	1	6	5	3	8	1	3	7	4	4	12	5	8	2	2	2	6	5	2	1	9	3	9	4	2
Neuroptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hymenoptera	8	5	3	5	1	3	3	2	3	2	8	4	3	1	1	1	3	1	1	1	2	6	4	2	2	2	5	1	1	1	3	2	2	3	4	2
Lepidoptera	6	1	2	1	6	6	3	1	9	8	7	7	5	9	11	6	0	19	3	2	1	3	3	0	0	0	0	1	1	0	0	0	0	0	0	0
Arthropleona	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Symphypleona	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aracnida	1	0	0	3	5	3	0	0	0	1	1	1	3	1	3	0	1	1	0	0	1	2	3	2	3	1	1	0	2	0	0	1	2	2	1	1
Acari	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orthoptera	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blattodea	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 21. Invertebrate abundances collected by sticky trap for all sites within Location 1 and Location 2 for August–September 2005. Terrestrial invertebrates are also reported for completeness.

R = Replicate	August																		September														
	Location 1									Location 2									Location 1									Location 2							
	Site 1			Site 2			Site 3			Site 1			Site 2			Site 3			Site 1			Site 2			Site 3			Site 1			Site 2			Site 3		
Taxon	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
Ephemeroptera	0	1	0	1	0	0	1	2	1	1	0	0	10	4	0	2	0	9	1	4	0	3	0	4	8	18	1	1	1	0	5	10	7	7	3	29
Plecoptera	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	1
Trichoptera	6	0	6	8	9	9	4	2	4	0	7	0	66	10	11	8	6	7	0	0	0	24	6	10	8	93	46	3	0	2	6	14	44	35	100	96
Megaloptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-tipulid Diptera	26	23	57	26	45	64	22	15	49	54	37	46	65	47	45	27	53	193	31	40	26	64	47	41	59	108	69	44	30	60	20	43	65	59	42	64
Tipulidae	0	4	6	8	6	6	5	1	1	2	5	2	14	6	3	5	3	1	3	10	0	22	9	10	11	16	25	9	4	5	20	18	13	17	24	21
Odonata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemiptera	0	1	0	0	0	0	1	0	0	0	0	1	0	0	1	1	1	0	3	4	1	0	1	0	0	1	2	1	0	0	2	0	0	0	1	2
Coleoptera	2	5	8	12	6	2	4	6	7	8	2	7	8	15	124	33	20	3	18	14	2	15	20	18	29	39	30	18	6	7	10	23	22	23	23	32
Neuroptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hymenoptera	2	0	1	2	0	2	1	3	4	3	1	0	2	1	1	0	4	3	3	4	4	5	3	4	7	12	4	3	0	0	1	3	3	0	12	5
Lepidoptera	3	0	0	4	0	3	0	1	0	6	6	3	4	0	3	2	4	2	5	3	3	3	4	3	3	5	1	6	3	3	2	4	3	4	5	7
Arthropleona	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Symphypleona	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aracnida	0	1	1	4	6	1	1	1	3	0	2	0	1	2	1	2	0	5	3	2	1	2	1	1	1	1	0	0	0	0	5	7	0	1	2	2
Acari	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orthoptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0
Blattodea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Table 22. Invertebrate abundances collected by sticky trap for all sites within Location 1 and Location 2 for October–November 2005. Terrestrial invertebrates are also reported for completeness.

R = Replicate	October																		November														
	Location 1									Location 2									Location 1									Location 2							
	Site 1			Site 2			Site 3			Site 1			Site 2			Site 3			Site 1			Site 2			Site 3			Site 1			Site 2			Site 3		
Taxon	R1	R2[34]	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
Ephemeroptera	0	-	0	6	4	6	4	10	37	0	1	1	8	23	22	24	22	30	0	0	0	11	13	5	3	11	17	5	1	1	16	14	29	22	8	18
Plecoptera	0	-	0	0	0	0	1	2	1	0	0	0	1	1	1	2	1	1	0	0	0	0	0	0	0	0	2	0	0	0	1	0	2	2	0	3
Trichoptera	26	-	3	63	8	11	95	120	200	4	1	2	41	28	29	39	203	148	27	7	3	27	35	14	62	47	78	6	6	2	35	16	28	26	121	113
Megaloptera	0	-	0	0	0	2	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	1	0	6	1	0	0	1	0	0	0	7	1	0	2	5
Non-tipulid Diptera	77	-	56	83	54	61	80	116	69	40	51	59	170	184	111	84	106	48	69	39	129	97	43	52	68	71	209	93	52	79	140	110	156	202	113	205
Tipulidae	6	-	4	15	6	4	13	23	15	6	11	10	28	56	20	13	35	26	6	6	1	12	10	4	5	12	7	9	8	3	26	15	16	6	6	12
Odonata	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Hemiptera	1	-	2	0	1	0	1	1	0	2	3	3	0	0	0	0	1	1	1	0	0	2	0	4	0	4	2	3	4	1	0	2	3	4	4	4
Coleoptera	9	-	11	26	19	17	36	32	50	10	8	9	33	34	31	21	44	38	10	11	21	64	11	20	8	12	15	21	8	5	11	14	12	22	22	19
Neuroptera	0	-	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hymenoptera	3	-	3	4	3	9	7	5	2	4	1	1	5	3	3	16	21	9	5	4	9	6	7	3	3	6	5	6	8	0	10	3	19	7	8	15
Lepidoptera	5	-	2	4	2	6	5	4	12	5	2	4	1	3	3	5	7	1	6	0	2	0	3	1	1	0	0	1	10	2	1	1	3	2	0	2
Arthropleona	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Symphypleona	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aracnida	2	-	1	17	9	1	6	3	4	1	1	1	8	0	3	3	4	2	0	0	4	16	10	1	7	5	3	4	3	2	4	3	0	1	4	0
Acari	0	-	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orthoptera	0	-	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blattodea	0	-	1	2	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	4	1	1	0	1	0	0	0

[34] Replicate destroyed by strong winds, thus data not collected.

Appendix 8 – Raw light trap data

Table 23. Invertebrate abundances collected by light trap for all sites within Location 1 and Location 2 for the period of June–November 2005. Terrestrial invertebrates are also reported for completeness.

S = Site	June						July						August						September						October						November					
	Location 1			Location 2			Location 1			Location 2			Location 1			Location 2			Location 1			Location 2			Location 1			Location 2			Location 1			Location 2		
Taxon	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Ephemeroptera	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	1	2	0	0	0	0	0	0	0	7	3	0	4	13	1	20	6	1	5	9
Plecoptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Trichoptera	14	1	2	0	0	0	134	11	14	26	4	6	7	6	11	3	7	26	191	4	11	5	20	21	40	23	28	26	72	42	58	156	117	28	70	210
Megaloptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Non-tipulid Diptera	17	27	12	8	11	1	61	60	30	135	59	30	12	29	32	25	19	63	21	275	331	33	47	23	29	31	18	46	13	20	47	95	41	29	83	141
Tipulidae	10	5	5	10	10	1	11	4	5	24	3	12	2	7	17	6	15	33	45	8	22	61	17	16	19	13	14	44	12	7	14	19	13	41	49	17
Odonata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Hemiptera	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	8	0	0	0	0	0	0	0	0
Coleoptera	2	1	3	0	1	1	0	1	2	2	1	2	2	4	1	1	5	6	1	4	1	0	1	4	2	12	3	3	2	0	1	8	3	0	4	3
Neuroptera	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hymenoptera	1	2	0	0	0	1	0	2	0	0	3	2	0	2	4	0	1	4	1	1	3	0	2	0	1	4	1	2	1	0	0	3	0	0	0	1
Lepidoptera	3	3	5	2	3	0	18	12	4	16	4	6	0	8	4	1	4	3	11	8	9	14	12	16	25	13	13	21	20	28	5	51	25	5	18	28
Arthropleona	8	0	0	2	0	0	18	0	0	2	1	0	2	0	0	2	0	0	2	0	1	1	1	0	0	1	1	0	0	0	0	1	1	0	0	0
Symphypleona	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Aracnida	0	0	0	0	0	0	0	0	0	2	1	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0
Acari	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	2	1	0	10	0	0	0	1	0	0	0	1	1	2	0	0	0	0
Orthoptera	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blattodea	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Appendix 9 – Faunal list of select light trap catches

Table 24. Aquatic orders Ephemeroptera, Plecoptera, Trichoptera, and Megaloptera adults recorded by light trap from Location 1 (one trap-night) and Location 2 (two trap-nights).

Location 1, Site 2 (Feb 2006)	Location 2, Site 3 (Oct/Nov 2005)
Ephemeroptera	**Ephemeroptera**
Deleatidium sp1.	*Atalophlebioides cromwelli*
Zephlebia sp1.	*Deleatidium* sp1.
Zephlebia sp2.	*Zephlebia* sp1.
Trichoptera	**Plecoptera**
Aoteapsyche colonica	*Stenoperla prasina*
Helicopsyche albescens	
Hydrobiosis parumbripennis	**Trichoptera**
Hydrochorema crassicaudatum	*Costachorema hecton*
Neurochorema confusum	*Helicopsyche zealandica*
Oecetis sp1.	*Hudsonema* sp1.
Olinga feredayi	*Hydrobiosella mixta*
Pycnocentria evecta	*Hydrobiosis gollanis*
Pycnocentrodes aureolus	*Hydrobiosis spatulata*
Triplectides obsoletus	*Hydrochorema tenuicaudatum*
	Oecetis sp1.
	Oeconesus maori
	Olinga feredayi
	Olinga jeanae
	Orthopsyche fimbriata
	Oxyethira albiceps
	Polyplectropus altera
	Psilochorema donaldsoni
	Psilochorema macroharpax
	Psilochorema mimicum
	Pycnocentrodes aeris
	Triplectides dolichos
	Triplectides obsoletus
	Zelandoptila moselyi
	Megaloptera
	Archichauliodes diversus