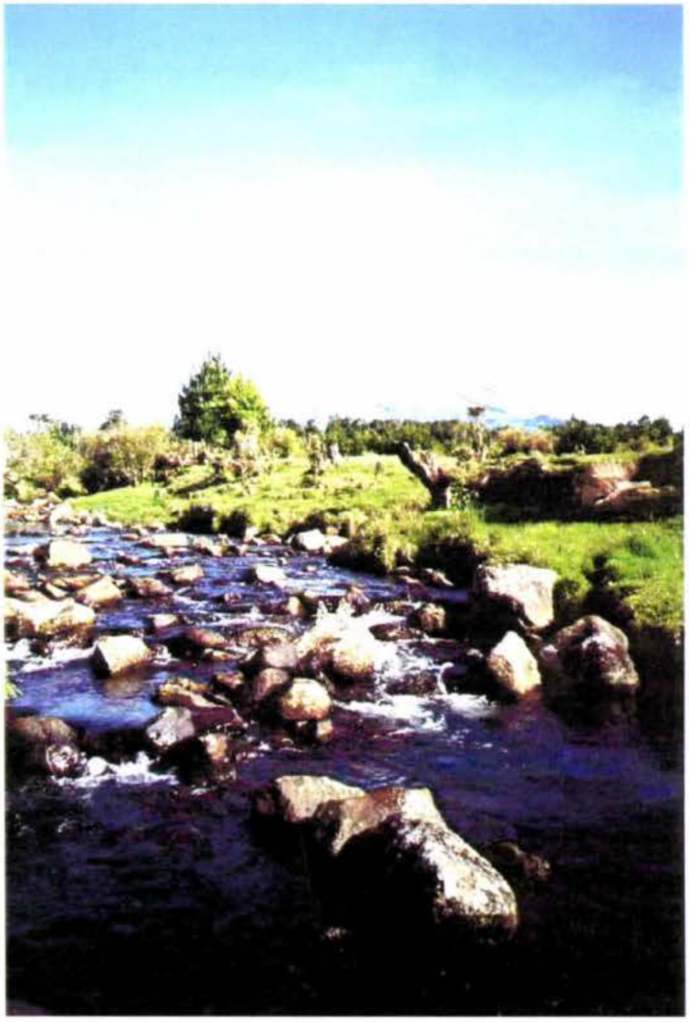
THE EFFECT OF SUBSTRATE STABILITY AND CANOPY COVER ON MACROINVERTEBRATE COMMUNITIES IN TARANAKI RING PLAIN STREAMS



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

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Front cover: Mt Taranaki and Kaupokonui East Stream Tributary.

ABSTRACT

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The relative effect of substrate stability and canopy cover on macroinvertebrate communities, and their possible interaction, were investigated in 10 Taranaki ring plain streams between April 1999 and March 2000. Substrate stability was examined as it is postulated to be the major influencing factor on stream invertebrates and canopy cover as it will effect periphyton, a major invertebrate food source. Invertebrate communities, periphyton biomass and stone movement were monitored at 20 sites on these streams of differing hydrological regime, a closed canopy site and an open canopy site on each stream. Macroinvertebrate species richness and periphyton grazer abundance were higher in open canopy sites than closed canopy sites and this was probably related to periphyton biomass which was higher at the open sites. Species richness displayed a strong quadratic relationship with periphyton biomass and overall macroinvertebrate community composition also appeared to be related to levels of periphyton as dictated by canopy cover. However this effect was overridden by substrate stability when disturbance levels were high.

The effect of substrate stability and cover was also examined in an experiment, in one of the 10 streams; Cold Stream, where both factors could be independently manipulated. Wire mesh substrate baskets which were subjected to either artificial disturbance or left undisturbed were used under an artificial cover. Cover was found to influence invertebrate community composition, probably via its' effect on periphyton biomass, while physical disturbance decreased both invertebrate abundance and diversity.

Keywords: substrate stability; canopy cover; disturbance; productivity; macroinvertebrates; periphyton; community structure; diversity.

CHAPTER 1:

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Within the past few decades disturbance has been increasingly regarded as one of the primary factors affecting community structure (Connell 1978, Huston 1979, Petriaitis et al. 1989). In stream systems disturbance is considered particularly important in structuring the benthic macroinvertebrate communities (Reice et al. 1990, Lake 2000) with Resh et al. (1988) even concluding that "[disturbance] is the dominant organizing factor in stream ecology". Hydrological disturbances such as floods or spates and periods of low flow and drought (Lake 2000) have been shown to affect the invertebrate communities. Disturbance affects invertebrate communities by decreasing total invertebrate abundance (Robinson and Minshall 1986, McCabe and Gotelli 2000), decreasing species diversity (Reice 1985, Sagar 1986, Death 1996) and determining species composition (Death and Winterbourn 1995) with a suite of disturbance resilient and resistant species being established at unstable sites.

Disturbance is thought to affect the invertebrate community directly by increased discharge, flow velocity and movement of sediment and streambed substrate washing away and crushing individual macroinvertebrates (Sagar 1986, Bond and Downes 2000, Lake 2000). Although often not considered or only briefly, it also acts indirectly by altering food resource availability (Lake 2000). Change in food resources is included in Pickett and Whites' (1985) widely referenced (Death and Winterbourn 1995, Resh et al. 1988) definition of disturbance. Scour and loss of periphyton, the primary producer in stream systems and a major food source for invertebrates by disturbance (Robinson and Minshall 1986, Biggs 1995) will intuitively affect the dynamics of many stream communities.

Rather than disturbance being the one controlling factor however, in reality there are multiple abiotic and biotic factors interacting to act on stream communities (Power et al 1988). Abiotic factors include disturbance, water chemistry parameters such as temperature and nutrient concentration and streambed substrate composition while biotic factors include food resource availability or productivity, competition and predation. Each will have varying importance in individual streams and also at differing spatial and temporal scales (Waide et al. 1999, Lake 2000). However, at present the interaction and relative importance of multiple factors is not well understood.

The influence and dynamics of multiple factors has been summarized in theoretical models such as Pecarskys' (1983) harsh-benign hypothesis where the occurrence and importance of competition and predation is dependent on the presence, absence or severity of disturbance. In a low disturbance or benign environment competition and predation will be more important in structuring the community and at high disturbance or in a harsh environment they will not occur. Much theory regarding disturbance however has been developed specifically to describe species diversity, an important emergent feature of community structure in relation to disturbance and productivity. For example, Connells' (1978) Intermediate Disturbance Hypothesis (IDH) predicts highest diversity at intermediate levels of disturbance with competitive exclusion and physical elimination leading to species loss at either end of the disturbance spectrum. Hustons' (1979) dynamic equilibrium model places more emphasis on productivity and regards community structure as a trade off between growth rates, rates of competitive exclusion and predation and the influence of the environment (e.g. disturbance) in allowing these biotic interactions to occur. Hildrew and Townsends' (1987) disturbance-productivity-diversity model follows the IDH at high levels of productivity but predicts lower diversity in less productive habitats which are in turn unaffected by increasing disturbance. This model predicts maximum species diversity at intermediate levels of productivity. Several authors have regarded Hustons' (1979) model to be most relevant to stream systems (Resh et al 1988, Reice et al 1990) but also admit that there is little empirical evidence from past studies. Conversely the IDH is regarded as not very relevant by many (Reice 1985, Reice et al. 1990) but does seem to have the most empirical support (e.g. Robinson and Minshall 1986 and Townsend et al. 1997). Lake (2000), believes that the IDH may have some validity in streams and suggests that the lack of support may simply be that the wrong scales have been used to test the IDH.

This study examines the effect of two factors, substrate stability or disturbance and canopy cover, a well known determinant of periphyton biomass (Cowie 1980, Behmer and Hawkins 1986, Quinn et al. 1997) or primary productivity, on the macroinvertebrate communities in Taranaki ring plain streams. In Chapter two a year long study was completed examining periphyton biomass and macroinvertebrate community structure in 10 streams and 20 sites with varying levels of substrate stability and contrasting canopy cover. In Chapter three an experimental study was run to investigate the role of substrate stability and cover on periphyton biomass and the macroinvertebrate community. Therefore the research questions of these studies were:

1. Does substrate stability effect periphyton biomass and macroinvertebrate communities?
2. Does canopy cover effect periphyton biomass and macroinvertebrate communities?
3. What is the relative influence of substrate stability and canopy cover on periphyton biomass and macroinvertebrate communities and what are the mechanisms which lead to these outcomes?

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CHAPTER 2:

THE EFFECT OF SUBSTRATE STABILITY AND CANOPY COVER ON INVERTEBRATE COMMUNITIES IN TARANAKI RING PLAIN STREAMS

ABSTRACT

Macroinvertebrate communities were sampled between April 1999 and March 2000 in 10 Taranaki ring plain streams with differing substrate stability. Two sites on each stream were sampled, one under complete forest canopy in Egmont National Park and the other approximately 1 km away in open pasture. Presence or absence of canopy cover was predicted to control primary productivity and allow examination of the interaction and relative influence of disturbance and productivity in determining community structure. Macroinvertebrate species richness and grazer abundance were higher in open canopy sites than closed canopy sites where periphyton food was more abundant. Species richness displayed a strong quadratic relationship with periphyton biomass and overall macroinvertebrate community composition also appeared to be related to levels of periphyton as dictated by canopy cover.

Keywords: substrate stability; canopy cover; disturbance; productivity; macroinvertebrates; periphyton; community structure; diversity.

INTRODUCTION

Of the multiple factors interacting to affect stream macroinvertebrate community structure, disturbance is regarded as one of the most important (Resh et al. 1988 Riece et al. 1990, Lake 2000). Hydrological disturbances such as floods physically wash away and crush stream invertebrate individuals. Another effect of disturbance often not considered to the same degree, is the reduction of periphyton biomass or primary productivity food source (Robinson and Minshall 1986, Biggs 1995).

Disturbance has been shown to decrease stream invertebrate abundance (Robinson and Minshall 1986, McCabe and Gotelli 2000), decrease species diversity (Reice 1985, Sagar 1986, Death 1996) and determine overall community structure (Death and

Winterbourn 1995, Cowie 1980) while productivity has been shown to largely increase invertebrate abundance (Towns 1981), both increase and decrease species diversity depending on level of productivity (Townsend et al. 1997) and also affect community composition (Behmer and Hawkins 1986). Disturbance and productivity are both included to varying degrees in several current theories proposed to explain species diversity, for example, in the Intemediate Disturbance Hypothesis (Connell 1978), Hustons' dynamic equilibrium model and Hildrew and Townsends' (1987) disturbance-productivity-diversity model.

Substrate stability is the scale of disturbance considered most relevant to invertebrate individuals (Townsend et al. 1997) while canopy cover is a well known determinant of periphyton biomass or productivity (Cowie 1980, Behmer and Hawkins 1986, Quinn et al. 1997). Therefore in this study I examined the effect of substrate stability and canopy cover on macroinvertebrate communities in 10 Taranaki ring plain streams and 20 sites of varying hydrological regimes and complete contrast in canopy cover as indicators of the influence of disturbance and productivity.

STUDY SITES

Mount Taranaki within Egmont National Park on the West Coast of the North Island, New Zealand is a steep andesitic cone drained by over 300 waterways (Taranaki Regional Council 1994). Inside the park the streams are covered by a full canopy of predominantly rimu-rata-kamahi forest and they all emerge from the circular park boundary into open pasture at an altitude of about 500 m a.s.l. This results in a rather unique situation where there are many streams in the same geographical and geological region which vary from 100 % to 0 % canopy cover within a distance of only several hundred metres. This study was conducted in 10 of these streams located on the south of the mountain chosen because they differ in hydrological regime (Fig. 2.1).

In each stream two sites were sampled: a closed canopy site approximately 50 metres within the park boundary and a lower open canopy site, several hundred metres after the streams' emergence into open pasture (Plate 2.1and 2.2). All streams are small to medium sized (3-7 m wide) first to third order streams, except Mangatoki which is fifth order. All sites have low temperature (8-10 °C) and conductivity (58-96 μS/cm) and all have similar substrate size distribution dominated by large cobbles and boulders. Mean physicochemical and substrate characteristics are given in Table 2.1.

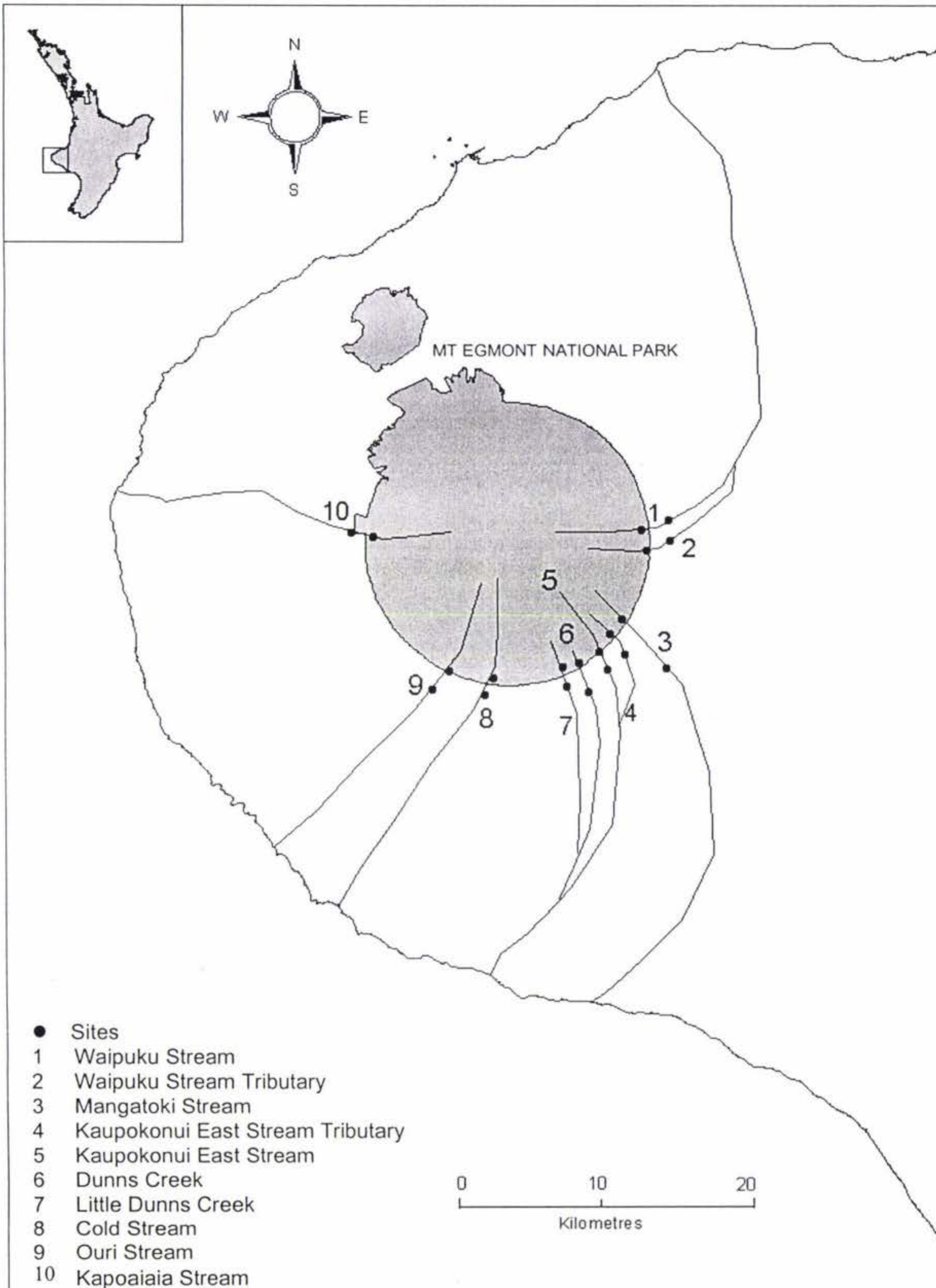


Figure 2.1. Location of 10 Taranaki, North Island, New Zealand, ring plain streams and 20 sites sampled between April 1999 and March 2000

PLATE 2.1.

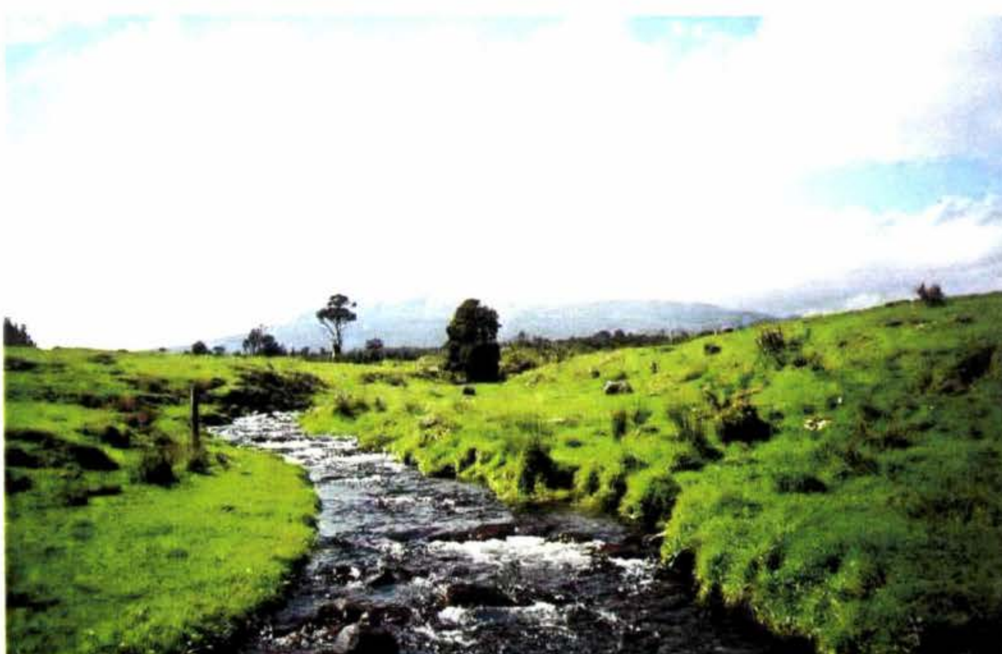


Plate 2.1. Closed canopy site on Waipuku Stream (top) and open canopy site on Cold Stream (bottom), two of 20 Taranaki ring plain stream sites sampled between April 1999 and March 2000.

PLATE 2.2.

Plate 2.2. Closed canopy site on Kaupokonui East Stream (top) and open canopy site on Kapoaiaia Stream (bottom), two of 20 Taranaki ring plain stream sites sampled between April 1999 and March 2000.

Table 2.1. Mean physicochemical, stability and substrate characteristics recorded monthly at 20 Taranaki ring plain stream sites between April 1999 and March 2000. Site grid co-ordinates, stream order, site distance from closed canopy site and site elevation are estimated from a NZMS 260 1:50 000 topographic map. (Cond. = conductivity, Temp. = temperature). F ratios and P values from a two way ANOVA testing the null hypothesis that characteristics are not different between streams and open or closed canopy sites are also given, degrees of freedom in all cases is 1, 9. (Cond. = conductivity, Temp. = temperature).

Stream	Site	Grid co-ordinates	Canopy cover present/ absent	Order	Altitude m a.s.l	Distance from closed canopy site (m)	Depth (cm)	Velocity (m/s)	Width (m)	Cond. (μS/cm)	Temp. (°C)	Substrate size index	Mean stone movement (%)	Intensity of disturbance	Frequency of disturbance	Maximum disturbance	Pfankuch, bottom component
Waipuku Stream	C1	P20:1090 1240	present	1	560		31	0.65	5	58	8	19	12	22	7	33	18
	O1	P20:1250 1285	absent	1	480	1650	31	0.69	7	64	9	19					18
Waipuku Stream Tributary	C2	P20: 1140 1200	present	1	529		33	0.51	5	63	9	22	15	19	7	33	21
	O2	P20:1755 1200	absent	1	520	400	22	0.40	7	62	9	18					29
Mangatoki Stream	C3	P20: 0940 0590	present	2	540		18	0.58	5	74	8	16	3	7	1	27	34
	O3	P20:1190 0270	absent	5	400	3800	26	0.89	5	96	10	16					34
Kaupokonui East Stream Tributary	C4	P20: 0800 0435	present	2	515		25	0.67	5	74	8	24	4	11	2	33	21
	O4	P20:0835 0385	absent	2	485	600	26	0.73	5	77	9	19					22
Kapokonui East Stream	C5	P20: 0755 0400	present	2	505		20	0.60	7	70	9	20	30	23	8	33	31
	O5	P20:0775 0380	absent	2	490	300	23	0.69	6	71	9	20					33
Dunns Creek	C6	P20:0620 0320	present	1	500		16	0.51	5	88	9	16	9	14	5	33	32
	O6	P20:0670 0230	absent	1	455	1000	20	0.55	3	92	10	17					29
Little Dunns Creek	C7	P20:0595 0300	present	1	500		20	0.55	4	88	9	16	7	11	2	33	29
	O7	P20:0590 0230	absent	1	460	750	22	0.53	3	91	9	16					29
Ouri Stream	C8	P20:0050 0220	present	3	450		26	0.99	5	78	8	18	9	16	5	33	23
	O8	P20:0045 0190	absent	3	435	225	28	0.96	5	79	9	23					18
Cold Stream	C9	P20: 9780 0290	present	1	400		27	0.83	4	85	9	16	5	16	6	33	23
	O9	P20:9725 0230	absent	1	370	900	28	0.77	5	86	9	11					23
Kapoaiaia Stream	C10	P20: 9240 1215	present	3	410		25	0.79	5	72	9	21	45	22	7	33	34
	O10	P20:9170 1215	absent	3	380	750	28	1.05	5	78	10	18					38
Stream			**F ratio**		5.96		2.65	6.26	2.07	10.23	1.20	2.68					12.09
			P value		0.01		0.08	0.01	0.15	0.001	0.40	0.08					<0.001
Canopy present/ absent			**F ratio**		12.09		0.72	1.87	0.06	4.98	10.76	1.22					0.39
			P value		0.01		0.42	0.20	0.81	0.05	0.01	0.30					0.55

METHODS

Substrate stability

Stream disturbance can be measured in a number of ways including the measurement of various flow regime characteristics (Clausen and Biggs 1998), bank and channel stability (Pfankuch 1975). One component of disturbance thought to be more relevant to invertebrates and periphyton is substrate movement (Townsend et al. 1997) and is measured here using tracer particles placed on the streambed. Although there are some disadvantages with using tracer particles, e.g. hand placed stones may not be as embedded as existing streambed substrate and under may differ in shear stress (Townsend et al 1997, Downes et al. 1998), they have been used successfully in the past to quantify substrate movement (Death and Winterbourn 1995, Townsend et al. 1997, Death submitted).

At each stream 15 locally-sourced painted stones in each of three size classes (91-180 mm, 61-90 mm and <60 mm) were placed in random order across the main flow of the stream at a point marked on the stream bank. Each month between April 1999 and March 2000 distance traveled by each stone was recorded and stones placed back at their initial position. Stones that were unrecoverable, i.e. that had been washed away, had been buried, or had traveled in excess of 50 m, were recorded as having moved 50 m and were replaced with a new stone in that size class. Stones which had not moved were picked up and replaced in their initial position so that they were not more embedded than freshly placed stones. Stone movement was used to give a figure that represented substrate movement for each month by multiplying the distance traveled by each stone by the mean weight of stones in that size class and summing all for each site. This sum was then converted to percentage stone movement by expressing it as a proportion of the maximum possible weight of stones moved (maximum possible weight of stones moved=405.5 kg). A percentage stone movement of 100 indicates all stones were washed away, buried or moved in excess of 50 m and a percentage stone movement of 0 means no stones were moved. Because of the close proximity of paired sites and their similar physical characteristics stone movement was measured at only one site, the closed canopy site, on each stream.

Other substrate stability measures

Stability of the streambed was also assessed using the bottom component of the Pfankuch Stability Index (Pfankuch, 1975). The bottom component of the index assesses the stream channel based on an observers evaluation of 4 categories of 5 characteristics of the streambed (rock angularity, substrate packing, permanence, evidence of mineral deposition and plant growth). The three disturbance metrics of Townsend et al. (1997) were also calculated. These were: 1) intensity of disturbance- measured as mean percentage of total stones moved regardless of stone size; 2) frequency of disturbance- measured as the proportion of times 40 % of the stones moved; and 3) maximum percentage of stones moved. These disturbance measures are referred to from now on as bed movement intensity, frequency and maximum, respectively.

Substrate and physicochemical habitat characteristics

Substrate size composition of 11 size classes (<8 mm, 8-11.3 mm, 11.3-16 mm, 16-22.6 mm, 22.6-32 mm, 32-45.3 mm, 45.3-64 mm, 64-90.5 mm, 90.5-128 mm, 128-300 mm, 300 mm+) was assessed for 100 stones collected using the Woolman Walk (Woolman 1954). The data was converted to a substrate size index (SI) (Quinn and Hickey 1990) by summing the mid-point values of the 11 size classes weighted by their proportional cover.

Type of riparian vegetation (native forest, exotic woodland, scrub, crop/pasture, fern and other) was visually estimated.

Temperature and conductivity were recorded at each site monthly between April 1999 and March 2000 using an Orian 122 conductivity meter. Temperature was also recorded over a 15 second period every hour using Hobo™ temperature loggers secured in the stream at 7 sites (at both open and closed sites on Waipuku Stream, Waipuku Stream Tributary, Ouri Stream and Cold Stream and at the closed site on Mangatoki Stream) continuously between September 1999 and August 2000. Conductivity is used here to give an indication of stream nutrient enrichment. Conductivity has been shown to be correlated with several dissolved nutrients (reactive-P, NH_4-N and NO_3-N) and accurately discriminates between streams with different nutrient loadings (Biggs 1988). Stream width, depth and velocity were measured in the center of the stream channel at 5 equidistant points within a 10 m stretch, the latter two with a velocity head rod.

Periphyton

Each month 4 small stones (maximum planar dimension <60 mm) were collected from each site and frozen. In the laboratory pigments were extracted in known volumes of 90 % acetone at 5 °C in the dark for 24 hrs. Absorbencies were read using a Varian Cary 50 Conc UV-Visible Spectrophotometer and converted to pigment concentration following Steinman and Lamberti (1996). They were corrected for stone surface area determined by wrapping stones in aluminium foil of known weight per unit area and this value divided by two as periphyton is generally found only on the upper exposed surface of stones.

Macroinvertebrates

Macroinvertebrates were sampled, at the end of April, July and October 1999 and January 2000 (Autumn, Winter, Spring and Summer season samples respectively). Five 0.1 m^2 Surber samples (250 μm mesh) were collected at each site and stored in 10 % formalin. In the laboratory samples were identified to the lowest possible taxonomic level using available keys (e.g. Cowley 1978, Winterbourn and Gregson 1989, Towns and Peters 1996) and counted. Those taxa which could not be identified to species level were separated into apparent morphospecies. Particulate organic matter (P.O.M.) remaining after the invertebrates had been removed was dried at 80 °C for 5 days, weighed, and ashed at 600 °C for 2 hours, the difference in weight yielding ash free particulate matter. Functional feeding groups were assigned to all species based on Cowie (1981), Winterbourn and Gregson (1989), Cowley (1978) and Thompson and Townsend (2000) using the categories of (grazer, filterer, predator, shredder, piercer and non-feeding organisms). The proportion of the functional feeding group grazer was further split into mobile grazer (e.g. most mayflies, stoneflies and caddisflies) and sedentary grazer (e.g. most chironomids and all oligochaetes and molluscs). Mean number of invertebrate species for each site in all four seasons are presented in Appendix 1.

Data analysis

The effect of canopy presence, stone movement (the covariate) and season were analysed using Analysis of CoVariance (ANCOVA) with the statistical package SAS (SAS 1995). Invertebrate community structure at all sites was analysed with Detrended Correspondence Analysis (DECORANA) using the PC-ORD multivariate statistical package (McCune and Mefford 1999). Environmental, stability and biological characteristics to which these gradients corresponded were assessed with the Spearman rank correlation procedure of SAS with a sequential Bonferroni correction (Rice 1989).

RESULTS

Site characteristics

Chemical and physical variables measured over the duration of the study were generally similar between streams and very similar between open and closed sites at each stream (Table 2.1). Mean depth ranged between 16 and 31 cm, width ranged between 3 and 7 m and velocity ranged between 0.40 and 1.05 m/s. Mean conductivity was generally low ranging between 58 and 96 μS/cm, mean annual temperature ranged between 8 and

11 °C. Temperature was not different between different streams ($F_{1,9}$=1.20, P=0.40) but was in some cases 1 or 2 °C higher in open sites compared to closed sites ($F_{1,9}$=10.76, P=0.009) e.g. at Mangatoki Stream and Dunns Creek. Conductivity showed some variation between streams ($F_{1,9}$=10.23, P=0.001) e.g. conductivity in Waipuku Stream and Waipuku Stream Tributary was a little lower than in the other streams (mean conductivity at both open and closed sites of 58-64 μS/cm compared to 70-92 μS/cm) but conductivity was not different between open and closed sites ($F_{1,9}$=4.98, P=0.053). Substrate size index ranged between 16 and 24 and indicated that substrate size was not different between different streams ($F_{1,9}$=2.68, P=0.079) and not different between closed and open sites at each stream ($F_{1,9}$=1.22, P=0.297).

Stability

Over the year, percentage stone movement was higher in Kaupokonui East and Kapoaiaia than in any other streams ($F_{1,237}$=14.58, P<0.001) (Fig. 2.2) and was different between months across all streams e.g. it was high in November and December and low in October and February ($F_{11,237}$=9.34, P<0.001). Percentage stone movement was strongly correlated with bed movement intensity, frequency and bed movement maximum (r=0.90, 0.87, and 0.46, respectively P<0.001). Percentage stone movement was however not related to the bottom component of the Pfankuch index (r=0.16, P=0.15).

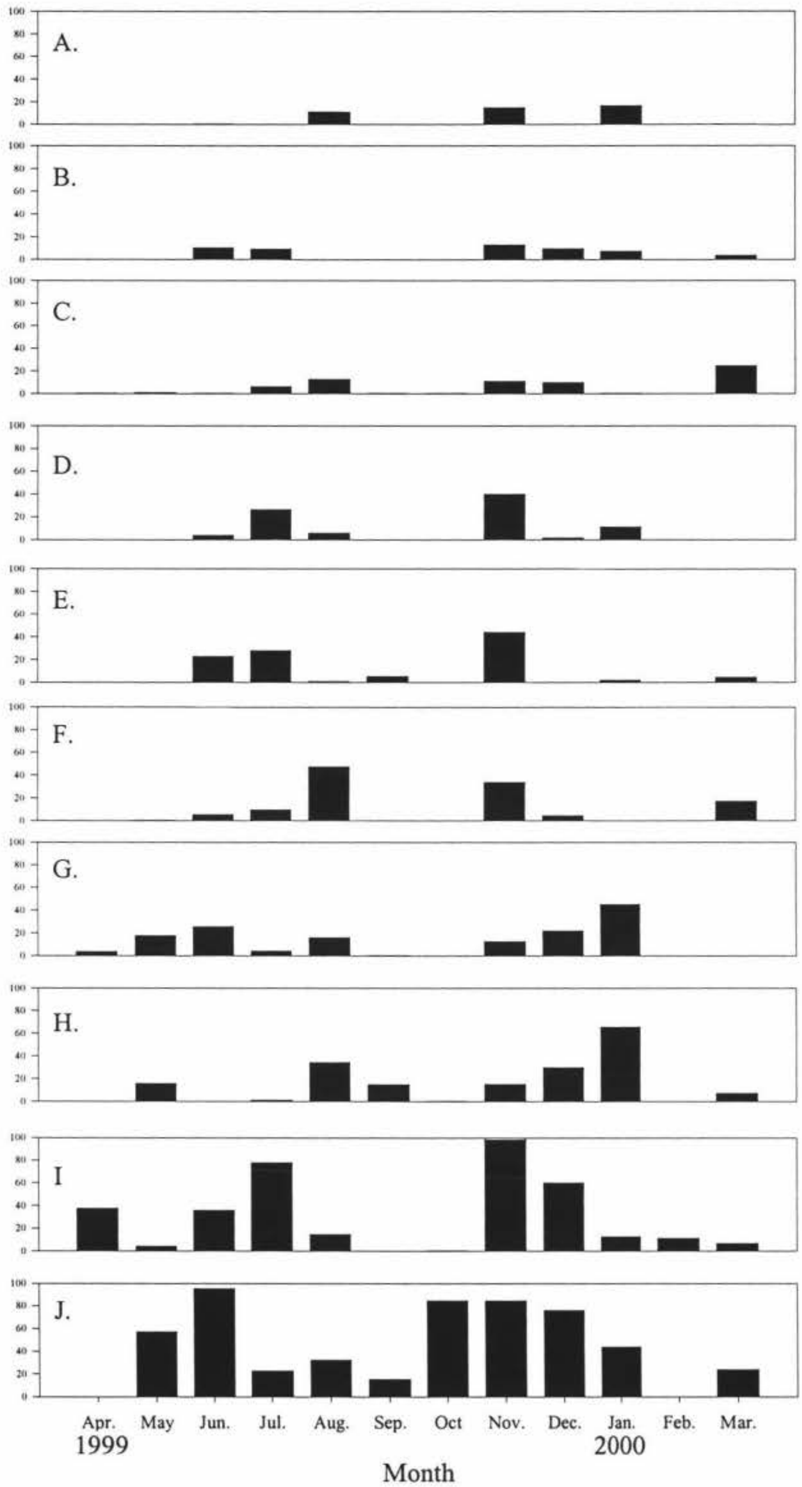


Figure 2.2. Percentage stone movement measured monthly between April 1999 and March 2000 in 10 Taranaki ring plain streams. Streams are ordered top to bottom from low to high stone movement. Letters refer to streams: A.=Mangatoki Stream, B.=Kaupokonui East Stream Tributary, C.=Cold Stream, D.=Little Dunns Creek, E.=Dunns Creek, F.=Ouri Stream, G.=Waipuku Stream, H.=Waipuku Stream Tributary, H.=Kaupokonui East Stream, I.=Kapoaiaia Stream.

Chlorophyll a and particulate organic matter (P.O.M.)

Canopy cover had a strong effect on chlorophyll *a* with over one and a half times the periphyton biomass at open sites (mean=2.52 $\mu g/cm^2$) compared to that in closed sites (mean=1.56 $\mu g/cm^2$) ($F_{1,927}$=210.54, P<0.001) (Fig. 2.3a). Chlorophyll *a* decreased linearly with increasing stone movement ($F_{1,927}$=59.29, P<0.001). Chlorophyll *a* was decreased with increasing stone movement at both open and closed sites but stone movement had relatively more effect in the open sites ($F_{1,466}$=66.20, P<0.001 and $F_{1,460}$=4.46, P=0.03 at open and closed sites respectively) and this pattern of response s to stone movement and canopy cover was not different between months at all sites ($F_{1,466}$=1.59, P=0.10 and $F_{1,460}$=0.91, P=0.53 for open and closed sites respectively).

The amount of P.O.M. was higher at closed canopy sites (2.34 $g/0.1m^2$) than at open canopy sites (1.75 $g/0.1\ m^2$) ($F_{1,399}$=38.35, P<0.001) but the amount of P.O.M. was not related to stone movement ($F_{1,399}$=1.17, P=0.28) (Fig. 2.3b).

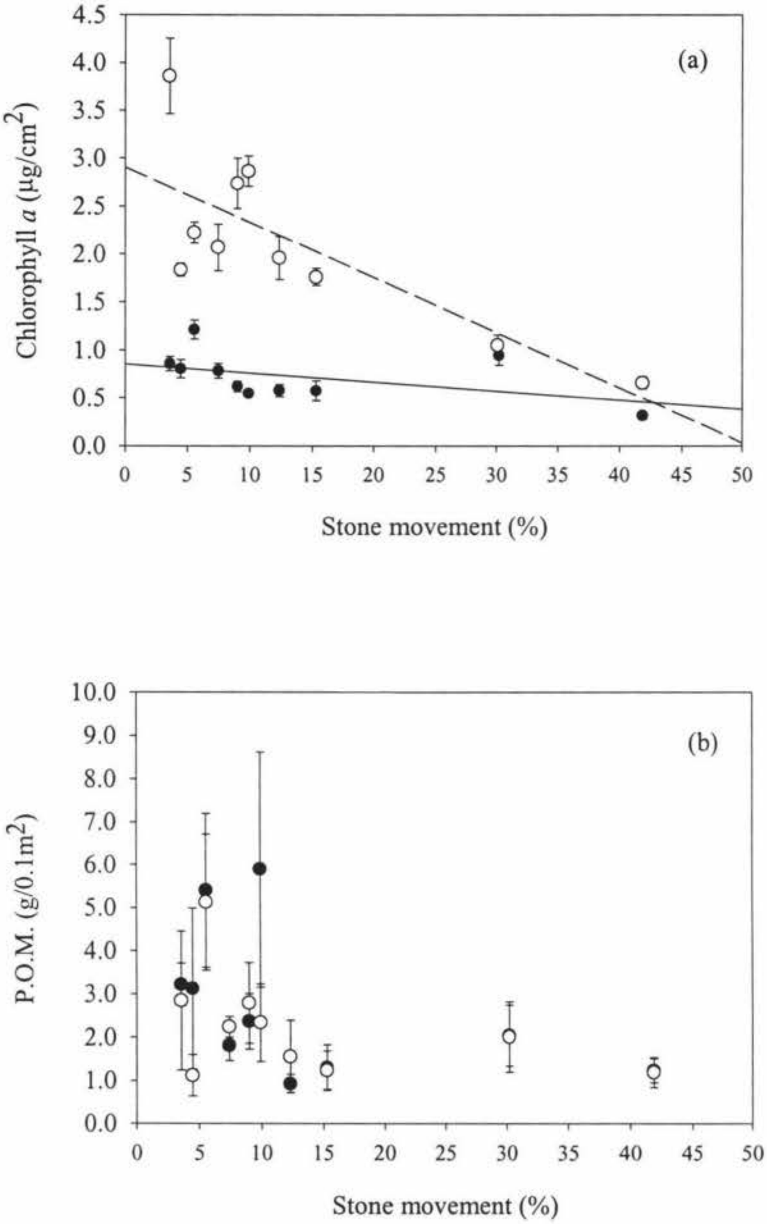


Figure 2.3. Mean (a) chlorophyll *a* ($\pm$ 1 SE), and (b) P.O.M. ($\pm$ 1 SE) as a function of stone movement at 20 Taranaki ring plain stream sites measured between April 1999 and March 2000. Solid symbols are closed canopy sites and clear symbols are open canopy sites. Regression analysis for chlorophyll *a* at open sites yielded the equation y=-5.75x+2.90, r^2=0.62, and at closed sites, y=-0.94x+0.85, r^2=0.22.

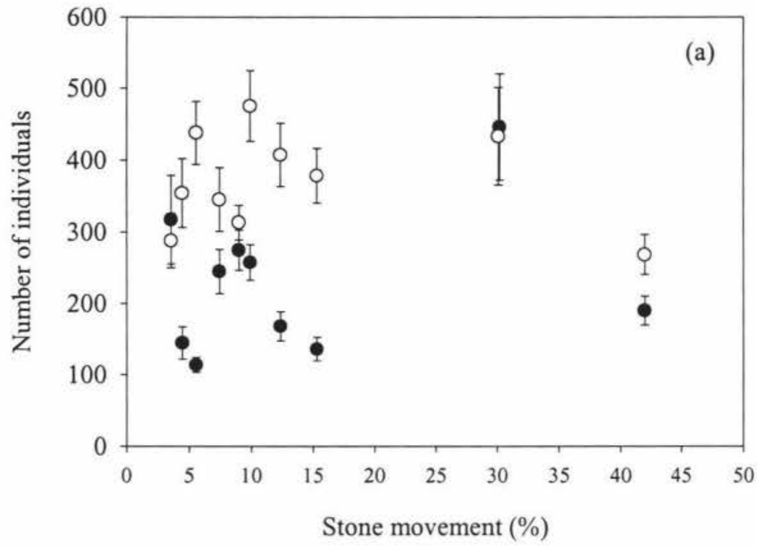
Total invertebrate individuals

On average open canopy sites had over one and a half times the number of total invertebrates (mean=370) than closed canopy sites (mean=228) ($F_{1, 396}$=61.03, P<0.001) (Fig. 2.4a). Stone movement had no influence on total individuals at either closed sites ($F_{1, 396}$=2.68, P=0.10) or open sites ($F_{1, 396}$=2.54, P=0.11). At open sites number of individuals was higher during spring than in any other season ($F_{1, 396}$=11.69, P<0.001) while at closed sites there was no difference in total number of individuals between the seasons ($F_{1,396}$=4.19, P=0.007).

Invertebrate species richness

Open canopy sites usually had a higher number of species (mean=21) than closed canopy sites (mean=17) ($F_{1,396}$=86.84, P<0.001) (Fig. 2.4b). The response of species number to stone movement was different at sites that were open and closed ($F_{1, 396}$=23.63, P<0.001). At open sites species number decreased with increasing stone movement ($F_{1, 396}$=37.16, P<0.001) while, at closed sites stone movement had no effect on number of species ($F_{1, 396}$=0.61, P=0.43). Number of species was higher at all sites during spring than in any other season, with 3 or 4 more species present at most sites ($F_{1, 396}$=11.91, P<0.001).

Number of species is also related to the level of chlorophyll *a*, fitting a quadratic relationship (r^2=0.63, P<0.001) (Fig. 2.5). This means that when periphyton biomass was low at sites, e.g. chlorophyll *a* concentration of 0-1.0 μg/ cm^2, species number was low and increased as periphyton biomass increased but at a decreasing rate.



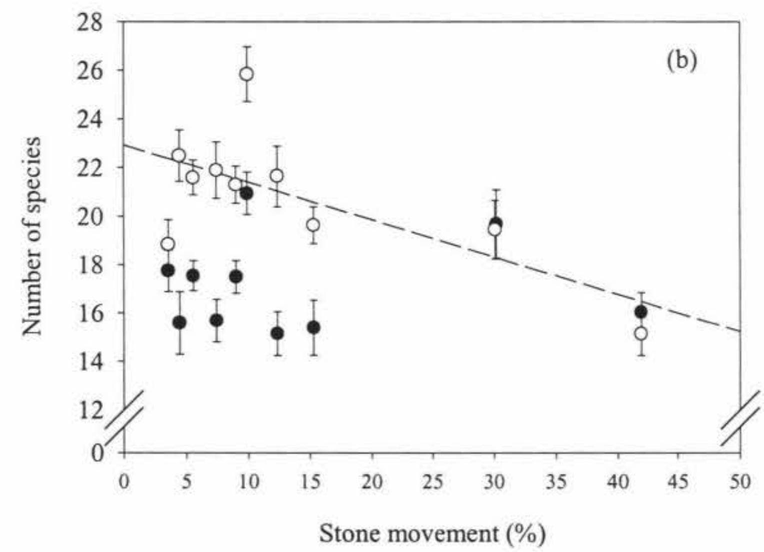


Figure 2.4. Mean (a) number of individuals ($\pm$ 1 SE), and (b) mean number of species ($\pm$ 1 SE) as a function of stone movement at 20 Taranaki ring plain stream sites measured between April 1999 and March 2000. Solid symbols are closed canopy sites, clear symbols, open canopy sites. Regression analysis for mean number of species at open sites yielded the equation y=22.94x+-15.43, r^2=0.47.

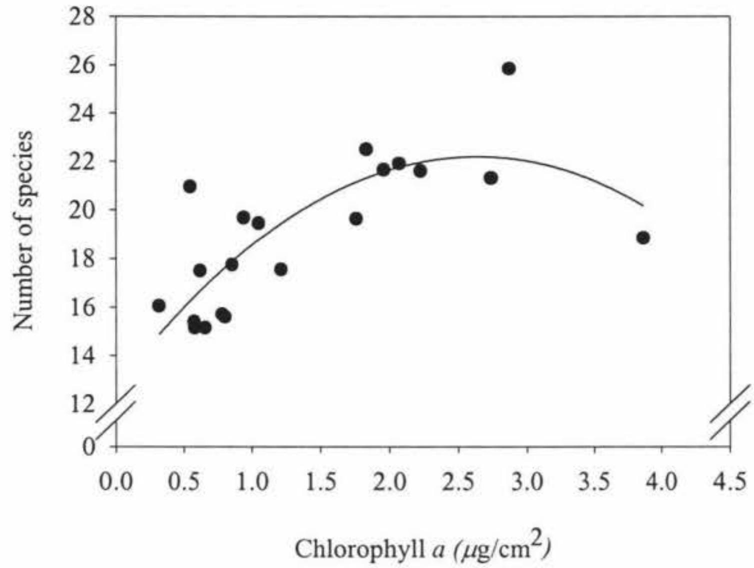


Figure 2.5. Mean number of species as a function of chlorophyll *a* at 20 Taranaki ring plain stream sites measured between April 1999 and March 2000. Regression analysis yielded the equation $f=12.38+7.13x-1.35x^2$.

Functional feeding groups

Grazers, both mobile and sedentary, responded similarly to the presence of canopy cover. Open canopy sites had a higher mean number of both mobile and sedentary grazers (mean=247 and 56 respectively) than closed canopy sites (mean=140 and 8 respectively) ($F_{1,396}$=53.90 and 70.22 respectively, P<0.001) (Fig. 2.6a and 2.6b). Number of sedentary grazers decreased as stone movement increased ($F_{1,396}$=12.35, P<0.001) while number of mobile grazers increased as stone movement increased ($F_{1,396}$=20.65, P<0.001). Although there was no difference in sedentary grazers between the seasons ($F_{1,396}$=0.04, P=0.989) there was a higher number of mobile grazers in spring than in any other season ($F_{1,396}$=18.53, P<0.001).

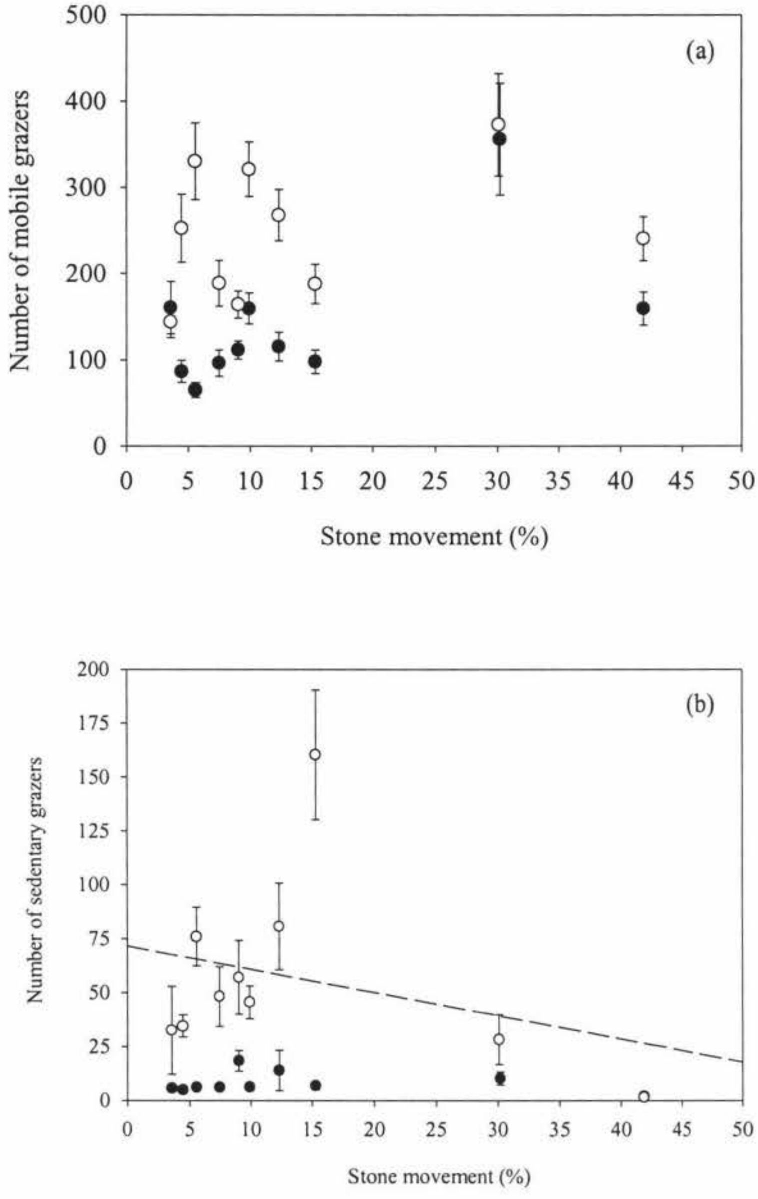


Figure 2.6. Mean (a) number of mobile grazer individuals (± 1 SE), and (b) number of sedentary grazer individuals (± 1 SE) as a function of stone movement at 20 Tararnaki ring plain stream sites measured between April 1999 and March 2000. Solid symbols are closed canopy sites, clear symbols, open canopy sites. Regression analysis for sedentary grazers at open canopy sites yielded the equation y=-107.38x+71.43, P<0.001, r^2=0.09.

Mobile grazers were the most common functional feeding group at all sites with filter feeders and sedentary grazers also making up a relatively large proportion (Fig. 2.7). Although there was no difference in proportion of mobile grazers between open and closed sites ($F_{1,396}$=4.33, P=0.14), there were a higher proportion of sedentary grazers at open sites than at closed sites ($F_{1,396}$=69.11, P<0.001) and a higher proportion of filter feeders at closed sites than at open sites ($F_{1,396}$=96.02, P<0.001). Proportion of mobile grazers increased as stone movement increased ($F_{1,396}$=183.77, P<0.001) while proportion of sedentary grazers and filter feeders decreased as stone movement increased ($F_{1,396}$=22.57 and 92.07, P<0.001 respectively). The difference in sedentary grazers and filter feeders at open and closed sites became less as stone movement increased ($F_{1,396}$=14.18 and 11.99, P<0.001 respectively), for example, at the two unstable streams Kaupokonui East and Kapoaiaia (streams 5 and 10 respectively on Figure 2.7).

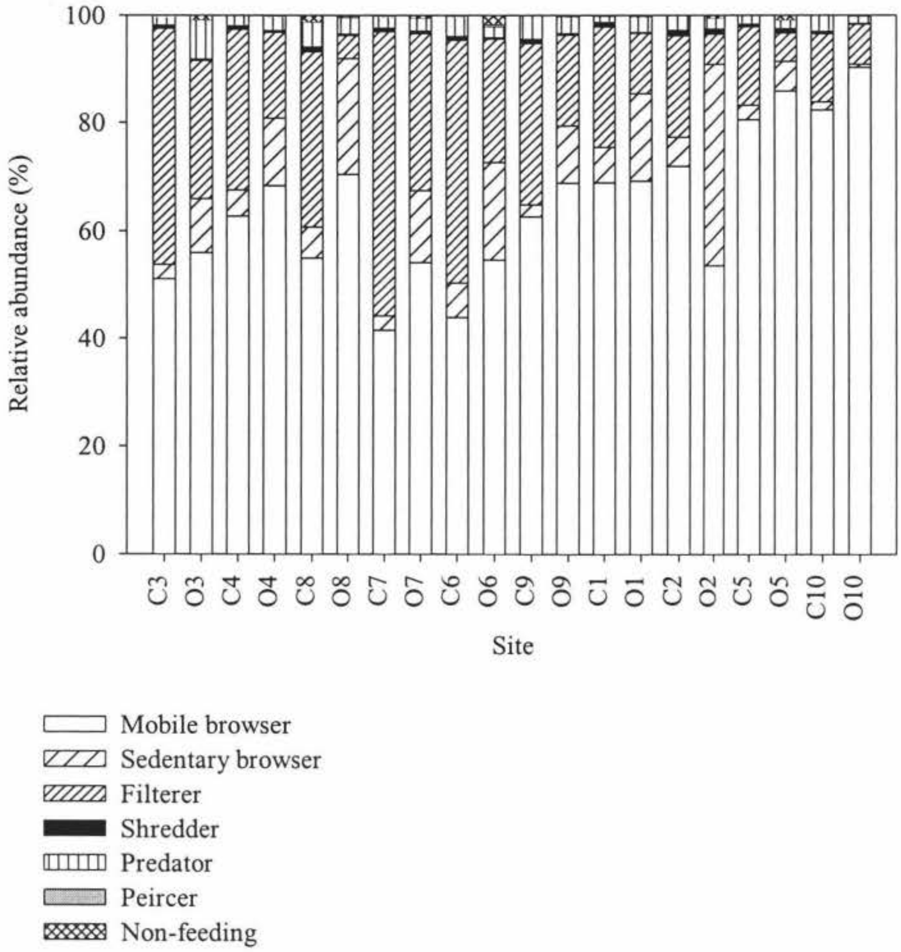


Figure 2.7. Mean relative abundance of individuals in functional feeding group categories at 20 Taranaki ring plain stream sites measured between April 1999 and March 2000. Letters indicate presence or absence of canopy (C=closed canopy sites, O=open canopy sites) and numbers the individual streams (1=Waipuku Stream, 2=Waipuku Stream Tributary, 3=Mangatoki Stream, 4=Kaupokonui East Stream Tributary, 5=Kaupokonui East Stream, 6=Dunns Creek, 7=Little Dunns Creek, 8=Cold Stream, 9=Ouri Stream, 10=Kapoaiaia Stream). Sites are given in left to right in order from low to high percentage stone movement.

Community composition

Ordination of invertebrate communities are presented in Figure 2.8. Axis one and two together accounted for 58 % of the variation (47 % and 11 % respectively). Communities were graded along axis one; closed canopy sites on the left and open canopy sites on the right. The exceptions were the open sites at the two most unstable Streams Kaupokonui East and Kapoaiaia (sites O5 and O10 respectively on Figure 2.8). Their invertebrate communities were more similar to invertebrate communities at their respective closed sites and all other closed sites than at the other open sites.

Of the 34 variables examined, axis one scores were most strongly correlated with riparian/ crop/ pasture (r_s=0.74) and were strongly negatively correlated with riparian fern composition (r_s=-0.87) (fern riparian margins are typical of closed bush sites) and canopy (r_s=-0.76). Axis two placed sites from low to high stability and was negatively correlated with percentage stone movement (r_s=-0.62).

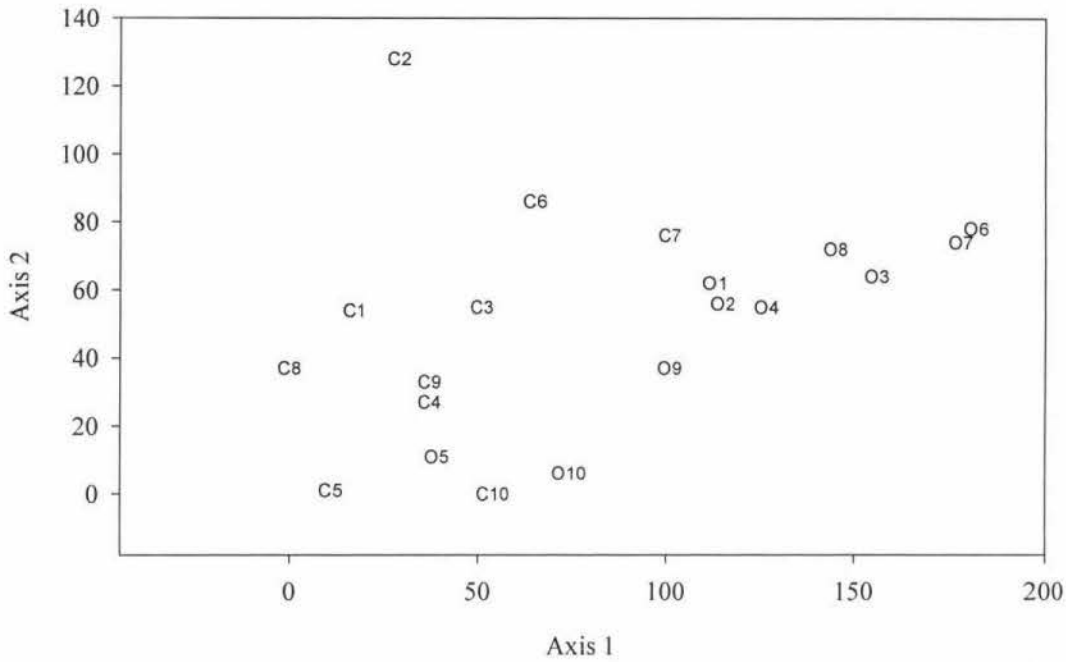


Figure 2.8. Axis one of a DECORARANA as a function of axis two for macroinvertebrate communities collected in 5 0.1 m^2 Surber samples seasonally at 20 Taranaki ring plain stream sites between April 1999 and March 2000. Letters indicate presence or absence of canopy (C=closed canopy sites, O=open canopy sites) and numbers the individual streams (1=Waipuku Stream, 2=Waipuku Stream Tributary, 3=Mangatoki Stream, 4=Kaupokonui East Stream Tributary, 5=Kaupokonui East Stream, 6=Dunns Creek, 7=Little Dunns Creek, 8=Cold Stream, 9=Ouri Stream, 10=Kapoaiaia Stream).

Table 2.2. Spearman rank correlation coefficients of DECORANA axis one and two against chemical, physical, stability, substrate, riparian and periphyton measurements recorded at 20 Taranaki ring plain stream sites between April 1999 and March 2000 (* P<0.01).

Site, chemical, physical, stability, substrate, riparian parameter	Axis 1	Axis 2
Canopy	-0.76 *	0.03
Order	0.24	-0.49
Altitude (m a.s.l.)	-0.36	0.35
Site distance from paired site (m)	-0.17	0.18
Mean conductivity (μS/s)	0.09	-0.32
Mean temperature (°C)	0.54	-0.18
Mean width (m)	0.10	0.50
Mean depth (cm)	0.04	-0.10
Mean velocity (m/s)	-0.15	-0.21
Mean stone movement (%)	-0.32	-0.62 *
Intensity of disturbance	-0.41	-0.39
Frequency of disturbance	-0.41	-0.28
Maximum disturbance	-0.13	-0.09
Pfankuch, bottom component	0.06	-0.02
Mean substrate size index (SI)	-0.43	-0.25
Substrate size class : <8 mm	0.26	0.13
8-11.3 mm	0.16	0.04
11.3-16 mm	0.27	-0.05
16-22.6 mm	0.28	-0.27
22.6-32 mm	0.55 *	0.07
32-45.3 mm	0.40	0.41
45.3-64 mm	-0.07	0.29
64-90.5 mm	-0.25	0.27
90.5-128 mm	-0.26	0.02
128-300 mm	-0.57 *	-0.43
300 mm+	0.31	-0.07
Native forest	-0.35	-0.33
Exotic woodland	0.07	0.26
Scrub	0.38	0.11
Crop/pasture	0.74 *	0.03
Tussock	0.13	-0.47
Fern	-0.87 *	0.23
Mean chlorophyll *a* (μg/cm²)	0.49	0.22

Animals' characteristic of forest streams, the uncased caddisfly *Orthopsyche thomasi* and the beetle larva Ptilodactylidae and also the uncased caddisflies *O. fimbriata* and *Psilochorema* sp. B and the stonefly *Zelandobius* sp. A were associated with closed canopy sites (Table 2.3) while the fly larva *Aphrophila neozelandica*, the cased caddisfly *Beraeoptera roria*, the uncased caddisflies early instar Hydrobiosidae and *Psilochorema* sp. B, and Elmidae adult beetles were distinctive of open sites. On axis two more unstable sites typically had Elmidae adult beetles, the stonefly *Zelandoperla decorata,* the cased caddisflies *Beraeoptera roria* and *Olinga feredayi* and the uncased caddisfly *Psilochorema* sp. A while more stable sites had small Oligochaets, pupa of Hydrobiosidae spp. and Dipteran Chironomidae spp., the uncased caddisfly *Costachorema callista* and the stonefly *Zelandobius* sp. A.

Table 2.3. Ten taxa most closely associated with axis one and two from a DECORANA of invertebrate community composition of 20 Taranaki ring plain stream sites collected between April 1999 and March 2000. Taxa are listed in order of importance.

		Axis 1		Axis 2
Negative	-0.84	*Orthopsyche thomasi*	-0.75	Elmidae spp., adult
	-0.76	*Zelandobius* sp. A	-0.68	*Zelandoperla decorata*
	-0.71	Ptilodactylidae spp.	-0.55	*Baeraeoptera roria*
	-0.69	*Orthopsyche fimbriata*	-0.51	*Olinga feredayi*
	-0.61	*Hydrobiosis parumbripennis*	-0.43	*Psilochorema* sp. A
Positive	0.80	*Aphrophila neozelandica*	0.70	Oligochaeta, small (<1.5 cm)
	0.80	*Beraeoptera roria*	0.70	Hydrobiosidae spp., pupa
	0.76	Hydrobiosidae, early instar	0.61	*Costachorema callista*
	0.74	Psilochorema sp. B	0.54	Chironomidae spp., pupa
	0.72	Elmidae spp., adult	0.48	*Zelandobius* sp. A

DISCUSSION

In this study periphyton biomass was generally higher in the open than under full canopy, a common trend in studies comparing open and forested sites (Cowie 1980, Behmer and Hawkins 1986, Quinn et al. 1997). Temperature and nutrients, can also be very important factors influencing periphyton biomass (Winterbourn 1990, Biggs and Gebreaux 1993) but here both variables were similar between paired sites. Periphyton biomass was also affected by substrate stability. Periphyton abundance declined linearly with increasing disturbance (Biggs 1995, Clausen and Biggs 1998) although this effect was more significant at open sites. The already low periphyton at closed sites was relatively less affected by disturbance. Robinson and Minshall (1986) also recognized this phenomenon, periphyton biomass in open sites being effected more strongly than periphyton biomass in closed sites. Overall, it seems disturbance had a greater relative effect on periphyton biomass than canopy cover. At high disturbance levels, i.e. in the two most unstable streams, Kaupokonui East and Kapoaiaia, high levels of stone movement meant no difference in periphyton biomass between open and closed sites.

Total number of invertebrates and number of species were both higher in open canopy sites than closed canopy sites. As the major difference between paired sites is periphyton biomass it seems that the invertebrates must be responding to change in food source (Towns 1981, Behmer and Hawkins 1986). Differences in particulate organic matter (P.O.M.), higher amount of P.O.M. food source available at closed sites than open sites, may also be important. However since there were not more invertebrates or invertebrate species at closed sites than open sites it appears that the level of P.O.M. is not as important as the level of periphyton. Species richness was decreased by increasing disturbance consistent with other studies (Cowie 1980, Sagar 1986, Death 1996). At closed sites species number was not effected by disturbance at all. The effect of disturbance appeared to be more influential than canopy cover with no difference in species number at high disturbance regardless of canopy cover.

It seems that in these streams, species diversity patterns are effected by both productivity and disturbance. There was no evidence however of maximum species richness at intermediate levels of disturbance as predicted by the Intermediate Disturbance Hypothesis (IDH) (Connell 1978) and the dynamic equilibrium model (Huston 1979). Rather maximum diversity occurred at low levels of disturbance with a linear decrease in diversity as disturbance intensity increased. The relevance of the IDH has been tested in lotic studies previously, with the majority, as here, finding little support for it (Riece 1984, 1985, Lake et al. 1989, Vinson and Hawkins 1998). I did however find evidence for maximum species diversity at intermediate levels of productivity and minimum diversity at low levels of disturbance as predicted by the disturbance-productivity-diversity model (Hildrew and Townsend 1987). Two recent New Zealand studies have also found the quadratic relationship between periphyton biomass and species richness in forested sites at Te Urewera National Park (Death submitted) and the Tararua and Ruahine Ranges (Minchin and Death in press). One explanation for this quadratic pattern is that an increase in range or supply of periphyton resource will mean more species are able to co-exist while further abundance in resources can lead to high rates of population increase, competitive exclusion and thus reduction in species diversity (Begon et al. 1996). There is some evidence for resource competition in streams to support this idea (e.g. McAuliffe 1984).

Total invertebrate abundance was unaffected by disturbance in this study. This is probably because unstable stream invertebrate faunas in New Zealand are often dominated by mobile generalist grazer species (Winterbourn et al. 1984, Thompson and Townsend 2000) that are resilient to disturbance events (Death and Winterbourn 1995). They have species traits to avoid flows such as generalist habitat preferences and two or more life cycle stages outside the stream (Thompson and Townsend 2000).

Grazers, those invertebrates which actively consume periphyton from rock surfaces as a major part of their diet (Cowie 1980, Winterbourn et al.1984), were of particular interest in this study. Of all the invertebrates, grazers were expected to follow any gradient in primary productivity and this did appear to be the case. Sedentary grazers, and to a lesser extent mobile grazers, were much more abundant in the open than in full cover. Hawkins and Sedell (1981) and Behmer and Hawkins (1986) also found a positive relationship between periphyton grazers/ scrapers and chlorophyll *a* biomass associated with contrasting canopy cover. Mobile grazers, the description 'mobile' again indicating those invertebrates resilient in flood events, made up an increasingly larger proportion of all invertebrates as disturbance increased, invertebrates of other functional feeding groups being relatively less resilient.

Invertebrate community composition in these streams was affected by canopy cover and substrate stability. All open canopy sites had similar faunas characterised by high abundances of periphyton grazers, *Beraeoptera roria* and Elmidae. The predator *Aphrophila neozelandica* was also characteristic of open sites and this was probably because of the high density of prey. Others have also found a positive relationship between predators and prey species (e.g. Hawkins et al. 1982). Communities at closed sites were also all similar to one another but distinct from those at open sites with characteristic fauna including two species, *Orthopshyce thomasi* and Ptilodactylidae, which are typically found in forested streams (Winterbourn and Gregson 1989). In unstable streams, however (i.e. in Kaupokonui East and Kapoaiaia) there was no difference between communities at open and closed sites. Winterbourn et al. (1984) in a study of sites along an unstable stream found, as in the unstable streams in this study, that although a few species were restricted to open sites and a few to closed sites, there was no marked change in community composition as the stream left the forest. Death and Winterbourn (1995) found that communities in unstable sites were more similar to stable forested sites than stable open sites. Unstable sites had characteristic fauna of which three species; *Zealandoperla decorata*, *Beraeoptera roria* and *Olinga feredayi*, were also found to be distinctive in unstable Te Urewera National Park, New Zealand, streams (Death submitted) while characteristic fauna at stable sites included the pupa of Hydrobiosidae and Chironomidae species. Pupa are probably vulnerable to being washed away during disturbance and this may be why they are found in stable sites as opposed to in unstable sites. It seems that community composition was strongly influenced by canopy cover but disturbance had an overriding influence.

It seems that disturbance by decreasing periphyton levels in open unstable stream sites results in the same species diversity, functional feeding group abundances and community composition that is associated with similarly low levels of productivity in closed sites at both stable and unstable streams. Disturbance also operates to affect the resident macroinvertebrate community directly with resilient invertebrates such as *Deleatidium* dominant at unstable sites. Although whether disturbance is acting on the invertebrate community via reduction of primary productivity, physical disruption, or a combination of the two at one time or place cannot be determined from this study.

In summary, both canopy cover and substrate stability affect invertebrate community structure in these Taranaki ring plain streams. Canopy cover through its effect on periphyton strongly influences diversity and overall community composition but in unstable streams this effect is overridden by disturbance. It seems that at high levels of disturbance, periphyton levels are kept low, and physical disturbance eliminates any difference between communities in unstable sites with or without canopy.

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CHAPTER 3:

AN EXPERIMENTAL EXAMINATION OF THE EFFECT OF SUBSTRATE STABILITY AND CANOPY COVER ON INVERTEBRATE COMMUNITIES

ABSTRACT

The effect of substrate stability and canopy cover on invertebrate communities was examined in a stable Taranaki ring plain stream during February and March 2000 using an artificial cover. Baskets were placed in the open or under cover and half were disturbed every week for four weeks. Cover determined invertebrate community composition, probably related to differences in primary productivity, while physical disturbance decreased both abundance and diversity.

Keywords: substrate stability; cover; disturbance; productivity; macroinvertebrates; periphyton; experiment; community structure; diversity.

INTRODUCTION

Disturbance is regarded as one of the principal factors influencing stream invertebrate communities (Resh et al. 1988, Riece et al. 1990, Lake 2000). Floods or increased discharges influence the invertebrate community by physically washing away and removing individuals and and by scouring and removing the periphyton food source (Robinson and Minshall 1986, Death 1996). Rather than complete control of the invertebrate community by disturbance however, community structure is determined by a dynamic array of abitotic (e.g. disturbance, water chemistry, substrate type) and biotic (e.g. productivity, competition, predation) factors (Peckarsky 1983, Power et al. 1988). The challenge is to elucidate the influence of each factor on the stream macroinvertebrate community, their relative impact and if and how they interact.

Often in correlative or observational studies of natural stream systems the influence of multiple factors are difficult to distinguish from one another (Power et al. 1988). Small-scale experimental studies in this way offer a useful tool where it is possible to focus on, manipulate and control individual factors of interest. Although there is some criticism as to whether results and conclusions from small-scale experimental studies can be extrapolated to the larger scales of stream reaches and entire catchments (Minshall 1988, Lake et al. 1989), it remains that experimental studies are potentially very useful in gaining understanding of processes effecting the stream faunal community (Power et al. 1988). Matthaei et al. (1997) found similar faunal patterns and dynamics resulting from a large natural flood and a concurrent experiment where small patches of streambed were disturbed.

Past stream disturbance experiments have found that disturbance can decrease abundance (Robinson and Minshall 1986, McCabe and Gotelli 2000), decrease species diversity (Death 1996) and alter community composition (Death 1996), however there are not always disturbance effects e.g. Riece (1985). Experiments have included the use of both natural (Death 1996) and artificial (Bond and Downes 2000) substrates and methods of disturbance such as turning single stones (Robinson and Minshall 1986), shaking baskets of substrate (Reice 1985) and raking patches of the streambed (Lake et al. 1989).

In this study I examined the effect of substrate disturbance and productivity, the latter controlled by an artificial cover, on the invertebrate community in a stable Taranaki stream.

STUDY SITE

The experiment was conducted in Cold Stream (P20: 9725 0230) (NZLSI 1984), a first order spring-fed stream which flows from the southeast side of Mt Taranaki within Egmont National Park, Taranaki, New Zealand. The study site was a 20 m length situated in open pasture (370 m a.s.l) approximately 500 m after the stream emerges from rimu-rata-kamahi forest canopy cover in Egmont National Park. Mean temperature and conductivity measured weekly over the duration of the experiment was

9 °C and 86 μS/cm respectively while mean width, depth and velocity also measured weekly over a 10 m stretch of the study area were 4 m, 30 cm and 1.03 m/s respectively. Streambed substrate is dominated by cobbles and is very stable (see Chapter 2 for more details including annual means and measurement techniques used).

METHODS

Twenty baskets were constructed from 13 mm square wire mesh (basket dimensions: 53x 27x6 cm), filled with small cobbles (60-120 mm) sourced from the dry bank of a nearby stream and embedded into the streambed so their tops were level with the surrounding substrate. Ten baskets were placed in pairs under a frame measuring 6x1.3 m covered with black polyethene plastic to exclude light (Plate 3.1). The remaining 10 pairs of baskets were placed uncovered in the stream on 10 January 2000 and all baskets left for 6 weeks. This is a similar length of time to previous experiments using artificial substrates (Downes et al. 1998).

Mechanical disturbance of half the baskets, one of each pair, was carried out following the 6 week colonization period at 1 week intervals for 4 weeks on 5, 12 and 27 February and 20 March 2000. Baskets were lifted from the streambed and placed in a large container of stream water. Invertebrates were removed by shaking and individual picking. Stones were then placed back in the baskets in their initial position; i.e. stones were placed the same side up and in the same order as before the disturbance so as not to disrupt periphyton growth.

PLATE 3.1.

Plate 3.1. Paired substrate baskets (top), and artificial cover (bottom) used for experiment conducted at Cold Stream, Taranaki in February and March 2000.

Macroinvertebrates

Invertebrates were collected on 26 March 2000 (one week after the last disturbance) from each basket in a net (250 μm mesh) placed behind each basket. Stones inside the basket were picked up and scrubbed to remove all invertebrates. Five 0.1 m^2 Surber samples (250 μm mesh) were also collected from the surrounding streambed to act as a control. All samples were preserved in 10 % formalin. In the laboratory, invertebrates in samples were identified to the lowest possible taxonomic level using available keys (e.g. Cowley 1978, Winterbourn and Gregson 1989, Towns and Peters 1996) and counted. Those taxa which could not be identified to species level were separated into apparent morphospecies. Particulate organic matter (P.O.M.) remaining after the invertebrates had been removed was dried at 80 °C for 5 days, weighed, and ashed at 600 °C for 2 hours, the difference in weight yielding ash free particulate matter. Functional feeding groups were assigned to all species based on Cowie (1980), Winterbourn and Gregson (1989), Cowley (1978) and Thompson and Townsend (2000). Mean number of invertebrates for each treatment and the Surber samples are presented in Appendix 2.

Periphyton

Three of the upper most stones from each basket were collected and frozen with the invertebrate samples on 26 March 2000. In the laboratory pigments were extracted in known volumes of 90 % acetone at 5 °C in the dark for 24 hrs. Absorbencies were read using a Varian Cary 50 Conc UV-Visible Spectrophotometer and converted to pigment concentration following Steinman and Lamberti (1996). They were corrected for stone surface area determined by wrapping stones in aluminium foil of known weight per unit area and this value divided by two since periphyton is generally only found on the upper exposed surface of stones.

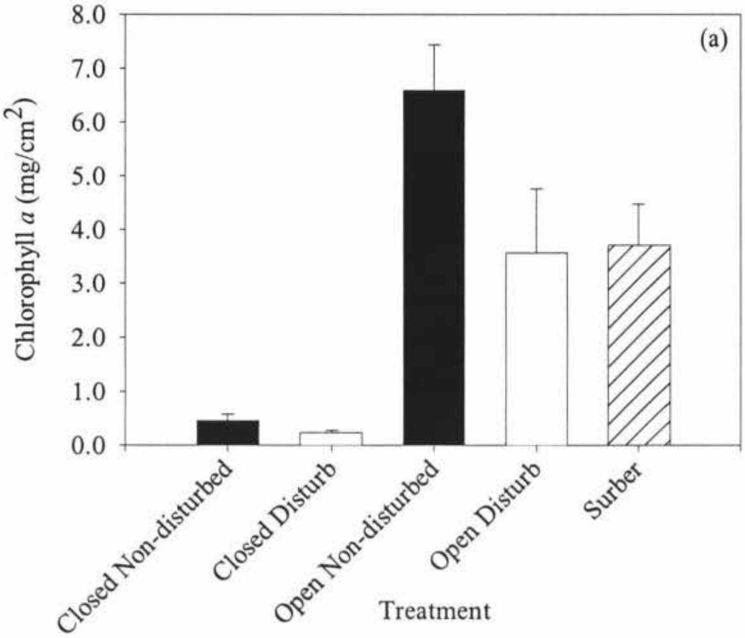
Data analysis

The effect of cover and disturbance was analysed using Analysis of Variance (ANOVA) with cover and disturbance as fixed factors using the statistical package SAS (SAS 1995). Logarithmic transformations, where appropriate, were applied after examination of the residuals. Invertebrate community structure at all sites was analysed with Detrended Correspondence Analysis (DECORANA) using the PC-ORD multivariate statistical package (McCune and Mefford 1999).

RESULTS

Chlorophyll a and particulate organic matter (P.O.M.)

The artificial cover had a strong effect on chlorophyll *a* with 15 times more chlorophyll *a* in open baskets (mean=5.10 $\mu g/cm^2$) than closed baskets (mean=0.34 $\mu g/cm^2$) ($F_{1,19}$=41.37, P<0.001) (Fig. 3.1a). Chlorophyll *a* levels were also lower in the disturbed baskets (mean=1.89 $\mu g/cm^2$) than in the non-disturbed baskets (3.52 $\mu g/cm^2$) ($F_{1,19}$=4.88, P<0.05), and this effect was no different between baskets whether open or covered ($F_{1,19}$=3.61, P=0.07). P.O.M. was also higher under the cover (mean=27.98 $g/0.1m^2$) than in the open (mean=5.41 $g/0.1m^2$) ($F_{1,19}$=23.19, P<0.001) but there was no difference between P.O.M. levels in the different disturbance baskets ($F_{1,19}$=0.02, P=0.89) (Fig. 3.1b).



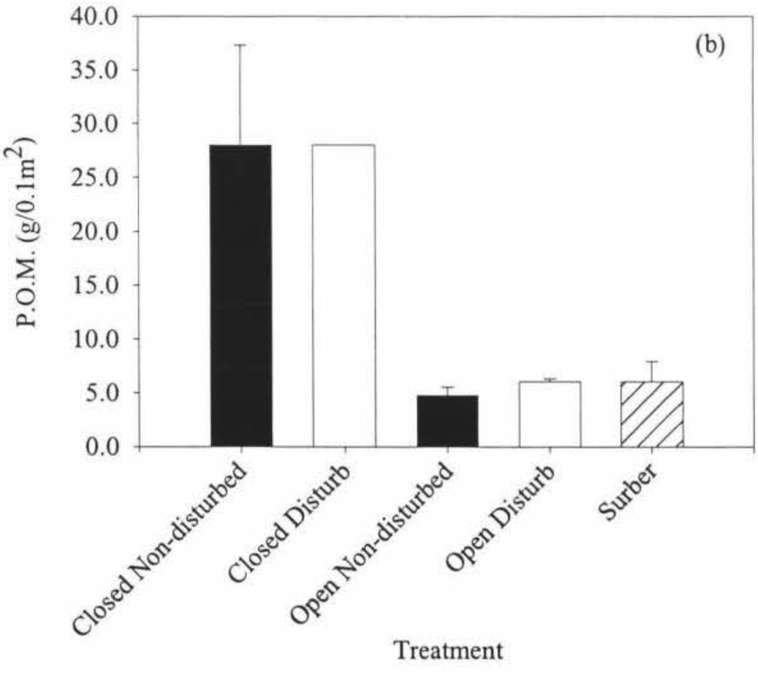


Figure 3.1. Mean (a) chlorophyll a levels (± 1 SE) and (b) P.O.M. (± 1 SE) collected in substrate baskets at Cold Stream, Taranaki, March 2000. Treatments were as labeled; Closed Non-disturbed, Closed Disturbed, Open Non-disturbed, Open Disturbed and Surber samples.

Macroinvertebrates

There were nearly twice as many animals in non-disturbed baskets (mean=317) than in disturbed baskets (mean=168) ($F_{1,19}$=14.4, P=0.02). Cover had no effect on total individuals either when considered alone ($F_{1,19}$=0.11, P=0.74) or in conjunction with disturbance ($F_{1,19}$=0.19, P=0.67) (Fig. 3.2a).

Non-disturbed baskets had overall more species (mean=21) than disturbed baskets (mean=18) ($F_{1,19}$=5.24, P=0.04). Number of species was not affected by cover ($F_{1,19}$=0.26, P=0.618) and there was no interaction between cover and disturbance ($F_{1,19}$=2.33, P=0.15) (Fig. 3.2b).

Community composition

Ordination of invertebrate communities from all replicate baskets and also Surber samples, are plotted in Figure 3.3. Together axis one and axis two explain 75 % of the variation (67 % and 8 % respectively). Along axis one communities were separated into open and covered treatments, open baskets plus Surber sample communities on the left, and covered basket communities on the right. There appeared to be no distinction between disturbed and non-disturbed baskets, all communities are intermingled on axis two and form no distinct groups.

Animals' charateristic of open baskets included the Diptera larvae *Maoridiameasa* and Orthocladiinae grp. spp., the mayfly *Deleatidium*, the caddisfly *Beraeoptera roria* and the stonefly *Zelandoperla decorata*, all generalist, periphyton grazer and collector/ browser species (Table 3.1). Animals' characteristic of covered baskets included the mayflies *Zephlebia dentata* and *Austroclima jollyae*, again two generalist feeding species, the stonefly *Austroperla cyrene*, a stone surface detritivore feeder, the caddisfly *Triplectides obsoleta*, a shredder species which feeds on large particles of organic matter such as fallen leaves and the mayfly *Coloburiscus humeralis*, a filterer.

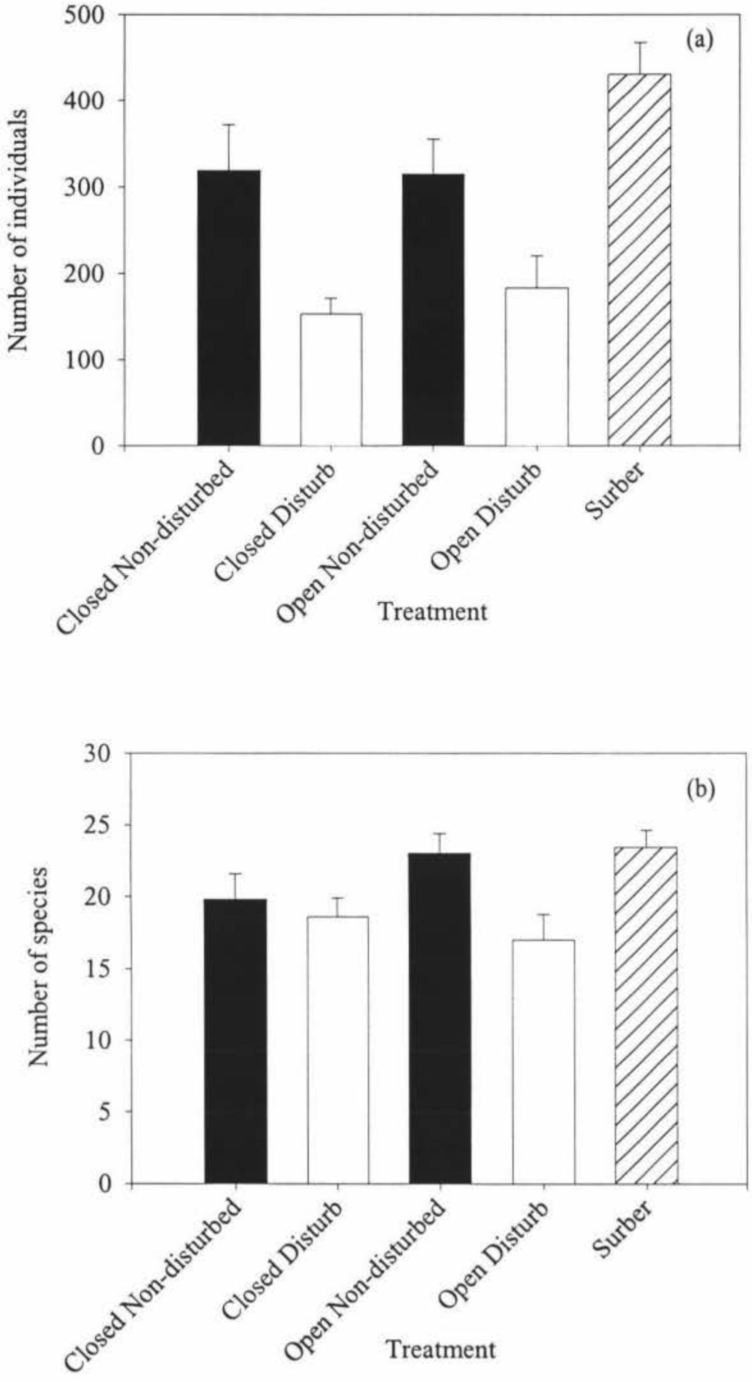


Figure 3.2. Mean (a) number of invertebrate individuals ($\pm$ 1 SE) and (b) species ($\pm$ 1 SE) collected in substrate baskets at Cold Stream, Taranaki, March 2000. Treatments were as labeled; Closed Non-disturbed, Closed Disturbed, Open Non-disturbed, Open Disturbed and Surber samples.

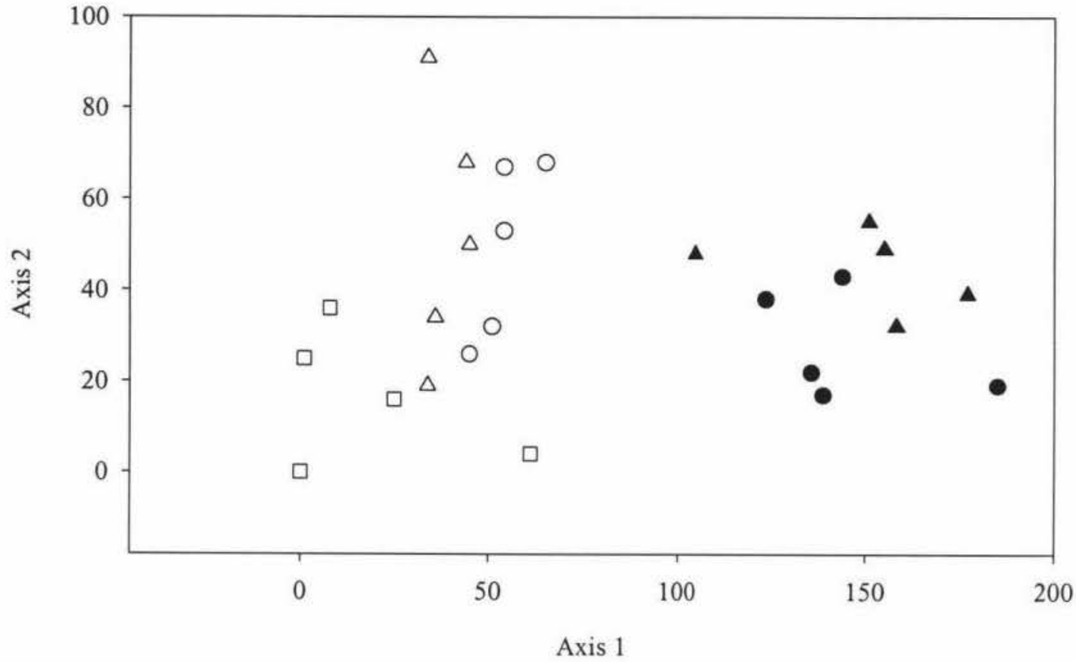


Figure 3.3. Axis one of a DECORARANA as a function of axis two for macroinvertebrate communities collected in substrate baskets at Cold Strea, Taranaki, 26 March 2000. Treatments were: Closed Non-disturbed (solid circles), Closed Diisturbed (solid triangles), Open Non-disturbed (clear circles), Open Disturbed (clear triangles) and Surber samples (clear squares).

Table 3.1. Ten taxa most closley associated with axis one and axis two from a DECORANA of invertebrate community composition collected in substrate baskets at Cold Stream, Taranaki, 26 March 2000. Taxa are listed in order of importance.

		Axis 1		**Axis 2**
Positive	0.72	*Coloburiscus humeralis*	0.51	Orthocladiinae grp. sp
	0.64	*Zephlebia dentata*	0.51	Empididae sp. A
	0.51	*Austroperla cyrene*	0.49	Helicopshychidae sp. A
	0.44	*Triplectides obsoleta*	0.42	Ptilodactylidae spp.
	0.40	*Austroclima jollyae*	0.34	*Taraperla* sp. A
Negative	-0.81	*Maoridiamesa*	-0.63	*Zelandoperla decorata*
	-0.67	*Deleatidium spp.*	-0.51	Elmidae spp., adult
	-0.60	*Beraeoptera roria*	-0.45	*Aprophila neozelandica*
	-0.58	*Zelandoperla decorata*	-0.45	Oligochaeta, large (>1.5 cm)
	-0.58	Orthocladiinae grp. sp.	-0.41	*Neurochorema forsteri*

DISCUSSION

The artificial cover in this study significantly reduced periphyton biomass, a result commonly reported from studies comparing open and closed sites (Cowie 1980, Behmer and Hawkins 1986, Quinn et al. 1997). In fact the cover appeared to reduce irradiance and resulting periphyton biomass well below that of full canopy forest. For example, in this study chlorophyll *a* levels were 15 times higher in the open than under cover, while during April 1999 to March 2000 (Chapter 2) the chlorophyll *a* levels at the open Cold Stream site were higher than those in the forested site by a factor of only 1.5. Disturbance, although to a lesser degree also affected periphyton biomass by decreasing it in both the open and under cover. A similar finding to a number of other studies (Biggs 1995, Clausen and Biggs 1998), although Robinson and Minshall (1986) found disturbance decreases periphyton in the open only and had no effect under cover.

Both total number of invertebrates and number of species were higher in non-disturbed treatments than disturbed treatments. Numerous disturbance experiments have also found that disturbance reduces total individuals, number of species or both e.g. Robinson and Minshall 1986, Death 1996, McCabe and Gotelli 2000, although not always. Bond and Downes (2000) found no reduction in Hydropsychidae density with increasing disturbance and Reice (1984, 1985) found no change in diversity with increasing disturbance. Others have found that cover, due to its strong effect on periphyton, affects invertebrate abundance and diversity, both characteristics being higher at higher levels of periphyton (Towns 1981, Quinn et al. 1997). However this was not the case here, cover had no effect on either total invertebrates or diversity.

Hydrological disturbance events are thought to reduce invertebrate abundance and species diversity in two ways; directly by washing away and crushing individuals (Sagar 1986, Reice et al. 1990) and indirectly by reducing primary productivity or the abundance of periphyton food source (Robinson and Minshall 1986, Death 1996). In this study disturbance did reduce periphyton biomass. However, since invertebrate abundance and diversity showed no response to the effect of cover, both appear to be primarily influenced by the physical mechanisms of disturbance. Whether productivity, disturbance or some combination of both is the major determinant of stream invertebrate diversity is the basis for much debate (Vinson and Hawkins 1998). Death and Winterbourn (1995) considered disturbance to be the most influential factor while Pearson and Connolly (2000) consider productivity to be most important and it has even been suggested that the two may be important at different scales (Lake 2000).

Interestingly, overall invertebrate community composition, unlike invertebrate abundance and diversity, was strongly effected by cover or the associated reduced periphyton biomass while disturbance had no effect. Communities in open baskets and Surber samples were similar but different from those under cover, while communities in disturbed and non-disturbed treatments showed no distinction. A difference in communities between open, relatively high productivity sites, and closed, relatively low productivity sites, was also seen within streams in Chapter 2. Although unlike this experiment, in unstable streams disturbance reduced periphyton to an equal level inside and outside the canopy, and eliminated the difference in community composition between open and closed sites.

Characteristic animals of communities in respective treatment baskets suggest that the difference between communities in the open and covered baskets was in response to differences in food source. Communities in the open, where primary productivity was relatively high, were dominated by generalists, periphyton grazers and collector/ grazers, all of which use periphyton as their major food source, while dominant taxa under cover included a filterer, a detritivore and a shredder. Suspended organic particle feeding filterers such as *Coloburiscus humeralis* are more commonly found in New Zealand forest streams compared to open streams (Harding and Winterbourn 1993) while shredders are predicted to be most abundant in the upper forested regions of streams where there is more large particulate organic matter input (Vannote et al. 1980). In this study, even though the experiment did not replicate forest exactly, suspended organic matter and detritis which filterers and detritivores feed on would not have been equivalent to a forest stream although leaves caught on the baskets (P.O.M.) would have been a food source for the shredder *Triplectides obsoleta*.

In summary this study shows that cover and disturbance both affect the macroinvertebrate community in this stream. Cover strongly influences primary productivity and, probably as a consequence, dictates macroinvertebrate community composition while the physical mechanisms of disturbance are largely responsible for reducing total invertebrate abundance and species diversity.

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SYNTHESIS

SYNTHESIS

Physical disturbance has been identified as one of the principal controlling factors of invertebrate communities (Resh et al. 1988, Riece et al. 1990). However disturbance effects animals by direct physical removal and removal of their food source but the relative importance of each mechanism is not known. In this thesis I have attempted to examine the relative importance of physical disturbance and the alteration of the communities food base by examining the relative importance of substrate movement, forest canopy and artificial cover in determining invertebrate community structure either directly or through its effect on the community food base.

To examine the relative importance of canopy cover and stability I examined 2 sites (inside and outside the forest) on each of 10 streams which differed in their stability. Canopy cover reduced periphyton biomass as did substrate movement at the more unstable sites. This was strongly associated with higher species richness and abundance of invertebrates at open stable sites. Diversity and abundance was correspondingly low at closed canopy sites and both unstable open and unstable closed sites. Taxonomic composition was most similar at unstable sites and closed canopy sites, but different from community composition at open stable sites. It appears stability is the primary determinate of community structure but at stable sites the presence of forest canopy leads to a large shift in taxonomic make-up between open and close sites on the same stream only several hundred meters apart apart.

Although the difference in communities between open and closed sites seemed to be strongly related to the abundance of periphyton an experimental manipulation was conducted to examine whether this was in fact the case. The experiment revealed that disturbance had the major effect on diversity and abundance but the presence of cover was the principal determinant of community composition. It would appear that both canopy cover and disturbance are both important, but that they determine different aspects of the community; disturbance controls diversity, and canopy cover controls the relative abundance of the more common animals.

It seems reduction of periphyton abundance by either canopy cover or disturbance is the primary determinate of community structure in these streams. While physical removal, as evidenced in the experiment, can lower diversity and abundance by removing individual animals. The nature of the food base clearly appears to be more important in affecting the majority of the community. Although it is difficult to separate the effects of disturbance and periphyton reduction as they are intimately linked it does appear that the primary mechanism by which disturbance affects community structure is by the reduction of a community's food base.

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APPENDICES

APPENDICES

Appendix 1. Mean number of macroinvertebrate individuals and species collected in 5 0.1m^{2}Surber samples in Autumn (April), Winter (July), Spring (October) and Summer (January) at 20 Taranaki ring plain stream sites between April 1999 and March 2000.

Waipuku Stream	**Site C1**				**Site O1**			
Species	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**
Archichauliodes diversus			0.2	0.4	0.8	0.4	1.6	1.0
Acanthophlebia cruentata	6.0	41.8	19.6	9.2	65.4	20.6	47.0	18.4
Ameletopsis perscitus	15.8	84.2	146.4	101.8	51.2	68.0	181.4	116.0
Austroclima jollyae	0.2	0.6	1.2	1.2	10.4	11.0	16.4	2.4
Coloburiscus humeralis	0.2		0.2	0.6	0.8	2.6	1.4	0.2
Deleatidium spp.								
Ichtybotus hudsoni		0.2			0.2			
Neozephlebia spp.	0.4		0.4	0.2			0.2	
Nesameletus spp.	1.0			0.2	1.0		0.6	
Oniscigaster wakefieldi	0.2				0.6		0.2	
Zephlebia dentata							0.2	0.2
Zephlebia versicolor								
Austroperla cyrene	1.6	1.4	1.2	0.6		1.0	0.8	0.6
Acroperla trivacuata								
Megaleptoperla diminuta	0.8	0.2	0.4	1.6	1.6	0.8	2.4	1.4
Megaleptoperla grandis	1.0	0.4	2.8	0.8	0.6	0.8	0.8	
Spaniocerca zelandica	2.4	14.8	10.4	7.4	0.6	0.8	2.4	
Stenoperla prasina	4.0	4.4	8.2	0.6	7.2	4.2	6.6	3.0
Taraperla sp. A								
Zelandobius sp. A								
Zelandoperla decorata								
Beraeoptera roria		1.4	7.4	0.4	105.6	114.6	136.0	1.0
Beraeoptera roria, pupa								
Confluens hamiltonii					3.4	0.8	0.2	0.8
Helicopsychidae sp. A					0.2	10.6	29.2	1.6
Oeconesus similis					3.8	0.2	0.2	
Olinga feredayi		0.8	0.4					
Oxyethira albiceps					0.8			
Oxyethira albiceps, pupa								
Pycnocentrella spp.			0.4					
Pycnocentria funera	0.2	0.4						
Pycnocentrodes spp.								
Triplectides obsoleta								0.2
Zelolessica cheira								
Costachorema callista					0.6		0.2	0.2
Aoteapsyche colonica		0.4	0.6		2.6	1.0	0.4	
Aoteapsyche raruraru							0.6	
Costachorema xanthoptera								0.2
Hydrobiosella stenocerca					8.8		2.4	0.6
Hydrobiosidae, early instar			0.8		0.4	0.4		
Hydrobiosis clavigera						0.2		
Hydrobiosis parumbripennis					6.6	1.0	1.4	
Hydrobiosidae spp., pupa					3.2	1.2	1.6	0.8
Hydropsychidae spp., pupa	1.8	3.4	1.6	2.2	0.4		0.4	1.2
Hydropsychidae, early instar	16.4	25.4	11.4	1.4		0.4	3.2	4.0
Neurochorema forsteri	0.8	1.0		1.2				0.2
Orthopsyche fimbriata			1.4	0.6			0.4	
Orthopsyche thomasi							0.2	
Polyplectropus puerilis							0.2	
Psilochorema sp. A					3.6	1.8	1.8	
Psilochorema sp. B	0.8			1.4	7.2	3.6	6.6	3.2
Hydraenidae spp., adult	3.0	1.0	2.8	4.4	2.6		1.2	2.0
Elmidae spp.		0.4				0.2	0.2	0.8
Elmidae spp., adult	3.6	1.8	6.2	8.4	21.2	16.6	15.4	8.0
Hydrophilidae sp. A			0.4	0.2				

Ptilodactylidae spp.								
Scirtidae spp.					0.2			
Aphrophila neozelandica	0.2	0.4	0.4		29.6	9.8	43.0	10.6
Empididae sp. A				0.6				
Empididae sp. B	0.2	0.6	1.0			0.8	0.8	
Ephydrella spp.					0.8			
Eriopterini- Molophilus								2.6
Eriopterini sp. A								
Hexatomini spp.								
Limnophora sp. A								
Limonia nigrescens		0.4			0.2	0.4	0.2	
Neoscatella vittithorax				0.2				
Paradixa spp.								
Paralimnophila skusei								
Psychodidae sp. A							0.2	
Psychodidae sp. B								
Simuliidae spp., australense grp.								
Simuliidae spp. pupa								
Tabanidae spp.								
Tanyderidae spp.								
Tipulidae/ Tanyderidae sp. A, pupa								
Zelandotipula spp.								
Orthocladiinae grp. spp	36.6	2.6	3.8	1.0	128.6	56.2	70.8	4.8
Chironimidae spp., pupa	2.8	0.4	0.8	0.2	3.8	2.0	1.4	0.6
Diamesinae sp. A	1.0	0.4	1.4		1.4	3.6	33.8	0.4
Maoridiamesa					1.0		0.2	
Podonominae		0.2	0.6	0.4			0.4	0.2
Polypedilum			0.6					
Tanypodinae							7.0	0.6
Tanytarsus		0.6		0.6		0.2		0.2
Oligochaeta, large (>1.5 cm)	0.4		1.0	0.2	5.2	0.4	0.2	0.6
Oligochaeta, small (<1.5 cm)								
Platyhelminthes spp.					0.2			
Potamopyrgus antipodarum								
Amphipoda spp.								
Collembola spp.								
Paranephrops								
Parayta								
Acarina spp.								
Mean No. Individuals/ Sample	101.4	189.6	234.0	148.0	482.4	336.2	621.8	188.6
Mean No. Species/ Sample	14.0	15.2	16.4	15.0	24.2	19.0	26.6	16.8

Waipuku Stream Tributary	**Site C2**				**Site O2**			
Species	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**
Archichauliodes diversus					0.8			
Acanthophlebia cruentata	9.8	19.4	13.6	7.6	20.3	13.6	7.8	5.0
Ameletopsis perscitus	22.8	76.4	117.2	76.0	45.8	103.8	191.6	199.2
Austroclima jollyae	1.4	1.4	1.0	6.0	4.8	0.8	0.8	0.6
Coloburiscus humeralis	0.4	0.4	0.2	0.6		0.6		
Deleatidium spp.								
Ichtybotus hudsoni			0.2	0.2				
Neozephlebia spp.				0.4				0.4
Nesameletus spp.			0.4	1.2		0.2	0.2	0.4
Oniscigaster wakefieldi	0.4		0.2	0.2	0.5		0.4	0.2
Zephlebia dentata								
Zephlebia versicolor							0.4	
Austroperla cyrene	1.0	1.0	2.2	0.8	1.3	0.4	0.8	0.4
Acroperla trivacuata			0.2					
Megaleptoperla diminuta		1.2		2.0	2.8	2.8	2.0	1.0
Megaleptoperla grandis	1.0	1.4	2.6	0.6	1.3	3.2	1.4	4.8
Spaniocerca zelandica	4.6	5.0	8.0	3.0	5.3	8.0	7.4	3.0
Stenoperla prasina	0.8	2.8	8.2	1.8	0.5	1.8		
Taraperla sp. A								
Zelandobius sp. A							0.2	
Zelandoperla decorata							0.2	

Beraeoptera roria	0.2	0.6	2.0		11.3	37.2	9.4	
Beraeoptera roria, pupa							1.4	
Confluens hamiltonii								
Helicopsychidae sp. A			2.2			0.4	1.0	
Oeconesus similis						0.2		0.2
Olinga feredayi	0.2	0.4			0.5			0.2
Oxyethira albiceps								
Oxyethira albiceps, pupa								
Pycnocentrella spp.						0.2		
Pycnocentria funera		0.2	0.4				0.4	
Pycnocentrodes spp.								
Triplectides obsoleta								
Zelolessica cheira								
Costachorema callista		0.4			1.5	0.6	1.4	0.4
Aoteapsyche colonica					1.0	6.2	0.4	
Aoteapsyche raruraru								
Costachorema xanthoptera								
Hydrobiosella stenocerca		0.2	0.6	0.2	0.8	0.2	0.8	0.2
Hydrobiosidae, early instar			0.4	0.4	0.3	1.0	1.2	
Hydrobiosis clavigera	1.0	0.4	0.2	0.8			0.4	0.2
Hydrobiosis parumbripennis					1.8	0.2		
Hydrobiosidae spp., pupa					4.0			
Hydropsychidae spp., pupa	0.8		1.0	2.4	0.3	2.2	1.8	0.8
Hydropsychidae, early instar	19.0	14.8	11.4	1.4	2.5	7.6	2.2	1.2
Neurochorema forsteri	0.6		0.2	2.2	0.3			1.2
Orthopsyche fimbriata	0.4	0.2	1.4	2.0			1.8	0.2
Orthopsyche thomasi								
Polyplectropus puerilis								0.4
Psilochorema sp. A							0.4	
Psilochorema sp. B	1.2	3.2	1.4	1.0	2.0	6.8	5.6	1.4
Hydraenidae spp., adult	1.0	1.4	2.8	1.2	0.8	1.0	0.4	1.2
Elmidae spp.	6.2				7.3			
Elmidae spp., adult		3.2	10.6	5.2		3.6	8.0	10.4
Hydrophilidae sp. A				0.2				
Ptilodactylidae spp.	0.2							
Scirtidae spp.								
Aphrophila neozelandica			0.6	0.6	7.3	9.8	23.8	5.4
Empididae sp. A				0.4				0.6
Empididae sp. B	0.2	1.2	1.0	0.2	0.3	1.4	1.4	
Ephydrella spp.								
Eriopterini- Molophilus								
Eriopterini sp. A								
Hexatomini spp.								
Limnophora sp. A								
Limonia nigrescens							0.2	
Neoscatella vittithorax				0.2				
Paradixa spp.								
Paralimnophila skusei								
Psychodidae sp. A								
Psychodidae sp. B								
Simuliidae spp., australense grp.								
Simuliidae spp. pupa								
Tabanidae spp.								
Tanyderidae spp.								
Tipulidae/ Tanyderidae sp. A, pupa								
Zelandotipula spp.								
Orthocladiinae grp. spp	1.2	1.2	6.2		143.3	203.6	44.4	3.0
Chironimidae spp., pupa	0.6	0.2	0.2	0.4	1.8	1.4	0.6	0.2
Diamesinae sp. A		3.2	3.8		1.5	93.2	103.8	0.6
Maoridiamesa				0.2		0.2		
Podonominae			0.4	0.2		0.6	0.4	0.4
Polypedilum		0.4	0.4					
Tanypodinae			0.2				18.4	
Tanytarsus		0.2				1.4		0.4
Oligochaeta, large (>1.5 cm)	1.6	5.0	0.6	0.8	10.5	9.8		1.6
Oligochaeta, small (<1.5 cm)								
Platyhelminthes spp.	0.2				1.3			
Potamopyrgus antipodarum								

Amphipoda spp.								
Collembola spp.			0.2					
Paranephrops								
Parayta								
Acarina spp.								
Mean No. Individuals/ Sample	76.8	145.4	202.2	120.4	282.8	524.0	442.8	245.2
Mean No. Species/ Sample	13.4	15.2	19.0	14.0	16.0	21.0	21.8	15.8

Mangatoki Stream	**Site C1**				**Site O3**			
Species	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**
Archichauliodes diversus	1.2		0.2		12.2	11.8	21.0	12.2
Acanthophlebia cruentata	20.2	59.8	206.6	42.0	172.2	35.0	78.0	4.0
Ameletopsis perscitus	16.8	82.8	249.6	96.8	35.4	30.6	23.0	74.2
Austroclima jollyae	0.2	0.2	0.2	3.4	5.8	10.2	7.0	6.4
Coloburiscus humeralis	1.8	12.4	5.6	6.4	0.8	1.0		0.6
Deleatidium spp.				0.2				
Ichtybotus hudsoni	0.4							0.4
Neozephlebia spp.								
Nesameletus spp.		0.8	31.0	21.6			2.0	
Oniscigaster wakefieldi				0.2				0.2
Zephlebia dentata								
Zephlebia versicolor								
Austroperla cyrene	0.8	0.4	1.2	0.6	1.2		0.2	
Acroperla trivacuata				0.6	0.2			
Megaleptoperla diminuta			0.6	1.0	0.6		3.4	
Megaleptoperla grandis	1.0	1.0	3.2	1.0	1.8	0.2	0.4	0.6
Spaniocerca zelandica	1.6	9.2	37.8	3.4		0.4		0.2
Stenoperla prasina	0.6	2.8	8.8	0.4	0.2	2.4	2.4	0.2
Taraperla sp. A				0.2				0.2
Zelandobius sp. A							0.2	
Zelandoperla decorata								0.2
Beraeoptera roria	1.2		0.8		14.8	27.6	163.8	
Beraeoptera roria, pupa							3.2	
Confluens hamiltonii	0.2				0.2		0.8	
Helicopsychidae sp. A		0.4	0.4	0.2			0.4	
Oeconesus similis	0.4				0.2	0.2	1.0	0.4
Olinga feredayi					0.2			
Oxyethira albiceps	0.2	5.2	1.2	0.4	1.0			
Oxyethira albiceps, pupa								
Pycnocentrella spp.		0.2						
Pycnocentria funera	0.6	0.8	0.2	0.2			0.2	
Pycnocentrodes spp.								
Triplectides obsoleta								0.4
Zelolessica cheira								
Costachorema callista		0.2	0.4	0.6				0.2
Aoteapsyche colonica	0.2	0.2	0.4	1.2	1.2	0.2	0.4	0.2
Aoteapsyche raruraru						2.2	1.2	
Costachorema xanthoptera				0.2	0.4		0.8	0.2
Hydrobiosella stenocerca	0.4	0.2	1.0	0.2	2.4	0.2	1.0	0.4
Hydrobiosidae, early instar		0.2				0.2		
Hydrobiosis clavigera	1.0	0.6	1.2	0.2				
Hydrobiosis parumbripennis	0.2	56.4			3.6			
Hydrobiosidae spp., pupa					2.6	0.6	6.4	3.4
Hydropsychidae spp., pupa	18.4	6.6	14.6	7.8	4.6	2.4	10.6	1.4
Hydropsychidae, early instar	17.6	13.4	114.6	4.4	6.8	3.4	16.8	2.2
Neurochorema forsteri				0.6	0.2			
Orthopsyche fimbriata			0.2					
Orthopsyche thomasi								
Polyplectropus puerilis								
Psilochorema sp. A								
Psilochorema sp. B		0.8	1.2	1.4	3.2	0.2	4.0	2.2
Hydraenidae spp., adult	0.6	0.4	1.0	1.0	1.0		0.4	1.0
Elmidae spp.	2.6						0.4	0.4
Elmidae spp., adult		2.4	5.4	3.6	10.6	9.0	9.6	13.8
Hydrophilidae sp. A			3.0	0.2			0.6	2.2

Ptilodactylidae spp.								
Scirtidae spp.		0.2						
Aphrophila neozelandica	0.6	0.8	2.8	0.4	27.6	12.4	38.0	17.2
Empididae sp. A				1.2				4.2
Empididae sp. B		0.6	0.2	0.2	0.8	4.2	0.4	
Ephydrella spp.								
Eriopterini- Molophilus				0.2				3.2
Eriopterini sp. A		0.2			0.2	0.2	0.4	0.2
Hexatomini spp.								0.2
Limnophora sp. A		0.2	0.2					
Limonia nigrescens						0.2		
Neoscatella vittithorax			0.2					
Paradixa spp.								
Paralimnophila skusei								
Psychodidae sp. A								
Psychodidae sp. B								
Simuliidae spp., australense grp.								
Simuliidae spp. pupa								
Tabanidae spp.								0.2
Tanyderidae spp.								
Tipulidae/ Tanyderidae sp. A, pupa								
Zelandotipula spp.					0.2			
Orthocladiinae grp. spp	2.8	1.2	2.6	2.0	89.6	1.0	12.8	16.0
Chironimidae spp., pupa	0.4		0.2	1.2	0.6		0.2	
Diamesinae sp. A					0.2		1.2	
Maoridiamesa						0.4	0.4	0.6
Podonominae					0.2		0.2	
Polypedilum		0.6	4.4			0.4		
Tanypodinae								
Tanytarsus					0.8			
Oligochaeta, large (>1.5 cm)	1.4	1.2	2.4	1.2	2.6			4.0
Oligochaeta, small (<1.5 cm)					0.2			
Platyhelminthes spp.	1.2			0.8	1.6			
Potamopyrgus antipodarum	0.4	0.2						0.2
Amphipoda spp.	0.2					0.2		
Collembola spp.								
Paranephrops								
Parayta			0.2					
Acarina spp.						0.2		
Mean No. Individuals/ Sample	95.2	262.6	703.6	207.2	408.0	157.0	412.8	173.8
Mean No. Species/ Sample	16.4	15.2	20.0	19.4	21.4	14.6	21.2	18.2

Kaupokonui East Stream Tributary	**Site C4**				**Site O4**			
Species	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**
Archichauliodes diversus	0.2				0.4	0.2	1.2	1.6
Acanthophlebia cruentata	19.2	18.2	76.0	14.4	22.4	32.0	87.4	24.6
Ameletopsis perscitus	21.2	40.4	99.0	70.8	33.8	91.4	207.6	151.8
Austroclima jollyae	2.6	1.0		0.6	1.4	7.6	7.8	1.0
Coloburiscus humeralis	0.4	4.2	1.8	1.4		3.4	1.2	0.2
Deleatidium spp.								
Ichtybotus hudsoni		0.2	0.2					0.2
Neozephlebia spp.				0.2				
Nesameletus spp.		0.2	6.0	2.0			3.4	3.2
Oniscigaster wakefieldi			0.8				2.0	
Zephlebia dentata			0.2	0.4				
Zephlebia versicolor								
Austroperla cyrene	0.6	0.4	2.0	0.6	0.6	1.0	1.2	1.2
Acroperla trivacuata								
Megaleptoperla diminuta	0.4		0.6	0.4	0.2	0.6	0.6	1.0
Megaleptoperla grandis	0.2	0.2	2.0	1.0	0.2	0.4	1.4	1.6
Spaniocerca zelandica	1.4	3.4	15.8	1.0	0.4	1.2	4.8	
Stenoperla prasina	1.2	2.6	5.6	4.0	1.2	4.8	10.8	1.4
Taraperla sp. A				0.2				
Zelandobius sp. A								

Zelandoperla decorata							0.2	
Beraeoptera roria	12.6	0.8	4.4	0.6	49.0	47.6	192.6	4.0
Beraeoptera roria, pupa								1.0
Confluens hamiltonii	0.2	0.6	0.4		1.0	1.6	1.0	
Helicopsychidae sp. A	0.2			0.2	0.2	10.6	29.2	0.4
Oeconesus similis	1.0				4.4	2.6	22.8	5.8
Olinga feredayi								
Oxyethira albiceps			0.2					
Oxyethira albiceps, pupa							0.2	
Pycnocentrella spp.			0.2					
Pycnocentria funera	0.2		0.2					
Pycnocentrodes spp.						0.2		0.2
Triplectides obsoleta								
Zelolessica cheira								
Costachorema callista				0.2				
Aoteapsyche colonica					0.6		0.6	0.4
Aoteapsyche raruraru								
Costachorema xanthoptera						0.4	0.8	
Hydrobiosella stenocerca	0.2	0.2	0.2		2.0	0.6	1.2	0.2
Hydrobiosidae, early instar	0.2	0.4	2.0	0.2	0.4	0.4	1.8	0.2
Hydrobiosis clavigera	0.4		0.6	0.4				0.2
Hydrobiosis parumbripennis					11.0	2.6	4.4	4.0
Hydrobiosidae spp., pupa	0.2		0.4	0.2	3.4	4.6	15.6	4.2
Hydropsychidae spp., pupa	1.6	0.4	4.0	3.8	0.2	0.2		0.2
Hydropsychidae, early instar	13.4	5.8	28.0	10.0		1.0	0.4	11.2
Neurochorema forsteri	0.6				0.2			
Orthopsyche fimbriata			2.8	0.4				
Orthopsyche thomasi		0.2						
Polyplectropus puerilis						0.2	0.2	0.4
Psilochorema sp. A					0.2	1.0	1.4	0.2
Psilochorema sp. B	1.6		0.6	1.4	3.6	4.6	4.6	2.6
Hydraenidae spp., adult			2.0	1.0		0.2	3.0	0.6
Elmidae spp.								
Elmidae spp., adult	7.0	0.4	1.2	5.6	1.8	1.2	8.0	7.6
Hydrophilidae sp. A		0.4	0.2	0.2			0.4	
Ptilodactylidae spp.								
Scirtidae spp.								
Aphrophila neozelandica	0.8	0.4	3.2	5.4	9.6	6.6	25.0	22.4
Empididae sp. A				0.6				0.2
Empididae sp. B	1.2	0.8	0.6	0.2	0.2	0.4	0.8	0.2
Ephydrella spp.	0.2	0.2						0.4
Eriopterini- Molophilus								0.4
Eriopterini sp. A		0.2						
Hexatomini spp.							1.0	
Limnophora sp. A								
Limonia nigrescens								
Neoscatella vittithorax								
Paradixa spp.								
Paralimnophila skusei								
Psychodidae sp. A								
Psychodidae sp. B								0.2
Simuliidae spp., australense grp.								
Simuliidae spp. pupa								0.8
Tabanidae spp.								
Tanyderidae spp.								
Tipulidae/ Tanyderidae sp. A, pupa								
Zelandotipula spp.								
Orthocladiinae grp. spp	5.0	0.8	1.4	2.0	26.0	34.4	14.6	15.6
Chironimidae spp., pupa		0.2		0.2	0.2	2.6	3.6	0.6
Diamesinae sp. A	0.2	0.2			1.2	8.6	5.4	7.8
Maoridiamesa							0.8	
Podonominae			0.4				0.2	
Polypedilum			1.0					
Tanypodinae							0.6	0.2
Tanytarsus				0.2		0.6	0.2	0.4
Oligochaeta, large (>1.5 cm)	3.2	1.2	2.0	1.4	5.0	1.4	2.0	
Oligochaeta, small (<1.5 cm)								0.4
Platyhelminthes spp.	0.4				0.2		0.4	0.2

Potamopyrgus antipodarum					0.6	0.6	1.6	3.4
Amphipoda spp.								
Collembola spp.								
Paranephrops								
Parayta								
Acarina spp.								
Mean No. Individuals/ Sample	97.8	84.0	266.0	131.2	181.6	277.4	674.0	284.4
Mean No. Species/ Sample	14.2	11.2	19.8	17.2	17.2	22.4	27.0	23.4

Kaupokonui East Stream	**Site C5**				**Site O5**			
Species	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**
Archichauliodes diversus	3.0	2.2	5.2	1.3	2.4	0.2	6.0	0.4
Acanthophlebia cruentata	87.4	79.6	44.2	19.0	41.6	9.0	3.8	10.4
Ameletopsis perscitus	80.4	90.8	275.8	149.3	83.4	153.4	154.0	163.6
Austroclima jollyae	3.8	0.8	1.8	0.5	1.2	2.0	3.8	0.2
Coloburiscus humeralis	0.2	0.6			0.2	0.2		
Deleatidium spp.								
Ichtybotus hudsoni							0.2	
Neozephlebia spp.		0.2				0.2		
Nesameletus spp.			0.4	0.5			0.6	0.4
Oniscigaster wakefieldi		0.2	0.2	0.3			1.2	0.6
Zephlebia dentata								
Zephlebia versicolor							0.2	0.2
Austroperla cyrene	0.2	0.6	1.0	0.3	0.6	0.4	0.2	
Acroperla trivacuata								
Megaleptoperla diminuta	3.0	1.4	4.6	12.5	2.0	1.2	4.2	8.2
Megaleptoperla grandis	1.6	0.6	2.8	2.3	1.0	4.4	3.8	1.6
Spaniocerca zelandica	4.0	1.8	2.0		1.4	3.6	5.2	
Stenoperla prasina	7.8	11.6	14.8	13.0	14.0	9.2	14.6	22.4
Taraperla sp. A								0.4
Zelandobius sp. A								
Zelandoperla decorata								
Beraeoptera roria	86.0	11.2	383.2	15.3	243.8	21.8	300.0	51.2
Beraeoptera roria, pupa				0.3			5.2	4.8
Confluens hamiltonii			1.8		0.2		1.0	
Helicopsychidae sp. A	0.4	0.2	4.4		3.6	0.4	32.4	3.0
Oeconesus similis	2.2	0.4	9.8	6.8	3.0	0.8	12.2	4.0
Olinga feredayi	0.4	0.2		0.5	0.2	0.4	0.6	
Oxyethira albiceps	0.8		0.2				0.2	
Oxyethira albiceps, pupa								
Pycnocentrella spp.								
Pycnocentria funera	0.2							
Pycnocentrodes spp.								
Triplectides obsoleta					1.6			
Zelolessica cheira								
Costachorema callista								
Aoteapsyche colonica	0.2	0.2			0.2	0.2	0.4	
Aoteapsyche raruraru							0.2	
Costachorema xanthoptera								
Hydrobiosella stenocerca		0.2	1.2		0.6	0.4	1.2	
Hydrobiosidae, early instar	1.4	2.4	3.0	0.3	0.6	1.8	2.2	0.6
Hydrobiosis clavigera	0.6						0.2	
Hydrobiosis parumbripennis	0.6		1.6		2.4		0.2	
Hydrobiosidae spp., pupa	0.6	9.0	4.8		0.6	0.2	2.0	0.2
Hydropsychidae spp., pupa	0.6	2.2	2.0	1.0		0.4	0.4	
Hydropsychidae, early instar	9.8	4.4	2.6	1.3	1.2	1.0		0.2
Neurochorema forsteri					0.4			
Orthopsyche fimbriata			0.8	1.5				0.4
Orthopsyche thomasi				0.3				
Polyplectropus puerilis								
Psilochorema sp. A			0.2				1.0	
Psilochorema sp. B	1.6	1.6	1.8	0.5	3.0	2.0	6.4	0.8
Hydraenidae spp., adult	2.8	1.0	5.2	4.5	2.4		4.2	1.6
Elmidae spp.		0.6		0.5			0.2	0.2
Elmidae spp., adult	27.0	8.8	37.2	20.8	27.8	4.8	29.6	26.6

Hydrophilidae sp. A								
Ptilodactylidae spp.						0.2		
Scirtidae spp.								
Aphrophila neozelandica	9.6	9.4	41.8	19.0	5.4	3.4	40.2	6.8
Empididae sp. A				0.3				0.2
Empididae sp. B	0.6	2.8	2.6		0.8	2.2	1.4	
Ephydrella spp.					0.6			
Eriopterini- Molophilus								
Eriopterini sp. A								
Hexatomini spp.			0.2				0.2	
Limnophora sp. A						0.2		
Limonia nigrescens			0.4	0.3			0.4	
Neoscatella vittithorax								
Paradixa spp.								
Paralimnophila skusei								
Psychodidae sp. A								
Psychodidae sp. B								
Simuliidae spp., australense grp.								
Simuliidae spp. pupa				0.3				
Tabanidae spp.								
Tanyderidae spp.								
Tipulidae/ Tanyderidae sp. A, pupa								
Zelandotipula spp.								
Orthocladiinae grp. spp	4.4	1.2	7.8	0.8	13.4	1.0	59.4	1.8
Chironimidae spp., pupa	1.0	6.4	3.4	1.5	0.4	1.2		1.4
Diamesinae sp. A		0.2	7.0		1.4	0.2	27.0	0.8
Maoridiamesa				0.3			0.8	
Podonominae			0.6	0.3				
Polypedilum		1.8				0.4	1.0	
Tanypodinae							0.6	
Tanytarsus							1.2	
Oligochaeta, large (>1.5 cm)	2.6		0.2	0.3	1.8			
Oligochaeta, small (<1.5 cm)					0.2			
Platyhelminthes spp.					0.8			
Potamopyrgus antipodarum		0.2						
Amphipoda spp.								
Collembola spp.								
Paranephrops								
Parayta								
Acarina spp.								
Mean No. Individuals/ Sample	344.8	254.8	876.6	274.8	464.2	226.8	729.8	313.0
Mean No. Species/ Sample	18.6	15.6	26.2	14.4	19.4	17.8	25.4	15.2

Dunns Creek	**Site C6**				**Site O6**			
Species	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**
Archichauliodes diversus			0.2		0.2	0.6	0.6	
Acanthophlebia cruentata	56.2	85.8	80.2	36.4	78.8	92.2	55.2	19.0
Ameletopsis perscitus	43.8	78.2	118.4	53.4	77.4	68.4	130.0	53.4
Austroclima jollyae		0.2	0.6	0.4	55.2	9.6	14.6	0.8
Coloburiscus humeralis	2.2	6.2	1.0	1.8		6.0	0.4	0.6
Deleatidium spp.								
Ichtybotus hudsoni	0.8							
Neozephlebia spp.	0.4		0.4	0.4			0.2	
Nesameletus spp.			9.4	5.2			5.8	1.6
Oniscigaster wakefieldi			0.4				1.0	
Zephlebia dentata								
Zephlebia versicolor								
Austroperla cyrene	1.0	1.0	0.2	2.2	0.6		0.8	0.6
Acroperla trivacuata			0.2					
Megaleptoperla diminuta			1.2					
Megaleptoperla grandis	1.4	1.2	3.2	2.6	0.6	0.8	1.4	0.4
Spaniocerca zelandica	18.0	36.6	13.6	25.8	3.4	3.0	4.6	2.4
Stenoperla prasina	1.2	2.0	1.8	1.4	2.2	4.2	4.6	4.6
Taraperla sp. A								
Zelandobius sp. A								

Zelandoperla decorata			0.2					
Beraeoptera roria	0.2	0.2	2.2		48.8	27.0	24.4	0.4
Beraeoptera roria, pupa								0.2
Confluens hamiltonii					2.6		0.4	
Helicopsychidae sp. A						1.2	0.6	
Oeconesus similis	0.6				0.4		1.2	
Olinga feredayi								
Oxyethira albiceps								
Oxyethira albiceps, pupa								
Pycnocentrella spp.								
Pycnocentria funera							0.2	
Pycnocentrodes spp.					6.8			0.6
Triplectides obsoleta					16.4			0.2
Zelolessica cheira								
Costachorema callista	0.2							
Aoteapsyche colonica	1.0		0.8	0.2	2.4	0.6	1.4	0.2
Aoteapsyche raruraru								
Costachorema xanthoptera						0.2		
Hydrobiosella stenocerca	0.4	0.2	0.2		1.2	0.4		2.2
Hydrobiosidae, early instar	0.4	0.2	0.2	0.8	1.4	0.2	0.4	
Hydrobiosis clavigera	1.8	0.8	0.6	0.4	0.6	0.4	0.2	
Hydrobiosis parumbripennis	0.2		1.4		3.2	0.2		
Hydrobiosidae spp., pupa					4.8	2.2	1.4	2.4
Hydropsychidae spp., pupa	5.0	5.6	5.4	8.8		7.4	5.6	3.0
Hydropsychidae, early instar	67.4	76.8	46.6	46.0	5.0	11.6	10.0	3.4
Neurochorema forsteri					0.2			
Orthopsyche fimbriata	0.4	14.2	12.6	3.6				0.6
Orthopsyche thomasi								
Polyplectropus puerilis							0.2	
Psilochorema sp. A							0.2	
Psilochorema sp. B	3.2	0.8	2.6	0.4	9.6	2.2	2.0	2.8
Hydraenidae spp., adult		0.4	0.2	0.8	0.2	1.0	1.6	1.2
Elmidae spp.			1.2					
Elmidae spp., adult	1.8	0.2	0.2	0.2	5.4	1.4	5.8	5.0
Hydrophilidae sp. A		0.8	1.4	1.8		0.4		
Ptilodactylidae spp.						0.4		
Scirtidae spp.				0.2				
Aphrophila neozelandica			0.4		17.8	13.4	13.8	17.4
Empididae sp. A								1.8
Empididae sp. B	0.6	1.2	1.0		0.4	1.0	1.6	
Ephydrella spp.					0.6			
Eriopterini- Molophilus				0.4				3.8
Eriopterini sp. A								
Hexatomini spp.							0.8	0.6
Limnophora sp. A	0.2							
Limonia nigrescens								
Neoscatella vittithorax								
Paradixa spp.								
Paralimnophila skusei								
Psychodidae sp. A								
Psychodidae sp. B							0.2	
Simuliidae spp., australense grp.				0.2				0.2
Simuliidae spp. pupa								
Tabanidae spp.								
Tanyderidae spp.								0.2
Tipulidae/ Tanyderidae sp. A, pupa								
Zelandotipula spp.								
Orthocladiinae grp. spp	6.8	3.2	0.8	3.2	8.2	1.6	5.0	100.8
Chironimidae spp., pupa	1.0	2.8		3.2	0.4	0.2	0.2	1.6
Diamesinae sp. A	0.4		0.2	3.0		0.2	1.2	73.2
Maoridiamesa			0.2					
Podonominae			1.0	4.4				0.4
Polypedilum		5.6	26.0			0.6	0.2	
Tanypodinae								3.4
Tanytarsus								1.2
Oligochaeta, large (>1.5 cm)	4.2	6.2	1.4		28.0	1.2		0.2
Oligochaeta, small (<1.5 cm)					0.2			
Platyhelminthes spp.	0.6				0.6			

Potamopyrgus antipodarum	0.2						0.2	
Amphipoda spp.	0.6		0.4	0.4				0.2
Collembola spp.							0.2	
Paranephrops								
Parayta								
Acarina spp.		0.2						
Mean No. Individuals/ Sample	222.2	330.6	338.0	207.6	383.6	259.8	298.2	310.6
Mean No. Species/ Sample	17.8	15.0	19.6	17.6	21.6	18.2	23.6	21.8

Little Dunns Creek	**Site C 7**				**Site O7**			
Species	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**
Archichauliodes diversus	0.8		0.2		2.0	0.4	1.0	0.4
Acanthophlebia cruentata	84.6	62.4	75.2	30.6	42.8	133.6	49.0	30.4
Ameletopsis perscitus	40.2	72.2	140.2	35.4	49.0	114.8	223.4	119.2
Austroclima jollyae	0.4		0.6	0.4	8.8	1.2	3.0	0.6
Coloburiscus humeralis		5.2			1.8	7.6	0.8	
Deleatidium spp.								
Ichtybotus hudsoni	0.4							
Neozephlebia spp.	0.6	0.2	0.6					
Nesameletus spp.			7.8	0.8		0.4	0.8	1.2
Oniscigaster wakefieldi			0.4					
Zephlebia dentata								
Zephlebia versicolor								
Austroperla cyrene	0.4	1.6	0.8	0.4	2.2	1.2	1.4	1.2
Acroperla trivacuata							0.4	
Megaleptoperla diminuta	0.2	0.2		0.6	0.4	0.8		0.2
Megaleptoperla grandis	1.8	0.6	2.8	0.8	1.4	1.4	2.6	0.8
Spaniocerca zelandica	6.8	15.2	18.8	5.2	3.0	7.2	10.2	3.0
Stenoperla prasina		5.8	7.6	2.2	5.4	17.4	10.6	12.4
Taraperla sp. A								
Zelandobius sp. A								
Zelandoperla decorata								
Beraeoptera roria	0.2	0.2			9.2	12.0	11.0	0.2
Beraeoptera roria, pupa							0.6	
Confluens hamiltonii								
Helicopsychidae sp. A		0.4	0.2		7.0	0.8	0.6	
Oeconesus similis			0.8			0.2		
Olinga feredayi	0.2	0.4	0.4					
Oxyethira albiceps		0.2			0.8			
Oxyethira albiceps, pupa								
Pycnocentrella spp.		0.2			0.2			
Pycnocentria funera						0.2		
Pycnocentrodes spp.					0.2		0.2	
Triplectides obsoleta					1.6			
Zelolessica cheira								
Costachorema callista	0.4		0.4			0.2	0.4	0.4
Aoteapsyche colonica		0.6	0.8	0.4	1.8		0.6	0.6
Aoteapsyche raruraru								
Costachorema xanthoptera					0.4			
Hydrobiosella stenocerca	0.4	0.2		0.2	0.8	0.8	0.8	1.2
Hydrobiosidae, early instar		0.6	0.6		0.2	0.4		0.2
Hydrobiosis clavigera	0.6	0.2	0.2	0.8	0.4	0.2	0.2	0.2
Hydrobiosis parumbripennis					0.6			
Hydrobiosidae spp., pupa				0.2	0.2	0.2		
Hydropsychidae spp., pupa	7.0	1.0	8.6	10.4	2.6	16.4	14.6	3.6
Hydropsychidae, early instar	113.0	60.0	58.0	28.0	35.8	39.0	12.4	9.0
Neurochorema forsteri	0.2				1.2			
Orthopsyche fimbriata	1.0	2.0	8.8	1.0		1.8	1.2	1.2
Orthopsyche thomasi					0.6			
Polyplectropus puerilis							0.4	
Psilochorema sp. A							0.4	
Psilochorema sp. B	1.4	0.2	0.6	0.6	1.8	1.6	3.0	2.8
Hydraenidae spp., adult	0.4	0.8	1.6	0.8	1.0	0.2	0.8	0.8
Elmidae spp.								
Elmidae spp., adult	1.0		0.6	0.2	0.8	0.4	1.6	1.4

Hydrophilidae sp. A		1.2	2.0			0.8	0.2	
Ptilodactylidae spp.						0.2		
Scirtidae spp.								
Aphrophila neozelandica	0.2	0.6	0.6		7.4	15.2	41.6	22.0
Empididae sp. A								0.4
Empididae sp. B		0.2	0.6		1.2	2.8	1.4	
Ephydrella spp.								
Eriopterini- Molophilus								0.4
Eriopterini sp. A		0.4		0.2				
Hexatomini spp.							1.2	
Limnophora sp. A								
Limonia nigrescens						0.4	0.2	
Neoscatella vittithorax								
Paradixa spp.		0.6						
Paralimnophila skusei								
Psychodidae sp. A								
Psychodidae sp. B								
Simuliidae spp., australense grp.								
Simuliidae spp. pupa								
Tabanidae spp.								
Tanyderidae spp.								
Tipulidae/ Tanyderidae sp. A, pupa							0.2	
Zelandotipula spp.		0.2						0.4
Orthocladiinae grp. spp	2.0	1.0	1.6	2.4	25.2	4.6	53.2	11.8
Chironimidae spp., pupa	0.6		1.0	1.6	2.0	0.6	37.4	3.6
Diamesinae sp. A	0.4		1.0		0.4	3.0	15.0	9.0
Maoridiamesa			0.2				0.8	0.4
Podonominae			0.6				0.4	0.4
Polypedilum		1.0	2.0			1.2	0.2	
Tanypodinae				0.2			1.2	0.4
Tanytarsus				0.2			0.6	
Oligochaeta, large (>1.5 cm)	6.0	1.4	1.2		5.8	1.6	1.2	11.4
Oligochaeta, small (<1.5 cm)							0.2	
Platyhelminthes spp.					3.4			
Potamopyrgus antipodarum		0.2			2.0	0.2		
Amphipoda spp.								
Collembola spp.								
Paranephrops								
Parayta								
Acarina spp.								
Mean No. Individuals/ Sample	271.2	237.2	347.4	123.6	231.4	391.0	507.0	251.2
Mean No. Species/ Sample	13.4	16.0	20.4	13.0	23.4	19.0	25.4	19.8

Cold Stream	**Site C8**				**Site O8**			
Species	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
Archichauliodes diversus						0.2		0.2
Acanthophlebia cruentata	5.4	6.6	15.0	13.8	7.6	10.0	31.4	17.0
Ameletopsis perscitus	32.0	3.0	45.8	43.6	58.0	80.0	153.2	156.8
Austroclima jollyae	0.4	7.4		0.4	1.2	2.2	0.2	0.6
Coloburiscus humeralis		5.6						
Deleatidium spp.								
Ichtybotus hudsoni		4.8				0.6		
Neozephlebia spp.		2.2						
Nesameletus spp.			0.2					
Oniscigaster wakefieldi								
Zephlebia dentata								
Zephlebia versicolor								
Austroperla cyrene	0.8	0.6	0.8			0.6	1.2	0.2
Acroperla trivacuata				0.2				
Megaleptoperla diminuta		0.2	0.6	3.4	0.2		0.8	4.2
Megaleptoperla grandis	1.2	0.6	1.0	1.0	0.2	1.2	1.4	1.8
Spaniocerca zelandica	3.8	4.8	11.0	5.8	1.2	5.2	6.4	3.0
Stenoperla prasina	2.0	2.4	10.2	2.6	21.8	7.2	2.6	2.0
Taraperla sp. A								
Zelandobius sp. A			0.2					

Zelandoperla decorata	0.2							
Beraeoptera roria	0.8	1.6	13.4	1.0	15.8	212.2	360.2	40.0
Beraeoptera roria, pupa							1.8	0.4
Confluens hamiltonii								
Helicopsychidae sp. A		1.2	0.2	1.0		3.0	4.6	0.6
Oeconesus similis							0.2	
Olinga feredayi	0.2	0.2	0.8	0.2	0.6	0.8	0.6	0.6
Oxyethira albiceps	3.2	3.0	3.4	12.2	1.8	0.6	3.4	3.8
Oxyethira albiceps, pupa								
Pycnocentrella spp.	0.2							
Pycnocentria funera		0.4		0.2				
Pycnocentrodes spp.								
Triplectides obsoleta								
Zelolessica cheira								0.2
Costachorema callista	0.2					0.2	0.4	0.2
Aoteapsyche colonica	2.4	1.0	0.4	0.8	2.4	1.0	0.6	0.4
Aoteapsyche raruraru							0.2	
Costachorema xanthoptera					0.6			0.2
Hydrobiosella stenocerca	1.2	0.2	1.0	0.4	2.8	7.4	3.6	4.2
Hydrobiosidae, early instar		0.2	0.4	0.2		0.6	1.2	0.4
Hydrobiosis clavigera		0.4	0.4	0.6	0.4	0.2		0.4
Hydrobiosis parumbripennis								
Hydrobiosidae spp., pupa								
Hydropsychidae spp., pupa	7.6	4.4	8.0	2.8				0.8
Hydropsychidae, early instar	15.2	17.8	29.0	12.8	0.4	1.0	2.8	1.6
Neurochorema forsteri	1.6					0.4		
Orthopsyche fimbriata	0.8	0.4	2.4	5.0	0.2	0.2	2.4	1.0
Orthopsyche thomasi								
Polyplectropus puerilis								
Psilochorema sp. A					0.6	0.8	0.4	0.2
Psilochorema sp. B	1.8	0.4	1.6	1.2	7.0	1.4	2.4	3.0
Hydraenidae spp., adult	0.6	0.2	0.6	0.4	0.2	1.4	0.2	
Elmidae spp.	3.0						1.4	
Elmidae spp., adult		1.8	1.2	2.4	7.4	9.6	15.8	15.6
Hydrophilidae sp. A		0.4	0.4	2.6		0.6		
Ptilodactylidae spp.								
Scirtidae spp.								
Aphrophila neozelandica	0.6	1.0	1.4	1.0	6.0	25.6	27.6	34.0
Empididae sp. A				2.6				2.0
Empididae sp. B	0.4	0.6	2.0		1.0	2.2	3.0	
Ephydrella spp.					3.2	1.0		2.4
Eriopterini- Molophilus								
Eriopterini sp. A								
Hexatomini spp.								1.0
Limnophora sp. A						0.2		
Limonia nigrescens		0.4						
Neoscatella vittithorax	0.4		0.2	0.4				
Paradixa spp.								
Paralimnophila skusei			0.2					
Psychodidae sp. A								
Psychodidae sp. B								
Simuliidae spp., australense grp.								
Simuliidae spp. pupa								
Tabanidae spp.								
Tanyderidae spp.								
Tipulidae/ Tanyderidae sp. A, pupa								
Zelandotipula spp.			0.2		0.2		0.8	
Orthocladiinae grp. spp	4.0	1.0	3.6	5.6	73.8	11.4	32.8	46.6
Chironimidae spp., pupa	0.6		1.4	0.6	1.0	0.4	3.8	1.8
Diamesinae sp. A	0.6	0.2	0.6	1.4	59.0	7.4	12.8	37.6
Maoridiamesa						0.4		
Podonominae			0.6		0.2	0.6	0.2	
Polypedilum				1.0				
Tanypodinae				0.2			1.4	1.8
Tanytarsus						0.6	0.6	
Oligochaeta, large (>1.5 cm)	0.4	1.8	0.4	0.2	1.8	4.0	2.0	0.6
Oligochaeta, small (<1.5 cm)					0.2		0.4	
Platyhelminthes spp.								

Potamopyrgus antipodarum				0.2	0.4	0.4		0.2
Amphipoda spp.								
Collembola spp.								
Paranephrops								
Parayta								
Acarina spp.								
Mean No. Individuals/ Sample	91.6	76.8	158.6	127.8	277.2	402.8	684.8	387.4
Mean No. Species/ Sample	16.8	16.0	18.6	18.8	19.6	21.6	23.4	21.8

Ouri Stream	**Site C9**				**Site O9**			
Species	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**
Archichauliodes diversus	4.2	8.8	0.8	4.0	3.2	1.3	1.0	2.2
Acanthophlebia cruentata	54.2	102.2	82.0	29.8	95.2	27.3	98.8	61.0
Ameletopsis perscitus	51.4	90.6	85.4	158.8	73.2	109.3	116.8	190.6
Austroclima jollyae	0.6	3.6	1.6		8.4	20.0	6.6	2.2
Coloburiscus humeralis	0.4	10.2	0.8	1.0	0.4	4.0		0.2
Deleatidium spp.								
Ichtybotus hudsoni		0.4	0.4	0.2	0.2	1.0		0.2
Neozephlebia spp.							0.2	0.2
Nesameletus spp.		0.6	2.4	1.0	3.4	1.3	10.4	3.6
Oniscigaster wakefieldi			1.0	1.2			0.2	
Zephlebia dentata								
Zephlebia versicolor								
Austroperla cyrene	0.6	1.8	2.2	3.8	4.2	1.5	1.6	3.2
Acroperla trivacuata								
Megaleptoperla diminuta	1.0	2.2	2.0	6.4	10.4	5.3	12.4	21.2
Megaleptoperla grandis		2.2	4.2	2.0	0.4	1.8	1.6	1.2
Spaniocerca zelandica	1.2	3.8	5.4	1.2	2.2	1.5	1.2	0.2
Stenoperla prasina	4.0	2.8	4.2	3.2	9.4	7.8	15.8	8.2
Taraperla sp. A								
Zelandobius sp. A				0.2				
Zelandoperla decorata			0.2				0.8	
Beraeoptera roria	6.0	44.8	24.2	0.8	79.6	95.8	227.6	8.4
Beraeoptera roria, pupa							3.2	1.4
Confluens hamiltonii	3.8	0.6	0.8	1.2	26.6	3.3	11.8	7.8
Helicopsychidae sp. A		2.6	1.0		0.2	4.0	1.2	0.4
Oeconesus similis					0.2		0.2	0.8
Olinga feredayi								
Oxyethira albiceps	0.2	0.2						0.2
Oxyethira albiceps, pupa								
Pycnocentrella spp.					0.2			
Pycnocentria funera	0.2		0.2		0.2			0.4
Pycnocentrodes spp.								
Triplectides obsoleta								
Zelolessica cheira								
Costachorema callista							0.4	
Aoteapsyche colonica		0.2			0.6		0.2	0.8
Aoteapsyche raruraru					0.2	0.3	0.4	
Costachorema xanthoptera					0.4		0.4	
Hydrobiosella stenocerca		0.8			2.6	1.3	1.4	1.4
Hydrobiosidae, early instar		3.8	0.6	0.8	0.8	0.8	1.8	1.0
Hydrobiosis clavigera	1.8	0.2			0.6			0.2
Hydrobiosis parumbripennis					15.6	1.0	0.4	
Hydrobiosidae spp., pupa	0.6	0.2	0.2	0.4	15.6		2.2	9.6
Hydropsychidae spp., pupa	3.0	3.8	2.6	1.6	2.2	0.5	3.0	2.2
Hydropsychidae, early instar	10.6	13.6	8.0	2.2		1.5	4.0	6.2
Neurochorema forsteri	0.4				0.2	0.3		
Orthopsyche fimbriata	0.4	2.8	7.6	3.4			2.0	0.8
Orthopsyche thomasi						0.3		
Polyplectropus puerilis								
Psilochorema sp. A					2.0	1.0	0.8	1.0
Psilochorema sp. B	0.8	0.8	0.8	1.2	3.0	2.3	2.8	10.6
Hydraenidae spp., adult	1.0	1.2	4.0	6.4	2.0	0.8	4.6	6.4
Elmidae spp.		0.8					0.2	2.2
Elmidae spp., adult	11.2	12.8	8.4	12.2	16.0	3.5	11.4	4.2

Hydrophilidae sp. A			0.2			0.5		0.6
Ptilodactylidae spp.								
Scirtidae spp.								
Aphrophila neozelandica	6.6	6.4	4.0	8.2	15.4	7.8	27.4	38.6
Empididae sp. A				1.0				0.4
Empididae sp. B	0.4	5.2	2.4		0.2	2.3	0.8	
Ephydrella spp.					0.2			0.4
Eriopterini- Molophilus								0.2
Eriopterini sp. A								
Hexatomini spp.								0.4
Limnophora sp. A								
Limonia nigrescens					0.2			0.2
Neoscatella vittithorax								
Paradixa spp.								
Paralimnophila skusei								
Psychodidae sp. A								
Psychodidae sp. B								
Simuliidae spp., australense grp.								
Simuliidae spp. pupa								
Tabanidae spp.								
Tanyderidae spp.								0.2
Tipulidae/ Tanyderidae sp. A, pupa								
Zelandotipula spp.								0.2
Orthocladiinae grp. spp	2.2	0.4	0.2	1.6	22.6	21.5	37.8	24.0
Chironimidae spp., pupa	0.2	0.2	0.4	1.8				0.6
Diamesinae sp. A		0.6		1.0	2.6	3.5	22.2	31.6
Maoridiamesa		0.4	1.0				15.0	
Podonominae				0.2			1.0	0.6
Polypedilum		6.6	0.4			1.0		
Tanypodinae							3.2	0.8
Tanytarsus						0.5	0.8	
Oligochaeta, large (>1.5 cm)	0.8	0.4	0.2	5.0	1.0	0.5		1.4
Oligochaeta, small (<1.5 cm)								
Platyhelminthes spp.								
Potamopyrgus antipodarum	0.2	1.8	0.4	0.2	0.8		0.2	
Amphipoda spp.								
Collembola spp.								
Paranephrops			0.2					
Parayta								
Acarina spp.	0.2							
Mean No. Individuals/ Sample	168.2	340.4	260.4	262.0	422.4	335.5	655.8	460.4
Mean No. Species/ Sample	17.6	23.6	22.0	20.6	24.8	16.6	26.6	30.2

Kapoaiaia Strem	**Site C10**				**Site O10**			
Species	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**
Archichauliodes diversus	2.4			1.8	0.6	0.2		0.2
Acanthophlebia cruentata	25.8	22.2	18.0	7.6	36.4	19.6	9.0	4.0
Ameletopsis perscitus	35.4	71.8	151.8	121.6	60.2	153.0	180.6	113.4
Austroclima jollyae	5.6	1.0	0.2	0.4	2.0	7.6	14.6	1.0
Coloburiscus humeralis							0.2	
Deleatidium spp.								
Ichtybotus hudsoni						0.2		
Neozephlebia spp.								
Nesameletus spp.	0.2		0.2	0.4			0.2	
Oniscigaster wakefieldi			0.4				0.6	
Zephlebia dentata							0.2	
Zephlebia versicolor						0.2		
Austroperla cyrene	0.4	0.2	0.4		0.8	0.2		
Acroperla trivacuata			0.2					
Megaleptoperla diminuta	0.6	1.6	1.8	3.2	3.6		2.2	2.0
Megaleptoperla grandis	0.4	0.8	0.8	0.8	0.2	0.2	0.2	0.8
Spaniocerca zelandica	0.6	1.8	4.0		0.4	1.6	1.0	
Stenoperla prasina	25.0	3.8	4.4	38.0	50.8	22.6	7.2	37.6
Taraperla sp. A								
Zelandobius sp. A								

Zelandoperla decorata								
Beraeoptera roria	28.8	2.6	16.2	8.4	64.4	10.8	64.2	20.4
Beraeoptera roria, pupa							0.8	0.2
Confluens hamiltonii						0.4	0.6	
Helicopsychidae sp. A	0.2	2.0	2.4	0.6	5.8	1.8	4.4	0.4
Oeconesus similis	2.6		1.6	1.2	0.8	0.4	1.8	0.8
Olinga feredayi								
Oxyethira albiceps	0.4	0.6	0.2		1.8	0.2	0.2	
Oxyethira albiceps, pupa								
Pycnocentrella spp.								
Pycnocentria funera								
Pycnocentrodes spp.					0.2			
Triplectides obsoleta								
Zelolessica cheira								
Costachorema callista			0.2			0.2	0.2	
Aoteapsyche colonica					0.2			0.2
Aoteapsyche raruraru								
Costachorema xanthoptera								
Hydrobiosella stenocerca	0.6		0.6	0.2	0.4	0.6		0.2
Hydrobiosidae, early instar	0.2	0.2	1.2		0.2	0.4	0.4	0.2
Hydrobiosis clavigera	0.4	0.2		0.2	0.2			
Hydrobiosis parumbripennis	0.4	0.2			3.6			
Hydrobiosidae spp., pupa	1.6		0.6	1.2	4.8	0.4	0.4	0.6
Hydropsychidae spp., pupa	0.8	1.4	0.4	0.2				0.2
Hydropsychidae, early instar	1.4	3.2	1.6	4.4	1.2	2.2	0.4	2.4
Neurochorema forsteri	0.6				0.6		0.2	
Orthopsyche fimbriata	0.8	2.6	1.2	0.4		1.0	0.4	0.2
Orthopsyche thomasi								
Polyplectropus puerilis								
Psilochorema sp. A	0.2							
Psilochorema sp. B	2.2	1.0	1.2	2.4	3.0	2.4	2.6	1.8
Hydraenidae spp., adult	1.4		2.0	3.8	0.4	0.2	1.2	0.8
Elmidae spp.			7.6	4.6			17.0	0.2
Elmidae spp., adult	14.6	5.4	24.8	18.2	14.6	10.6	23.8	14.4
Hydrophilidae sp. A								
Ptilodactylidae spp.			0.2					
Scirtidae spp.								
Aphrophila neozelandica	3.2	1.0	1.8	4.0	18.6	4.8	3.0	6.2
Empididae sp. A				0.4				
Empididae sp. B		1.0			0.6	3.2		
Ephydrella spp.								
Eriopterini- Molophilus								0.2
Eriopterini sp. A								
Hexatomini spp.								
Limnophora sp. A								
Limonia nigrescens								
Neoscatella vittithorax								
Paradixa spp.								
Paralimnophila skusei								
Psychodidae sp. A								
Psychodidae sp. B								
Simuliidae spp., australense grp.								
Simuliidae spp. pupa								
Tabanidae spp.								
Tanyderidae spp.								
Tipulidae/ Tanyderidae sp. A, pupa								
Zelandotipula spp.								
Orthocladiinae grp. spp	1.0	1.6	0.4	0.2	2.8	1.2	0.6	
Chironimidae spp., pupa	0.4	0.4			0.2	0.2		
Diamesinae sp. A			0.2					0.2
Maoridiamesa	0.2			0.4			0.2	
Podonominae				0.2				
Polypedilum		0.2						
Tanypodinae								
Tanytarsus					0.2			
Oligochaeta, large (>1.5 cm)	2.8	0.2			0.6	0.2		
Oligochaeta, small (<1.5 cm)								
Platyhelminthes spp.								

Potamopyrgus antipodarum		0.2						
Amphipoda spp.								
Collembola spp.								
Paranephrops								
Parayta								
Acarina spp.								
Mean No. Individuals/ Sample	161.2	127.2	246.6	224.8	280.2	246.6	338.4	208.6
Mean No. Species/ Sample	18.6	13.6	16.4	15.6	17.8	15.0	14.6	13.2

Appendix 2. Mean number of macroinvertebrate individuals and species from 5 replicate experimental disturbance and cover treatment baskets and 5 Surber samples at Cold Stream, Taranaki, on 26 March 2000.

Experiment, Cold Stream	**Open**	**Closed**	**Open Non-**	**Closed Non**	**Surber**
Species	**Disturb**	**Disturb**	**disturbed**	**disturbed**	
Archichauliodes diversus		0.2			
Ameletopsis perscitus	0.2				
Austroclima jollyae		0.6	0.2	0.4	
Coloburiscus humeralis	14.4	57.2	27.8	126.0	34.6
Deleatidium spp.	81.0	29.4	107.0	55.8	125.4
Nesameletus spp.	0.4				0.4
Zephlebia dentata	0.6	1.4	1.0	4.0	
Austroperla cyrene		1.0	0.6	0.8	0.2
Megaleptoperla grandis	2.8	1.0	1.8	3.2	4.4
Spaniocerca zelandica				0.4	
Stenoperla prasina		0.2	0.6		1.2
Taraperla sp. A	0.4				
Zelandobius sp. A	0.8	5.4	5.2	13.2	6.2
Zelandoperla decorata	2.6	0.2	1.4		8.8
Baeraeoptera roria	8.4	0.4	16.2	0.8	76.0
Baeraeoptera roria, pupa			0.2		3.8
Helicopsychidae sp. A	4.0		6.6	0.6	2.8
Pycnocentrella spp.		0.2	0.4		0.4
Pycnocentria funera	5.6	11.6	22.2	27.0	9.8
Triplectides obsoleta	0.6	3.6	1.6	2.4	0.4
Costachorema callista		0.2			0.2
Costachorema xanthoptera				0.2	
Hydrobiosella stenocerca		0.2	0.4	0.4	1.0
Hydrobiosidae, early instar	2.6	3.4	7.4	4.4	5.0
Hydrobiosis parumbripennis	5.6	3.4	5.4	10.2	7.2
Hydrobiosidae spp., *pupa*				0.2	0.4
Nuerochorema forsteri	0.2		0.6	0.2	0.8
Orthopsyche fimbriata	0.4	2.0	1.2	6.8	1.0
Orthopsyche thomasi	0.2	0.6	0.8	2.4	0.4
Psilochorema sp. A				0.6	
Psilochorema sp. B				0.2	
Elmidae spp., adult		4.2			
Elmidae spp.	1.2		3.4	1.8	10.2
Hydraenidae spp., adult	0.4	0.4	0.2	0.4	1.6
Ptilodactylidae spp	0.4	0.2		0.2	
Aphrophila neozelandica	11.2	12.0	39.4	37.8	58.0
Diptera sp. A	1.0	0.2	0.2		2.0
Empididae sp. A	0.2				
Eriopterini- Molophilus		0.6			
Limnophora sp. A		0.2	2.2	1.0	2.4
Chironimidae spp., pupa			1.2	0.4	1.8
Orthocladiinae grp. spp	21.4	7.2	32.4	5.8	19.8
Polypedilum	2.2	3.4	4.0	4.8	4.0
Maoridiamesa	14.6	0.6	20.2	1.2	37.4
Tanytarsus		0.2	0.8	0.2	0.4
Potamopyrgus antipodarum		1.4	1.8	4.4	1.4
Oligochaeta, large (>1.5 cm)		0.2	0.4	0.6	1.2
Total No. Individuals/ Sample	183.4	153.0	314.8	318.8	430.6
Total No. Species/ Sample	10.6	12.0	15.2	13.4	15.8

Addendum

The effect of substrate stability and canopy cover on macroinvertebrate communities in Taranaki ring plain streams

Erna Maria Zimmermann 2001

1.

To investigate the effect of substrate stability on macroinvertebrate communities in this study, streambed substrate stability was quantified by monitoring the movement of painted stones or tracer particles. The painted stones were placed on the streambed and their movement monitored monthly for a year-long period. Stone movement was measured at only one site, the closed canopy or forested site, in each pair of closed and open canopy sites in the 10 streams studied, and this stone movement was used to characterize both sites. Application of the stone movement data to characterize at both sites in each stream can be considered a logical study method for several reasons:

- Paired sites, apart from the obvious contrast in canopy cover, were similar in physical characteristics. This was in fact the criteria for stream selection in the study: That is paired sites, apart from canopy cover, did not differ visually in any streambed or channel characteristics. Although it cannot be ruled out that stream characteristics, other than those measured, may have caused variation in substrate stability between paired sites, results confirmed that sites were similar in depth, velocity, width, conductivity, temperature and substrate size composition at all streams (Table 1, Chapter 2).

- An additional measure of substrate stability used in this study was the bottom component of the Pfankuch Stability Index (Pfankuch 1975). This is a measure that has been used by others (Death and Winterbourn 1995), sometimes even as the sole indicator of streambed stability (Winterbourn and Collier 1987). In this study the Pfankuch Index values were not different between open and closed sites in any streams (Table 1, Chapter 2), suggesting that there was uniformity in substrate stability between paired sites. However Death (submitted) found the two measures of substrate stability; stone movement and the bottom component of the Pfankuch Stability Index, showed no relationship to each other.

- Streambed gradient, another characteristic that could potentially effect stone movement, was not different between paired sites.

- Logistically it was more practical to measure stone movement at only closed sites. Revisiting and checking stones every month is a labour intensive task. If this had been carried out at all open and closed sites, rather than at just the closed sites, it may not have been possible to assess the same number of streams (10) or maintain the frequency of monitoring. Both of these were important in ensuring the study was relatively comprehensive. Being able to place the stones in forested sites out of sight and the influence of humans was also an important consideration because in other studies tampering with tracer particles has occurred (Death pers. comm.).

2.

The method used to assess canopy cover in this study was visual assessment of proportion or percentage canopy cover over the entire stream channel. Again one of the primary criteria for stream and site selection in the study was that all closed canopy sites had complete, 100 %, native bush canopy cover, complete shade and received little incident light for the entire day (Plate 2.1, top), and all open canopy sites had no cover (Plate 2.1, top). The only exception was the closed site on Kaupokonui East Stream (Plate 2.2, top). Here, although the stream still had much more shade than all open sites, overhead canopy was not entirely closed (canopy cover approximated 60 %). Davies-Colley and Quinn (1998) in their study of incident light reaching streamwater level using a 'fish-eye lens' technique found incident light reaching streams in forest increased steadily with increasing widths over 3.5 m. The closed site on Kaupokonui East Stream was wider than the other sites (7 m in comparison to 4 and 5 m). Vegetation at all closed sites was dense predominantly rimu-rata-kamahi forest growing to the edge of the stream channel.

3.

Differences in coarse woody debris, moss, coarse particulate organic matter (C.P.O.M), microbial activity and presence or absence of trout between paired open and closed sites in the same stream and between streams were not assessed in this study. Each parameter and how it may relate to this study are discussed below.

Coarse woody debris

Wood, trees and branches, lying in the streambed can be important in providing habitat and food for invertebrates and can have some impact on shaping the stream channel (Collier and Baillie 1999). However, because of the relatively steep gradients, moderate to high velocities and frequent high flow events in the study streams, even in those that were considered relatively stable, there was little in-stream wood at any of the 20 sites. Furthermore there did not appear to be any noticeable difference between amount of wood at paired open and closed sites on each stream (personal observation Taranaki Regional Council staff pers. comm.).

Moss

The amount of moss was different between streams, largely as a result of streambed stability. The more stable streams had more moss than unstable streams, but there was no difference in amount of moss between paired open and closed canopy sites on the same stream (personal observation). Submerged, bryophytes and macrophytes provide important habitat for invertebrates but because all moss at the study sites was on the upper surfaces of large boulders, only submerged during flood events, presence of moss is unlikely to have had any effect on in-stream invertebrate communities.

Microbial activity

Microbial activity in streams is the breakdown of organic matter by microbes and is an important part of stream trophic structure. Microbial activity may have varied between sites in this study. However Nikolai and Winterbourn (1997) in a New Zealand study found no difference in microbial activity between stream sites with differing canopy type including native forest and pasture over a three week period.

Trout

Brown and rainbow trout, introduced to New Zealand in the 1800's, are widespread throughout waterways in New Zealand. They predate on and are thought to have some impact on invertebrate behaviour and invertebrate abundance (McIntosh 2000). There are brown trout present in all stream sites used in this study, most are juvenile individuals with some larger adults residing for a short time over the trout spawning season in Autumn. There may be some difference in brown trout population sizes between streams but no major difference between paired sites on each stream. There are no barriers to fish passage between paired sites and the trout do not seem to have any preference for the presence of canopy cover (Department of Conservation staff pers. comm.).

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