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Substrate Stability and Invertebrate Distribution in Two New Zealand Streams: a Survey Employing Easily Measured Hydrologic Parameters

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Winnipeg, Manitoba
R3T 2N6

1992

Canadian Technical Report of
Fisheries and Aquatic Sciences
No. 1827

Fisheries and Oceans   Pêches et Océans

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Canadian Technical Report of Fisheries and Aquatic Sciences

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SUBSTRATE STABILITY AND INVERTEBRATE DISTRIBUTION IN TWO NEW ZEALAND STREAMS: A SURVEY EMPLOYING EASILY MEASURED HYDROLOGIC PARAMETERS

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This is the 38th Technical Report

from the Central and Arctic Region, Winnipeg

Cat. No. Fs 97-6/1827E ISSN 0706-6457

Correct citation for this publication is:

Flannagan, J.F., P.M.L. Flannagan, and M.A. Chapman. 1992. Substrate stability and invertebrate distribution in two New Zealand streams: a survey employing easily measured hydrologic parameters. Can. Tech. Rep. Fish. Aquat. Sci. 1827: iv + 7 p.

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The fauna of two North Island, New Zealand streams was sampled at each of 4 stations and simple hydrologic measurements (tractive force (τ) at bankfull depth, slope and median substrate diameter (Φ_{50})) were made to investigate the potential usefulness of aquatic invertebrates as indicators of stream substrate stability. Invertebrate densities were correlated with hydrologic parameters and two derived indices of substrate stability, and indicated that hydrologic parameters were significant determinants of benthic invertebrate density. In the Rangitukia Stream, five taxa (Zephlebia spectabilis, Zelandoperla decorata, Beraeoptera roria, Olinga (feredayi?) and Archicauliodes diversus) showed a positive best correlation with substrate stability indices, indicating a preference for unstable substrates, whereas three taxa appeared to prefer stable substrates (Austroclima sepia, Costachorema xanthoptera and an elmid beetle). In Stony Stream, four taxa preferred unstable substrates (Austroclima sepia, Neozephlebia scita, Zephpebia spectabilis, Orthopsyche thomasi). A lack of stable substrate taxa in this stream was attributed to flooding resulting from the passage of cyclone "Bola". Although many taxa occurred at too few stations or in insufficient numbers for reliable analysis, only the density of Coluburiscus humeralis could definitely be considered to be independent of the hydrologic parameters.

Key words: hydrology; substrate stability; instability; slope; index; aquatic invertebrate; insect.

RÉSUMÉ

Flannagan, J.F., P.M.L. Flannagan, and M.A. Chapman. 1992. Substrate stability and invertebrate distribution in two New Zealand streams: a survey employing easily measured hydrologic parameters. Can. Tech. Rep. 1827: iv + 7 p.

On a échantillonné la faune de deux cours d'eau de l'île du Nord, Nouvelle-Zélande, à partir de quatre sites et on a mesurédes paramètres hydrologiques simples (force tractrice (τ) au niveau de débordement, pente et diamètre médian du substrat (Φ_{50}) pour évaluer l'utilité des invertébrés aquatiques comme indicateurs de la stabilité du substrat des cours d'eau. La densité d'invertébrés a été corrélée à des paramètres hydrologiques et à deux indices de stabilité du substrat, et on a constaté que les paramètres hydrologiques déterminaient de façon importante la densitédes invertébrés benthiques. Dans le cours d'eau Rangitukia, on a observé une forte corrélation positive entre cinq taxons (Zephlebia spectabilis, Zelandoperla decorata, Beraeoptera roria, Olinga (feredayi?) et Archicauliodes diversus) et les indices de stabilité du substrat indiquant une préférence de ces espèces pour les substrats instables, alors que trois taxons ont semblé préférer les substrats stables (Austroclima sepia, Costachorema zanthoptera et un coléoptère de la famille des Elmidés). Dans le cours d'eau Stony, quatre taxons ont préféré les substrats instables (Austroclima sepia, Neozephlebia scita, Orthopsyche thomasi et Zephlebia spectabilis). L'absence de taxons préférant les substrats stables dans le Stony a été attribuée à l'inondation provoquée par le cyclone Bola. Bien que de nombreux taxons aient été trouvés dan un trop petit nombre di sites d'échantillonnage ou en quantité insuffisante pour réaliser une analyse fiable, on a pu établir, uniquement dans le cas de Coluburiscus humeralis, que la densité était nettement indépendante des paramètres hydrologiques.

Mots-clés: hydrologie; stabilité du substrat; instabilité; pente; indice; invertébrés aquatiques; insectes.

INTRODUCTION

Winterbourn et al. (1981, 1988), Cowie (1985), Statzner and Higler (1985, 1986), Collier and Winterbourn (1987), Scrimgeour and Winterbourn (1989) and Flannagan et al. (1990) have suggested that hydrologic conditions can play a major role in controlling the distribution and/or density of invertebrate populations in streams. Sagar (1986) and Flannagan and Cobb (1990) documented the effects of spates and an unstable stream bed on aquatic insect populations. While the distribution of aquatic invertebrates in streams may be strongly influenced by the availability and type of organic materials as suggested by Minshall (1967) and the "River Continuum" concept of Vannote et al. (1980), the basic, measurable hydrological characteristics of the stream itself must be expected to be of paramount importance. Potentially, therefore, some invertebrates may be good indicators of stability of stream substrates.

Statzner and Higler (1986) noted the scarcity of data on hydraulic characteristics in the numerous publications on invertebrate stream zones. Perhaps biologists believe that measuring gross hydraulic factors such as slope, median substrate diameter and especially the subjective measure of bankfull depth are outside their area of expertise, nevertheless Newbury (1984) has demonstrated that non-professional estimates of bankfull depth satisfactorily compare to data from his comprehensive hydrological surveys and that these estimates are consistent.

In Manitoba, Canada, stream insects were found to be useful as instability indicators for identifying potential fish spawning sites (Cobb and Flannagan 1990; Flannagan and Cobb, in press) and are likely to prove useful in other management situations. A stability index referred to in the 2 preceding papers (likelihood of substrate motion) is particularly useful for streams or rivers in which the bed-paving substrate is only marginally unstable, i.e. will only move in extremely high floods or only a portion of this substrate will move in annual flood events.

The fauna of two of these marginally unstable North Island streams was sampled and some simple, but quantitative, hydrological measurements were made to investigate the potential usefulness of aquatic invertebrates as indicators of stream substrate stability in New Zealand.

METHODS

From March 1987 to May 1988 a series of physical, chemical, biological and hydrologic measurements were taken at four stations on each of two marginally unstable streams. The two streams were the Rangitukia Stream, which flows from Mount Pirongia to the Waipa River, and Stony Stream which rises in the Coromandel Range and flows into the Tairua River. Both are ground-water-fed streams which had similar pH (6.8-7.0 and 6.7, respectively), and conductivity (mean = 65.5 and 67.5 $mS \cdot cm^{-1}$ at 25°C, respectively), had little water temperature difference along their lengths and were near their summer base flow discharges (Rangitukia Stream, 0.57 $m^3 \cdot s^{-1}$; Stony Stream, 0.63 $m^3 \cdot s^{-1}$). Summerhays (1983) provides a detailed description of the Rangitukia Stream. Station 1 in both streams was above the bush line. Here the natural riparian vegetation formed a closed canopy over the stream. Station 2 in both streams and Station 3 in the Rangitukia Stream and Station 4 in the Stony Stream were below the bush line, but in areas of well-preserved riparian vegetation which formed a partially closed canopy. The remaining station on each stream was situated in open pasture land where the riparian vegetation consisted of grass with isolated trees and bushes.

Three to four biological samples were taken in the selected riffle areas at each station using a collapsible, modified Hess sampler (Waters and Knapp 1961) fitted with 0.4 mm mesh nylon screen and sampling an area of 0.1 m^2. Where possible, substrates were disturbed or washed to a minimum depth of 15 cm. Samples were preserved in 10% formalin solution in the field, sorted in the laboratory and identified to species where possible. Chironomids, other Diptera and oligochaetes were excluded because the sampler mesh size precluded their quantitative sampling.

Hydrological measurements at each station comprised:

a) Bankfull Depth (D_{bf}). The mean depth (m) of water at bankfull was assessed at four or five randomly selected cross-sections in the immediate vicinity of each station. Clues such as scoured, lichen-free parts of emergent rocks as well as the general channel shape in the entire sample reach were used to indicate the bankfull water level.

b) % Slope. The drop in elevation was measured, using a hand level, through at least one pool-riffle series above, one within and one below the area of each station. Values were averaged and expressed as % slope for the station.

c) Median Substrate Diameter (Φ_{50}). Length, width and height of 24 randomly selected rocks of the bed paving material (i.e. rocks that would likely impede flow, the anchor layer of other authors) were measured and their mean diameters (L+W+H/3) plotted cumulatively, where plotting position = rank/25 x 100%. The median substrate size was read off at the 50% level.

CALCULATIONS

Tractive force (τ). Using a) and b) above, the tractive force at bankfull depth (τ_{bf}) was calculated as:

$$\tau_{bf} = \bar{D}_{bf} \text{ (m)} \times \% \text{ slope} \times 1000 \text{ kg}\cdot\text{m}^{-2}$$

where $\bar{D}_{bf}$ is mean bankfull depth in meters.

Since the tractive force ($\text{kg}\cdot\text{m}^{-2}$) approximately equals the mean diameter of rounded, non-cohesive substrate (cm) in incipient motion (Newbury 1984), the percentage of the bed paving material in motion at bankfull flows can be calculated from the plot for c) above. This was the first index used.

Stability Index 1 = % substrate in motion = (# stones < τ)/$N_{(sample\ size)}$ x 100. However, since all of the bed paving materials in Stony Stream were stable at bankfull discharges, a second index was required. This was provided by tau/substrate diameter, previously used by Flannagan et al. (1990) as an indicator of the likelihood of the median substrate to move.

Stability Index 2 = likelihood of substrate motion = τ/Φ_{50}. An Index 2 value of more than one is equivalent to a value of >50% for Index 1, and means that more than 50% of the stream bed paving materials will be in incipient motion at bankfull discharges.

Since only the simplest relationships were sought, Pearson coefficients of correlation between density distribution of each species in each river and each of the five parameters (τ_{bf}, Φ_{50}, slope and the two indices) were calculated. Within each station the benthos density variance tended to be as large as the mean, so these densities were transformed using L_{n+1} to make the variances homogeneous (Bartlett 1947). The analyses were carried out for taxa that were present at a minimum of three of the four stations in a stream. Data on other taxa are given because presence at the downstream stations in these small streams is generally indicative of a preference for stable substrates, whereas restriction to headwater areas may indicate a preference for unstable areas (Statzner and Higler 1986).

RESULTS

In general, the va overlapped between the two streams. The faunas of the two streams were also similar in species composition. Species density sometimes differed widely between stations. The density of the fauna in Stony Stream was comparable to or less dense than Rangitukia Stream (Table 1). Nine taxa taken from Rangitukia Stream were not found in the Stony Stream. Sixteen ephemeropteran taxa were collected in all. Of these, Coloburiscus humeralis, Austroclima sepia, and Deleatidium spp. dominated numerically. Similarly, of 15 trichopteran taxa, Helicopsyche (zealandica?), Pycnocentrodes sp. and Olinga (feredayi?) dominated. No stonefly species recorded occurred in large numbers (Table 1).

In the Rangitukia Stream, 17 species showed a significant correlation with at least one of the hydrologic variables (Table 2). The best correlations were with (τ) tractive force (seven taxa), and with one of the stability indices (eight taxa). Five of the latter eight taxa seemed, within the range of stabilities investigated, to prefer unstable substrates (positive relationship with an index), the other three preferred more stable substrates (negative relationship with an index) (Table 2).

In Stony Stream 14 taxa exhibited significant correlations with hydrologic parameters. Only four taxa showed the highest correlation with Stability Index 2, and they all were positive - appearing to prefer more unstable substrates. One, three and four taxa showed a positive best correlation with median substrate, slope and tractive force, respectively. One taxon had a negative best fit with slope and one with tractive force (Table 2).

Austroclima sepia showed a negative correlation with most hydrologic parameters in the Rangitukia Stream and positive correlations in the Stony Stream.

DISCUSSION

The temperature, conductivity and pH of the two streams investigated were similar as were the hydrologic parameters measured, and the species composition and density of most species. However, Stony Stream, as indicated by the stability indices, was more stable, had fewer species and lower densities of the species which were common in both streams (Table 1). The lower numbers and possibly even the higher apparent stability in Stony Stream may be the result of the flooding resulting from cyclone "Bola" which passed through this area only a few weeks before we sampled this stream. This is supported by the much lower densities relative to the Rangitukia Stream, of taxa with a negative correlation with the stability index, i.e. the species which preferred a stable substrate (Table 2). Cowie (1980), Sagar (1986) and Scrimgeour and Winterbourn (1989) report reductions in density following floods in South Island streams. Selective density changes resulting from the likelihood that discharge increases were more intense in the lower portions of the stream may be responsible for the apparent sign difference in the correlations between the numbers of Austroclima sepia and the various hydrological parameters in the two streams. Alternatively, and perhaps more likely, this species may reach its optimum density at the stability found in the headwaters of the Stony Stream and the lower reaches of the Rangitukia Stream and where stabilities are either greater or less than this, populations decrease.

Because the hydrological parameters in the analyses are interrelated, a fit with one often means a fit with most of the others. Tractive force is a product of mean depth and slope. Median substrate (ϕ_{50}) is a little more independent, but still related since substrate size is the result of the tractive force acting on the bed and bank materials. The stability indices are perhaps most independent since their relationship with the other parameters is more complex. This is reflected in the results where every taxon with a good correlation with slope always has a good correlation with tractive force, usually has a good correlation with median substrate and sometimes has a good correlation with one or other of the stability indices.

In general, and bearing in mind the limitations of the study, it seems that the invertebrates of these two streams can be divided into four groups:

a) Taxa apparently not affected by hydrologic parameters. This includes the common cases where the taxon was collected in numbers too low for reliable analyses. Typically, benthic faunas in New Zealand streams are dominated by a few genera of invertebrates (Towns 1987) thus, it can be expected that many species will occur in low numbers. By contrast, Coluburiscus humeralis was present in fairly large numbers and did not exhibit correlations with hydrological parameters.
b) Taxa which have potential as indicators of substrate stability but occurred at too few stations to judge.
c) Taxa which appear to prefer stable substrates. These taxa had negative best correlations with one of the indices. It is possible that all taxa with a significant negative correlation with either of the indices would be good indicators of stable substrate within the range of substrates examined. These include Austroclima sepia (in the Rangitukia Stream), Costachorema xanthoptera and the elmid beetle collected.
d) Taxa which appear to prefer unstable substrates. As above, only the "best correlations" taxa are included. These were: Zephlebia spectabilis, Neozephlebia scita, Austroclima sepia (in the Stony Stream), Zelandoperla decorata, Orthopsyche thomasi, Olinga (feredayi?), Beraeoptera roria and Archichauliodes diversus.

It is worth noting that Zephlebia dentata, Z. spectabilis and Z. borealis all show positive best fits with tractive force or tractive force/median substrate, indicating a preference for unstable substrates. Towns (1983) also noted that congeneric mayfly species in the Waitakere River also had an overlap in habitat. In contrast, two hydropsychid species, O. thomasi and Aoteapsyche sp., show opposing best fits with tractive force (Table 2) and therefore appear to prefer very different habitats to each other.

In the Stony Stream only one species of the genus Deleatidium, the most common mayfly in both streams, and a genus not readily identifiable to species in the larval stages, appeared common whereas several species occurred in the Rangitukia Stream. A significant correlation was found only in the Stony Stream. This suggests that the genus contains species adapted to both stable and unstable habitats (Table 2). Town (1987) collected different Deleatidium species in stable and unstable habitats.

CONCLUSIONS

Although this is a preliminary survey for New Zealand, since several taxa were found to have a positive or negative correlations with substrate stability and only a few taxa were not correlated with hydrologic factors or indices, further work might profitably be pursued to develop the use of aquatic invertebrates as indicators of substrate stability. To be most useful to resource managers, many more streams with a wider range of stabilities should be sampled through a wider seasonal range. This will test these preliminary findings and provide a longer and more precise list of indicator species.

ACKNOWLEDGMENTS

We would like to thank Mr. Dudley Bell and Ms. J. Lee Laboyrie of the Department of

Biological Sciences, University of Waikato, for technical assistance; Drs. J.M. Quinn, DSIR, Hamilton, Stella F. Penny, Whitianga, D.M. Rosenberg and Mr. D.G. Cobb, Freshwater Institute, Winnipeg for reviewing and providing useful comments on the manuscript. Prof. W.B. Silvester kindly provided facilities and space for the Flannagans at the Dept. of Biological Sciences, University of Waikato.

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Table 1. Mean numbers per Hess samples and (standard deviations) of the various taxa and values of hydrologic parameters at the four stations in each of the two streams sampled.

Species/Station Number	Rangitukia Stream R-1	R-2	R-3	R-4	Stony Stream S-1	S-2	S-3	S-4
Ephemeroptera								
Ephemeridae								
Ichthybotus sp.	0	0.3(0.6)	0	0	0.5(1)	0	0	0
Oligoneuriidae								
Coloburiscus humeralis (Walk.)	27(34.7)	65.3(53.5)	27(10.9)	7(4.4)	18(15.1)	22.3(9.5)	5.8(3.2)	7.5(4.2)
Siphlonuridae								
Ameletopsis perscitus (Eat.)	1(1)	0.7(1.2)	0.5(0.6)	0.3(0.6)	0.3(0.5)	0.3(0.5)	0	0
Nesameletus sp.	0.7(1.2)	0.3(0.6)	1.3(1.3)	0.3(0.6)	0.3(0.5)	0	0	0
Rallidens mcfarlanei Penn.	0	0	0	0	0.3(0.5)	0.3(0.5)	0.3(0.5)	1(0)
Leptophlebiidae								
Acanthophlebia cruentata (Hud.)	1.7(2.9)	1(1)	0	0	0.8(1.5)	0	0	0
Austroclima jollyae Tow. & Pet.	0	0.7(0.6)	0.3(0.5)	4.7(5.1)	0.3(0.5)	0	0	0
A. sepia (Phil.)	5(5)	4.3(4.5)	0.5(0.6)	20.7(6)	11.3(6.2)	5.5(3.9)	2.3(1.9)	4.3(1.3)
Deleatidium spp.	47.3(32)	87.3(56.2)	48.3(16.7)	46.7(12.6)	39.8(24.5)	5.5(3)	0.8(0.9)	0.5(1)
Mauiulus luma Tow. & Pet.	0	0	0	0.7(1.2)	1.5(0.6)	0.8(0.9)	0	0
Neozephlebia scita (Walk.)	1(0)	1.3(2.3)	0.5(0.6)	0	1.3(1)	0.3(0.5)	0	0.3(0.5)
Zephlebia dentata (Eat.)	1(1)	1.7(1.5)	0	1(0)	6.3(3.3)	1.5(1.3)	0	1(0.8)
Z. spectabilis Tow.	4.7(4)	4.7(7.2)	0	1.3(1.5)	15.3(11.1)	2.3(1)	0.3(0.5)	1(1.2)
Z. versicolor (Eat.)	1(1.7)	3(5.8)	0	0	0	0	0	0
Z. borealis (Phil.)	0	0	0	0	1(0.8)	0.5(0.6)	0.5(0.6)	0
Z. sp. a	0	0	0	0	0.8(0.5)	0	0	0.5(0.6)
Mean number of species per grab	7(1.7)	7(3.5)	4.5(1.3)	6.3(1.5)	10(2.7)	6.8(1.3)	3.5(1.3)	5.3(0.5)
Plecoptera								
Eustheniidae								
Stenoperla prasina (New.)	1.7(0.6)	1(1)	1.5(1.3)	0	0	0	0	0
Austroperlidae								
Austroperla cyrene (New.)	1(1.7)	0	0.3(0.5)	0	0.3(0.5)	0.5(0.6)	0	0
Gripopterygidae								
Zelandoperla decorata Til.	3(1)	5(2.6)	6.3(2.2)	0	0	0	0	0
Z. agnetis McL.	0	0	0	0	1(0.8)	1(0.8)	0.8(1.5)	0
Megaleptoperla grandis (Hud.)	0.7(0.6)	0.3(0.5)	0	0	0	0	0	0
Zelandobius furcillatus Til.	2.7(0.6)	0.3(0.6)	1.5(0.6)	0	0	0	0	0
Acroperla trivacuata (Til.)	0	0	0	0	0.3(0.5)	0	0	0
Mean number of species per grab	4(1)	2.3(1.5)	3(0)	0	1.3(0.5)	1.3(0.5)	0.3(0.5)	0
Trichoptera								
Hydropsychidae								
Aoteapsyche sp.	1(0)	13(1.7)	12.3(6.7)	48.3(17.2)	1.3(1.5)	0.5(0.6)	0.5(0.6)	1(1.4)
Orthopsyche thomasi (Wise)	18.3(7)	5.3(1.2)	5(1.6)	0	1.3(1)	0.3(0.5)	0.3(0.5)	0

Table 1. Cont'd.

Species/Station Number	Rangitukia Stream R-1	R-2	R-3	R-4	Stony Stream S-1	S-2	S-3	S-4
Hydrobiosidae								
Psilochorema sp.	0	0.3(0.6)	0	2.3(1.5)	1.5(2.4)	0.3(0.5)	0	0.3(0.5)
Tiphobiosis sp.	0	0	0.3(0.5)	7(1.4)	1.5(1.9)	1(1.4)	0	0.5(0.6)
Costachorema xanthoptera McF.	0.7(0.6)	1(1)	0	4.7(1.2)	0	0	0	0
Neurochorema (confusum McL.?)	0	0	0	0	0.8(1.5)	2.3(1.7)	1.5(1)	2.5(1.7)
Polycentropodidae								
sp.	0	1.7(2.9)	0	0	0	0	0	0
Philopotamidae								
Hydrobiosella mixta (Cow.)	1(1.7)	0	1.3(1.9)	0	0.5(1)	0	0	0
Helicopsychidae								
Helicopsyche (zealandica Hud.?)	96.3(48.6)	10.7(10.8)	23.5(10)	0	1.5(2.4)	10.5(9.5)	1.5(1.7)	0
Leptoceridae								
Hudsonema amabilis (McL.)	0	0.3(0.6)	0	0	0	0	0	0
Triplectides obsoleta (McL.)	1(1.7)	0	0.3(0.6)	0	0	0	0.3(0.5)	0.3(0.5)
Conoesucidae								
Pycnocentrodes sp.	4.3(2.3)	39.7(26.4)	2(1.2)	410.7(8.3)	11.8(7.4)	21.8(6.7)	44.8(24.9)	55.3(34)
Beraeoptera roria Mos.	3.7(0.6)	3.7(2.1)	9.5(5.7)	0.3(0.6)	0.8(0.5)	0	0	0
Olinga (feredayi (McL.)?)	10.7(4.7)	36.7(14.4)	1.5(1.5)	9.7(8)	3.8(1.3)	3.5(1)	1.8(0.5)	1.5(1.7)
Pycnocentria evecta McL.	0	0	0	2.3(1.5)	0	0	0	0
Mean number of species per grab	7.3(0.6)	8(1.7)	6.8(0.5)	7.3(0.6)	6(1.4)	5.3(0.5)	4.8(0.5)	4.3(1)
Megaloptera								
Archichauliodes diversus (Walk.)	1.7(1.5)	4.7(3.2)	0.5(1)	1.7(1.2)	1.3(1)	0.3(0.5)	0.8(1)	1.3(1.3)
Coleoptera								
Elmidae	1.7(1.2)	2.3(2.5)	0.3(0.5)	90.3(24.9)	2.5(1.3)	1.3(1.3)	0.8(1)	2.3(0.5)
Gastropoda								
Hydrobiidae								
Potamopyrgus antipodarum (Gray)	24.7(20.6)	21(16.5)	1(0.8)	42(45.9)	0.5(1)	0.8(1)	1.8(1.7)	4.8(4.9)
Latiidae								
Latia neritoides Gray	5(4.6)	4.7(3.2)	0	0	0.5(0.6)	0.8(1)	1(0.8)	30(19)
Hydrological Data								
Slope (%)	0.06	0.04	0.08	0.01	0.05	0.03	0.01	0.001
Tractive force (τ) ($kg \cdot m^{-2}$)	15.6	14.8	15.3	3.4	14	7.9	3.1	0.3
Median substrate diameter (ϕ_{50}) (cm)	22.8	19.4	31.6	6.7	20.3	32	23.7	18
Stability Index 1	8	8	12	0	0	0	0	0
Stability Index 2	0.68	0.76	0.48	0.50	0.69	0.25	0.13	0.02
Average bankfull depth (D_{bf}) (m)	0.28	0.34	0.19	0.35	0.28	0.26	0.31	0.30

Table 2. Correlation coefficients between density of the various taxa and distribution of the hydrologic parameters and indices. (*, P < 0.05; **, P < 0.01; parentheses = best fit; N.S. = regression not significant; N.P. = taxon not present; I.S. = taxon present at insufficient stations for analysis).

	Rangitukia Stream					Stony Stream			
Species/Hydrologic Parameter	Slope	Tau	Med. Sub.	% Sub. Mot.	Tau/Med. Sub.	Slope	Tau	Med. Sub.	Tau/Med. Sub.
Ephemeroptera									
Leptophlebiidae									
Austroclima jollyae	-*	(-**)	-*	-*	N.S.	I.S.	I.S.	I.S.	I.S.
A. sepia	-**	-**	-**	(-**)	N.S.	*	*	N.S.	(*)
Deleatidium spp.	N.S.	N.S.	N.S.	N.S.	N.S.	**	(**)	N.S.	**
Neozephlebia scita	N.S.	N.S.	N.S.	N.S.	N.S.	*	*	N.S.	(*)
Zephlebia dentata	N.S.	N.S.	N.S.	N.S.	N.S.	**	(**)	N.S.	**
Z. spectabilis	N.S.	N.S.	N.S.	N.S.	(*)	**	**	N.S.	(**)
Z. borealis	N.P.	N.P.	N.P.	N.P.	N.P.	*	(*)	N.S.	*
Mean number of species per grab	N.S.	N.S.	N.S.	N.S.	N.S.	(**)	**	N.S.	**
Plecoptera									
Eustheniidae									
Stenoperla prasina	*	(**)	*	*	N.S.	N.P.	N.P.	N.P.	N.P.
Gripopterygidae									
Zelandoperla decorata	**	**	**	(**)	N.S.	N.P.	N.P.	N.P.	N.P.
Zelandobius furcillatus	**	(**)	**	**	N.S.	N.P.	N.P.	N.P.	N.P.
Mean number of species per grab	**	(**)	**	**	N.S.	(**)	**	N.S.	*
Trichoptera									
Hydropsychidae									
Aoteapsyche sp.	-*	(-**)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Orthopsyche thomasi	**	(**)	**	**	N.S.	*	*	N.S.	(**)
Hydrobiosidae									
Costachorema xanthoptera	-**	-**	-**	(-**)	N.S.	N.P.	N.P.	N.P.	N.P.
Helicopsychidae									
Helicopsyche (*zealandica*?)	**	(**)	**	**	N.S.	N.S.	N.S.	(**)	N.S.
Conoesucidae									
Pycnocentrodes sp.	(-**)	-**	-**	-**	N.S.	(-**)	-**	N.S.	-**
Beraeoptera roria	**	**	**	(**)	N.S.	I.S.	I.S.	I.S.	I.S.
Olinga (*feredayi*?)	N.S.	N.S.	N.S.	N.S.	(**)	(**)	*	N.S.	*
Mean number of species per grab	N.S.	N.S.	N.S.	N.S.	N.S.	*	(*)	N.S.	*
Megaloptera									
Archichauliodes diversus	N.S.	N.S.	N.S.	N.S.	(**)	N.S.	N.S.	N.S.	N.S.
Coleoptera									
Elmidae	-**	-**	-**	(-**)	N.S.	N.S.	N.S.	N.S	N.S.
Gastropoda									
Hydrobiidae									
Potamopyrgus antipodarum	-**	N.S.	(-**)	-**	N.S.	N.S.	N.S.	N.S.	N.S.
Latiidae									
Latia neritoides	I.S.	I.S.	I.S.	I.S.	I.S.	-**	(-**)	-*	-*