STICKY TRAPPING OF ADULT MAYFLIES, STONEFLIES AND CADDISFLIES ALONGSIDE THREE CONTRASTING STREAMS NEAR HAMILTON, NEW ZEALAND

KEVIN J. COLLIER & BRIAN J. SMITH

National Institute of Water and Atmospheric Research Limited, P.O. Box 11-115, Hamilton, New Zealand

(Received 29 September 1994; revised and accepted 18 November 1994)

ABSTRACT

Collier, K.J. & Smith, B.J. (1995). Sticky tapping of adult mayflies, stoneflies and caddisflies along three contrasting streams near Hamilton, New Zealand. *New Zealand Natural Sciences* 22: 1-9.

Sticky traps were used to catch adult mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera) alongside three second order streams bordered by pines (*Pinus radiata*), willow (*Salix* sp.) or native forest (predominantly kanuka, *Kunzea ericoides*) near Hamilton, New Zealand. Five traps were attached to tree trunks at each of three heights (0.5 m, 1.5 m and 5.0 m from base), and were changed monthly between September 1993 and February 1994. During this period, species richness and numbers of mayflies, stoneflies and caddisflies were highest at the willow site (31 species and 75% of total numbers), followed by the native site (17 species and 19% of numbers) and the pine site (14 species and 6% of numbers). Catches at the pine site were dominated by mayflies (78% of numbers), whereas mayflies and stoneflies were both relatively abundant at the native site (49% and 33%, respectively), and mayflies and caddisflies at the willow site (53% and 44%, respectively). Highest numbers at each site were recorded in December-January, but there did not appear to be a seasonal pattern in species richness. Trap height did not have a significant effect on numbers of mayflies or caddisflies caught at the willow site in December. Sticky traps represent a cheap and passive means of catching predominantly flying adults where numbers are high. Our trap design is likely to be most effective alongside larger streams where the area of streambed relative to trap area is greater.

KEYWORDS: Adult insects -Ephemeroptera -Plecoptera -Trichoptera - sticky trap - land use - New Zealand.

INTRODUCTION

Most ecological studies of aquatic insects have focussed on immature stages living in the water, but with the exception of some Odonata and Diptera, comparatively little is known of the habitat requirements of adults, many of which live in the riparian zone (Jackson & Resh 1989a). The adults of some species actively select streamside trees as the preferred site to complete metamorphosis (*e.g.*, moult from sub-imago to adult for mayflies), to rest while awaiting swarming time, to feed in order to produce eggs, or to mate (Sweeney 1993). In addition, adult aquatic insects can influence the distribution and abundance of riparian insectivores (*e.g.*, fantails) since they often provide an important source of food (Jackson & Fisher 1986).

The distribution of adult aquatic insects in the riparian zone can vary with height, distance from the stream and season. Highest numbers of individuals are generally caught in summer, although some species may have flight periods at other times of year (Norrie 1969, Svensson 1974, Crichton & Fisher 1978). The species richness, abundance and biomass of aquatic insects were found to decrease as distance (up to 150 m) increased into a riparian forest from the edge of a third order stream in Oregon, U.S.A. (Jackson & Resh 1989a). Although some species were most abundant near the tree tops in that study, no general relationship was found with height above the ground.

In New Zealand, most published studies that consider adult aquatic insects have been associated with investigations of species distributions, taxonomy and life histories (*e.g.*, Michaelis 1973, McLellan 1977, Towns 1987, Ward 1991), although some observations of oviposition behaviour and flight periodicity have also been carried out (McLean 1967, Norrie 1969). Few (if any) New Zealand studies have investigated terrestrial habitat use by adult aquatic insects. Our aim was to investigate the composition and abundance of the adult mayfly (Ephemeroptera), stonefly (Plecoptera) and caddisfly (Trichoptera) fauna colonising riparian areas alongside three streams differing in catchment land use and riparian vegetation type. We also wished to evaluate the use of sticky traps as a means of quantitatively assessing species abundance at these sites.

METHODS

STUDY SITES

Adult insects were trapped alongside three second order tributaries of the Waipa River draining the Hakarimata Ranges near Whatawhata west of Hamilton (Table 1). The general topography of the area is steep (>30°) and hilly with a basal geology of sedimentary sandstones and siltstones (greywacke and argillite) overlain with yellow brown earths (Smith *et al.* 1993). The mean annual air temperature of the area is 13.7° C with highest temperatures in February and coolest temperatures in July. Annual rainfall averages 1614 mm and is reasonably evenly distributed throughout the year (Smith *et al.* 1993).

Land use in the area includes pastoral farming and production forestry with large areas of unmodified hill country protected as reserves. The sampling reaches ranged from 35-70 m a.s.l. in elevation and had upstream catchment areas of 1.31-3.00 km^2 (Table 1). EM2 was lined by pines (*Pinus radiata*), whereas DB5 was lined by a mixture of native species dominated by kanuka (*Kunzea ericoides*). These sites are referred to hereafter as the "pine" and "native" sites, respectively. The catchment of DB4 was a mixture of native forest and pasture (Table 1), and along the study reach it was lined mainly by grass and willows (*Salix* sp.) (referred to hereafter as the "willow" site).

TRAP DESIGN

Sticky trap frames consisted of a cylinder (*c.* 20 cm high, 18 cm diameter) of brown Nylex garden trellis (5 cm mesh) wired to brown shelf brackets (25 cm x 30 cm) (Fig. 1). The colour brown was used as this was similar to the colour of the tree trunks onto which the traps were nailed. Five frames were attached to randomly selected trees along both sides of a 100 m reach of each stream at each of three heights (0.5 m, 1.5 m or 5 m from the tree base), one trap per tree. Kanuka trees were used for all traps at the native site. At the native and pine sites, a height of 5 m was generally in between the canopy and subcanopy (mostly tree ferns) layers, whereas at the willow site this height was within the tree foliage. All trees were within 6 m of the stream channel margin.

Two A4 overhead transparencies were painted on one side with a coating of the all-weather, non-drying adhesive Tangle-trap (Tanglefoot®). They were then lightly sprayed on site with a tetramethrin based, long-lasting (30 days) insecticide (Blackflag® Regular) to minimise the influence of trapped insects (*e.g.*, by pheromone release) on the behaviour of non-trapped individuals (after Jackson & Resh 1989a). The coated transparencies were stapled to the mesh cylinders (Fig. 1) to provide a sampling area of approximately 0.12 m^2 on each trap.

SAMPLE COLLECTION AND ANALYSIS

The traps were deployed on 29 September 1993,

Table 1. Some physical characteristics of the three study sites on tributaries of the Waipa River.

Site name[1]	Grid ref. (NZMS 260 S14)	Elevation (m a.s.l.)	Catchment area (km^2)	Catchment vegetation
EM2	968861	35	1.31	100% pine
DB4	926780	60	2.66	42% pasture, 58% native
DB5	926785	70	3.00	100% native

[1] After Smith *et al.* (1993).

Figure 1. A sticky trap attached at a height of 0.5 m on a kanuka trunk at the native site.

and the transparencies were changed on 14 October 1993, 11 November 1993, 9 December 1993, 10 January 1994 and 7 February 1994. Maximum-minimum thermometers were attached to trees at all sites in September to measure air temperature, and were secured underwater in November to measure water temperature. The water temperature thermometer at the willow site was swept away by a flood prior to the December site visit. The thermometer at the pine site received direct afternoon sunlight for a short period on clear days, but at the willow and native sites thermometers were shaded by adjacent hills and trees throughout the day.

In the laboratory, pieces of the transparencies to which adult mayflies, stoneflies and caddisflies were adhering were cut out and soaked in X4 to remove the insects. Species were identified under a binocular microscope using the keys of Tillyard (1923), Phillips (1930), McLellan (1969), McFarlane (1976), McLellan (1977), Neboiss (1986), Towns (1983), Towns & Peters (1979), and J. Ward (Canterbury Museum, unpublished). Some insects had partially decomposed by collection time, and some appeared to have been preyed on by birds while on the traps leaving only wings and appendages. A reference collection made from light trap and sweep net collections was used to confirm the identification of sticky trap specimens that were in poor condition.

RESULTS

AIR AND WATER TEMPERATURES

Air temperatures alongside the streams ranged from 0° C - 29° C at the willow site, 2° C - 36° C at the pine site and 1° C - 26 ° C at the native site during the course of the study (Table 2). Highest air temperatures were recorded in January and the lowest at the start of the study in September. The high maximum temperatures at the pine were probably caused by exposure to direct afternoon sun. Water temperatures between November and February ranged from 12° C - 28° C at the willow site, 10° C - 18° C at the pine site and 8° C - 19° C at the native site (Table 2). Highest temperatures were recorded in January and February. In contrast to the air temperatures, maximum water temperatures occurred at the willow site.

COMPOSITION OF THE CATCHES

Of the 38 species collected on all dates combined, most (31) were caught at the willow site, followed by the native (17) and pine (14) sites (Fig. 2). Catches were dominated by mayflies and caddisflies (38% - 52% of total species in each Order) at the willow and native sites, and mayflies at the pine site (71% of species). *Pseudoeconesus* sp.A, *Psilochorema mimicum* and *Pycnocentria funerea* were collected at only one site on more than one occasion (all at the willow site; Table 3).

A total of 424 adults was collected during the study, and of these 75% were caught at the willow site, 19% at the native site, and 6% at the pine site. Catches at the willow site were dominated numerically by mayflies (53% of individuals over all dates combined) and caddisflies (44%), with *Neozephlebia scita*, *Deleatidium* spp. and *Hydrobiosis parumbripennis* the most common taxa (all >14%). Catches were heavily dominated by mayflies (78% of individuals) at the pine site, but at the native site

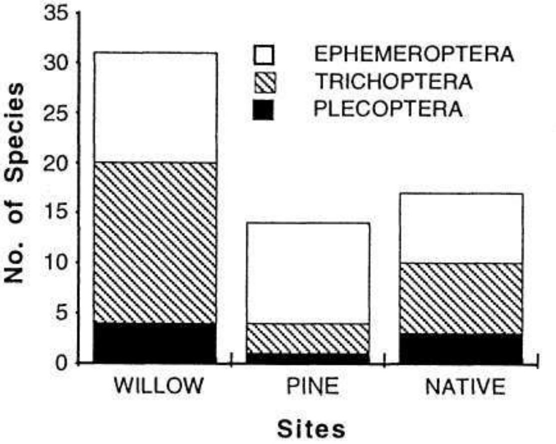

Figure 2. Number of species of mayflies (Ephemeroptera), caddisflies (Trichoptera) and stoneflies (Plecoptera) collected at the three sites (all months and traps combined).

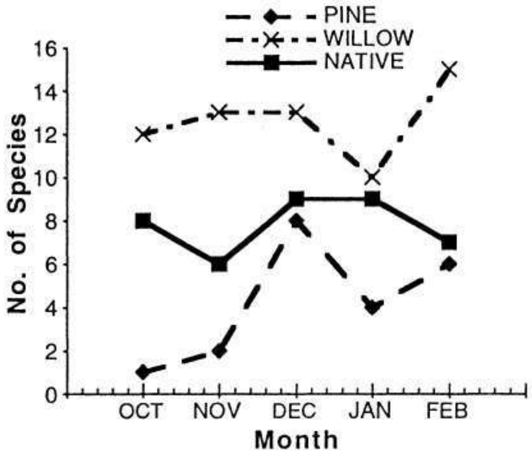

Figure 3. Number of mayfly, caddisfly and stonefly species caught at three sites in each month (all traps combined).

mayflies and stoneflies were both relatively common (49% and 33%, respectively). Caddisflies were relatively uncommon in catches at the pine and native sites (15% - 17%), and stoneflies were uncommon at the pine and pasture sites (3% - 7%). *N. scita* was the most common mayfly caught at all sites, whereas *Acroperla trivacuata* and *Zelandobius confusus* were the most abundant stoneflies trapped at the native site.

TEMPORAL CHANGES

The number of species trapped on a given date was highest at the willow site (usually >10 on all traps), and was lowest at the pine site on all dates (Fig. 3). Seasonal patterns in the number of species caught were not evident, however. *Deleatidium* spp., *N. scita*, *Z. dentata*, and *A. trivacuata* were caught in all months, whereas 20 species were caught on only one occasion (see Table 3).

Table 2. Spot and maximum-minimum (in parentheses) air and water temperatures (°C) recorded at the three sites over five months. - = no data.

Date	Location	Willow	Pine	Native
14 October 1993	Air	- (0-25)	- (2-18)	- (1-18)
	Water	-	-	-
11 November 1993	Air	- (4-28)	- (6-19)	- (5-18)
	Water	15 (-)	12 (-)	12 (-)
9 December 1993	Air	16 (4-26)	19 (6-29)	15 (4-19)
	Water	14 (-)	13 (10-13)	12 (8-16)
10 January 1994	Air	23 (8-29)	31 (10-36)	22 (9-26)
	Water	19 (12-25)	18 (12-18)	15 (10-19)
7 February 1994	Air	21 (7-28)	19 (7-33)	14 (6-25)
	Water	17 (12-28)	16 (13-17)	14 (11-18)

Table 3. Adult mayflies (Ephemeroptera), caddisflies (Trichoptera) and stoneflies (Plecoptera) caught on sticky traps at three sites (W=willow, N=native, P=pine) during September 1993 to February 1994.

	Sept-Oct	Oct-Nov	Nov-Dec	Dec-Jan	Jan-Feb
EPHEMEROPTERA					
Acanthophlebia cruentata					N
Austroclima sp.				W	
Coloburiscus humeralis			P		
Deleatidium spp.	W, N	N, W	N, P	N, W	N, W
Ichthybotus hudsoni				N, P	
Mauiulus luma			P		
Neozephlebia scita	W	N, P, W	N, P, W	N, P, W	N, P, W
Nesameletus ornatus			N	N	W
Zephlebia borealis			P	P, W	P, W
Zephlebia dentata	W	N, W	N, P, W	N, W	P, W
Zephlebia inconspicua	P		W	W	
Zephlebia planulata					P, W
Zephlebia spectabilis					W
Zephlebia versicolor	W		P		W
Zephlebia sp.		N, W	N, W	W	N, W
TRICHOPTERA					
Aoteopsyche colonica			W		
Helicopsyche albescens			W		
Helicopsyche zealandica			N	N	N, P, W
Hudsonema amabilis	W				
Hydrobiosis parumbripennis	N, W	W	W		W
Hydrobiosis umbripennis	W				
Hydrochorema crassicaudatum	N				
Neurochorema confusum	N				
Oeconesus maori	N, W	P, W	W		W
Olinga feredayi			W		
Oxyethira albiceps	N, W	W	N, W		W
Polycentropodidae sp.			W		
Pseudoeconesus sp.A	W				W
Psilochorema mimicum	W	W			
Pycnocentria evecta			W		
Pycnocentria funerea		W	W		
Pycnocentrodes aeris		W			
Zelandoptila moselyi				N, P, W	N, P, W
PLECOPTERA					
Acroperla trivacuata	W	N	N, P	N, W	N
Megaleptoperla diminuta		W			
Stenoperla prasina				N	
Zelandobius confusus	N	N, W	N		
Zelandoperla fenestrata		W			

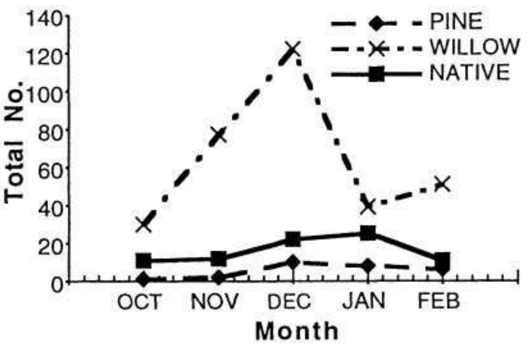

Figure 4. Total number of mayflies, caddisflies and stoneflies caught at three sites in each month (all traps combined).

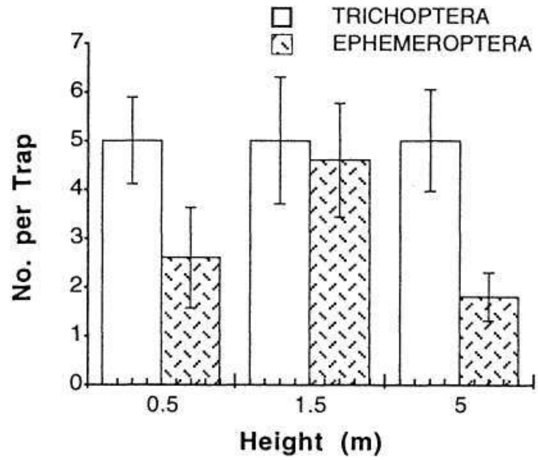

Figure 5. Mean number (± 2SE) of mayflies and caddisflies caught at three heights at the willow site in December 1993.

The number of adult mayflies, stoneflies and caddisflies caught on all traps ranged from 1 at the pine site in October to 122 at the willow site in December (Fig. 4). Catches in the pine and native sites were low in all months (<25 on all traps at a site), with highest numbers being caught in December and January. At the willow site, catches increased from October to December and then declined markedly in January and February (Fig. 4).

EFFECT OF TRAP HEIGHT

The effect of trap height on the numbers of mayflies and caddisflies caught was assessed at the willow site in December. This was the dataset with the greatest number of individuals and therefore the best chance of detecting differences among traps. Similar mean numbers of caddisflies were caught at all heights (Fig. 5), and the apparent peak in mayfly numbers at 1.5 m was not significantly different from catches at other heights (Kruskall-Wallis test, $P>0.05$). At least 8 traps would have been required to have an 80% chance of detecting a 10% difference in numbers between two of three means at the 1% level of significance (following Sokhal & Rohlf 1981).

The number of mayfly and caddisfly species on individual traps at the willow site in December was too low (mean = 1.4-3.2) to make meaningful comparisons between trap heights. Over all dates combined, nine species were collected from only one height, but, except for the stoneflies *Megaleptoperla diminuta* and *Zelandoperla fenestrata* (both caught only at 0.5 m), all were single specimens.

DISCUSSION

During the course of our study, most species and highest numbers of mayflies, stoneflies and caddisflies were caught at the willow site, followed by the native site and then the pine site. Community composition also differed between sites with mayflies and caddisflies relatively common (both numerically and in terms of species richness) at the willow site, mayflies and stoneflies most abundant at the native site, and mayflies dominant at the pine site.

An extensive study of the benthic invertebrate faunas of runs in streams around the Whatawhata area (including EM2 and two sites upstream of DB5 of our study) was carried out by Quinn *et al.* (1994) in November 1992. No comparable willow sites were sampled in that survey. In contrast to our findings for the adult insects, benthic faunas in 1992 were dominated by mayflies and stoneflies (each 44% of total taxa) at the pine site (EM2), and by mayflies at the two native sites upstream of DB5 (60% - 70% of total taxa). Mayflies dominated the benthos numerically at EM2 (84% of individuals; predominantly *Deleatidium* spp., *C. humeralis* and *Z. dentata*) and the two upstream native sites (87% - 93%; mainly *Deleatidium* spp.). At EM2, 8 taxa (including 5 caddisflies) were collected in the benthos in 1992 but were not recorded as adults on sticky traps in 1993/1994, whereas 7 taxa (5 were mayflies) were collected on sticky traps but not in benthic samples.

These differences between benthic and adult insect faunas may partly reflect differences in the years that samples were collected. In addition, samples of adult insects will integrate the fauna of a wider range of instream habitats *(e.g.*, riffles, pools) compared to the benthic sampling of runs. Furthermore, it should be remembered that adult fauna represents those animals that have survived past emergence or pupation, and it is not surprising that relative abundances of the different groups can be different to those found in the benthos where a range of mortality factors may influence the insects that finally reach maturity. Assessments of adult insect faunas could provide valuable insights into the impacts of disturbances on stream ecosystems.

In the study of Quinn *et al.* (1994), streams draining pasture catchments contained much lower densities of benthic mayflies, stoneflies and caddisflies compared with pine or native forest streams. None of the pasture streams sampled in that study were lined by riparian trees, and entire catchments were developed for farming. This contrasts with the situation in our study where the stream flowing through pasture was shaded (by willows) and half of the catchment area upstream was in native forest. These factors may have contributed to increased instream production of mayflies, stoneflies and caddisflies at the willow site, and consequently greater numbers and species richness of adults than at the pine or native sites.

Although no temporal patterns were evident in species richness during our study, highest numbers of adults were trapped in early-mid summer (December-January). Stream water temperatures were highest in these months (maxima ranged from 19° C - 25° C), and warmer water temperatures may have led to higher larval emergence rates (Sweeney 1984) and consequently greater numbers of adults. Crichton & Fisher (1978) caught caddisflies (excluding Limnephilidae) mainly in summer in Britain with numbers falling off rapidly in early autumn (September), whereas Svensson (1974) found greatest numbers of caddisflies in late summer to early autumn but most species in mid summer in a south Swedish stream. Norrie (1969) collected most species in at least eight months of the year in Waitakere Stream near Auckland, although numbers were generally highest over summer.

Flight periods appear to be affected by ambient temperature. Caddisflies at least fly for longer periods in warmer climates (McElravy & Resh 1987), and emerge predominantly during the day in many arctic and north temperate streams, apparently due to cold night temperatures (Jackson 1988 and references therein). High air temperatures have also been associated with reduced adult lifespans, with temperatures of 38° C reducing the longevity of several species of mayflies and caddisflies by 47% - 78% compared with 25° C (Jackson 1988). Air temperatures as high as 36° C were recorded in direct sunlight in our study, suggesting that this could potentially be an important factor affecting the survival of some adults.

Along with changes to microclimate, riparian vegetation type has the potential to affect the composition of the adult aquatic insect community indirectly by altering instream conditions (*e.g.*, by increasing periphyton and temperature in pasture streams; Quinn *et al.* 1994) which can influence the survival and growth of larvae (Jackson & Resh 1989b). In addition, loss of riparian trees may reduce inputs of woody debris which can serve as egg deposition sites for some species, and result in the loss of important food plants on which the adults of some aquatic insects depend (Sweeney 1993). The effects of these factors on the patterns associated with riparian vegetation type in our study have not been determined.

Finally, given the limited work carried out on the ecology of adult insects in New Zealand, it seems worthwhile to comment on some of the advantages and disadvantages of the sticky traps used in our study. Sticky traps are cheap to construct, can be left unattended in the field for extended periods, and collect in a passive manner (*cf.* light traps which attract certain species). As the sticky surface is about 10 cm away from the point of attachment (tree trunks in our study), the traps are more likely to collect adults when they are flying rather than when crawling. The cylindrical shape (*cf.* malaise traps which are typically flat) of the traps meant that they sampled insects potentially flying from all directions. However, some of the specimens collected on sticky traps were in poor condition by the time traps were cleared due to decomposition or predation by birds. In addition, low numbers of adults were frequently collected indicating that either larger traps or more traps would be desirable, or that they would be more effective along larger streams where the ratio of streambed area (for invertebrate production) to trap area is higher.

ACKNOWLEDGEMENTS

Thanks to Wayne Linklater for his help with setting up the study, and to Morag Smith and Glenys Croker for field assistance. John Ward, Dave Towns and Ian McLellan kindly assisted with sample identification. John Quinn, Mike Winterbourn and an anonymous referee made constructive criticisms of drafts. The study was funded by the Department of Conservation and the Foundation of Research Science and Technology.

REFERENCES

Crichton, M.I. & Fisher, D. (1978). Life histories and distribution of British Trichoptera, excluding Limnephilidae and Hydroptilidae, based on the Rothamsted insect survey. *Holarctic Ecology* 1: 31-45.

Jackson, J.K. (1988). Diel emergence and longevity of selected adult aquatic insects from a Sonoran desert stream. *The American Midland Naturalist* 119: 344-352.

Jackson, J.K. & Fisher, S.G. (1986). Secondary production, emergence, and export of aquatic insects of a Sonoran Desert stream. *Ecology* 67: 629-638.

Jackson, J.K. & Resh, V.H. (1989a). Distribution and abundance of adult aquatic insects in the forest adjacent to a northern Californian stream. *Environmental Entomology* 18: 278-283.

Jackson, J.K. & Resh, V.H. (1989b). Activities and ecological role of adult aquatic insects in the riparian zone of streams. USDA Forest Service Gen. Tech. Rep. PSW-110. pp 342-345.

McElravy, E.P. & Resh, V.H. (1987). Diversity, seasonality, and annual variability of caddisfly (Trichoptera) adults from two streams in the California coast range. *Pan-Pacific Entomologist* 63: 75-91.

McFarlane, A.G. (1976). A generic revision of the New Zealand Hydropsychinae (Trichoptera). *Journal of the Royal Society of New Zealand* 6: 23-35.

McLean, J.A. (1967). Studies of Ephemeroptera in the Auckland area I: light trapping in Cascade Kauri Park. *Tane* 13: 99-105.

McLellan, I.D. (1969). A revision of the genus *Zelandobius* (Plecoptera: Antarctoperlinae). *Transactions of the Royal Society of New Zealand, Biological Science* 11: 25-41.

McLellan, I.D. (1977). New alpine and southern Plecoptera from New Zealand, and a new classification of the Gripopterygidae. *New Zealand Journal of Zoology* 4: 119-147.

Michaelis, F.B. (1973). The distribution and life history of *Rakiura vernale* (Trichoptera: Helicopsychidae). *Journal of the Royal Society of New Zealand* 3: 295-304.

Neboiss, A. (1986). *Atlas of Trichoptera of the Southwest Pacific-Australian Region*. W. Junk, Dordrecht.

Norrie, P.H. (1969). The flight activity of Ephemeroptera and Trichoptera in a Waitakere stream. Unpubl. M.Sc. thesis, University of Auckland.

Phillips, J.S. (1930). A revision of New Zealand Ephemeroptera. *Transactions of the New Zealand Institute* 61: 271-390.

Quinn, J.M., Cooper, A.B., Davies-Colley, R.J., Rutherford, J.C. & Williamson, B. (1994). Land-use effects on New Zealand hill country streams and implications for riparian management. In: Proceedings of International Workshop on the Ecology and Management of Aquatic-terrestrial Ecotones (eds. L.L. Link & R.J. Norman) pp. 19-27, University of Washington, Seattle, U.S.A.

Smith, M.J., Cooper, A.B. & Quinn, J.M. (1993). Land-water interactions research at Whatawhata - the start. NIWA Ecosystems Publ. No. 4, July 1993.

Sokhal, R.R. & Rohlf, F.J. (1981). Biometry 2nd edn. W.H. Freeman & Co., New York.

Svensson, B.W. (1974). Population movements of adult Trichoptera at a south Swedish stream. *Oikos* 25: 157-175.

Sweeney, B.W. (1984). Factors influencing life history patterns of aquatic insects. In: *The Ecology of Aquatic Insects* (eds. V.H. Resh & D.M. Rosenberg), pp. 56-100. Praeger, New York.

Sweeney, B.W. (1993). Effects of streamside vegetation on macroinvertebrate communities of White

Clay Creek in eastern North America. *Proceedings of The Academy of Natural Sciences of Philidelphia* 144: 291-340.

Tillyard, R.J. (1923). The stoneflies of New Zealand (Order Perlaria) with descriptions of new genera and species. *Transactions and Proceedings of the New Zealand Institute* 54: 197-217.

Towns, D.R. (1983). A revision of the genus *Zephlebia* (Ephemeroptera: Leptophlebiidae). *New Zealand Journal of Zoology* 10: 1-52.

Towns, D.R. (1987). The mayflies (Ephemeroptera) of Great Barrier Island, New Zealand: macro- and micro-distributional comparisons. *Journal of the Royal Society of New Zealand* 17: 349-361.

Towns, D.R. & Peters, W.L. (1979). Three new genera of Leptophlebiidae (Ephemeroptera) from New Zealand. *New Zealand Journal of Zoology* 6: 213-235.

Ward, J.B. (1991). Two new species of New Zealand caddisflies (Trichoptera: Hydrobiosidae). *New Zealand Entomologist* 14: 15-21.