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# Benthic invertebrates of the lower Waitaki River and tributaries

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# Benthic invertebrates of the lower Waitaki River and tributaries

by

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## SUMMARY

Benthic invertebrates were sampled quarterly from 1978 to 1980 in the lower Waitaki River and three of its tributaries.

The invertebrate fauna of the tributaries was typical of small New Zealand rivers which contain high quality water; *Deleatidium* (Ephemeroptera) and caddisfly larvae were the most abundant taxa present.

In the mainstem Waitaki the invertebrate fauna differed from the *Deleatidium* dominated communities typical of large less modified South Island east coast rivers (e.g., Rakaia). *Deleatidium* dominated the Waitaki fauna on only a few occasions; elmid larvae most often dominated the fauna with various caddisflies, dipteran larvae, oligochaetes, or molluscs dominant at other times.

Benthic invertebrate habitat has been altered by hydro-electric power development on the Waitaki River. Impoundments upstream have substantially modified the rivers natural flow regime and have resulted in enhanced substrate stability and siltation of the substrate. The patterns of invertebrate composition and abundance in the lower Waitaki are considered to have altered in response to these changes.

Although the benthic invertebrate fauna has been modified it sustains the substantial fish populations in the river and also forms an important source of food for several bird species.

If power development proceeds on the lower Waitaki attention should be given to providing suitable conditions for benthic invertebrates in a residual river. Siltation could be a major problem in a stable residual river.

# 1. INTRODUCTION

The fish stocks and fisheries of the lower Waitaki River are currently under investigation by Fisheries Research Division (FRD) because of the proposal by Electricity Division (ED), N.Z. Ministry of Energy, to develop the lower river for the generation of hydro-electric power. Options for power development have been presented by Ministry of Works and Development (1979) and McColl and Natusch (1982). FRD has made preliminary recommendations that the option that includes a residual river, power canal, and floodway holds the greatest potential for conservation of existing fish populations (Graynoth, Pierce, and Wing 1981).

Benthic invertebrates play an important role in lotic (running water) ecosystems, where they form a trophic link between the organic matter derived from within the stream (autocthonous production) and outside of the stream (allochthonous production) and fish production (Townsend 1980). Several New Zealand studies have shown both native and introduced fish species to be heavily dependent on benthic invertebrates as a source of food (Burnet 1969, Hopkins 1970, Sagar and Eldon 1983, and McLellan and MacMillan 1984).

Because no information was available on the benthic invertebrate populations of the lower Waitaki River, FRD undertook an inventory survey in the lower Waitaki and three of its tributaries. Sampling was done quarterly from 1978 to 1980. This report documents the composition and abundance of the lower Waitaki benthic invertebrate fauna and compares it with that of the Rakaia, a relatively unmodified large braided river that has been extensively studied. Consideration is also given to the role of the benthic invertebrates in the biota of the lower Waitaki and to their habitat requirements in a residual river.

# 2. STUDY AREA

## 2.1 Lower Waitaki River

### 2.1.1 General Features

The lower Waitaki River runs in a wide, fairly steep (0.0033 gradient) braided channel, and has at its mouth a mean annual flow of about 360 $m^3/s$. Most of the flow (about 345 $m^3/s$) is derived from the upper Waitaki; the tributary streams of the lower Waitaki contribute about 15 $m^3/s$ on average (Waitaki Catchment Commission and Regional Water Board 1982). Flow patterns past the Waitaki dam are dictated by electricity demand and ED operating policy resulting in often large diurnal and weekly flow fluctuations. Occasionally, natural flow events in the upper catchment, such as large floods, can result in flood flows being passed on beyond the Waitaki dam (e.g., during December 1984 a flood peaked at 1684 $m^3/s$). Highest seasonal flows normally occur in spring to early summer with spring rainfall and snow melt, and lowest flows occur in autumn to winter when precipitation in the headwaters is bound up as ice and snow.

Chemical and silt load characteristics of the lower Waitaki River, at least initially, resemble those of the upstream impoundments. That is, the waters are well oxygenated, close to neutral in pH, low in faecal coliform counts (Waitaki Valley Acclimatisation Society 1976), and their conductivity ranges from "5.0-7.0 millisiemens/m" (Stout 1978). Discolouration due to the presence of glacial silt (derived primarily from Lake Pukaki) is characteristic of upper and lower Waitaki water. The lower Waitaki River carries an average annual suspended load of 1.6 million tonnes per year (2 million cubic metres per year) (Gibb and Adams 1982). Samples of Waitaki River gravels indicate the median grain size (d 50) to be 21 mm with 90% of the material (by weight) smaller than 83 mm and a maximum size of about 140 mm (McColl and Natusch 1982). In the lower Waitaki River channel up to one-third of the wetted area of the coarser gravel substrate was observed to have a silt/clay coating and siltation was severe where velocities were low and depths shallow (Jowett 1983). The problem of siltation in the lower Waitaki River is a consequence of decreased flushing effects in the lower channel. Development of the river for hydro-electricity generation has created a situation in which higher flows no longer produce the same pattern of high velocities and bed-load transport which resulted in lower levels of silt retention (Kirk 1983).

Physical characteristics, land use, water management, and other features of the Waitaki catchment are described in Waitaki Catchment Commission and Regional Water Board (1982). Features of the fish populations and fishery are outlined by Wing (1978) and Graynoth, Pierce, and Wing (1981), and the avifauna is described in Robertson, Law, de Hamel, Wakelin, and Courtenay (1984).

### 2.1.2 Sampling Sites

#### 2.1.2.1 Ferry Road Inner

This site was a minor braid on the south bank of the lower Waitaki River about 10 km upstream from the mouth and where Ferry Road meets the river (Fig. 1). Flow in the braid was estimated at about 0.9 $m^3/s$ and consisted of a mixture of Waitaki River water and groundwater. When flow exceeded 800m $m^3/s$ in the main river the braid was subject to flooding, otherwise flow at the site was stable. Substrate in the

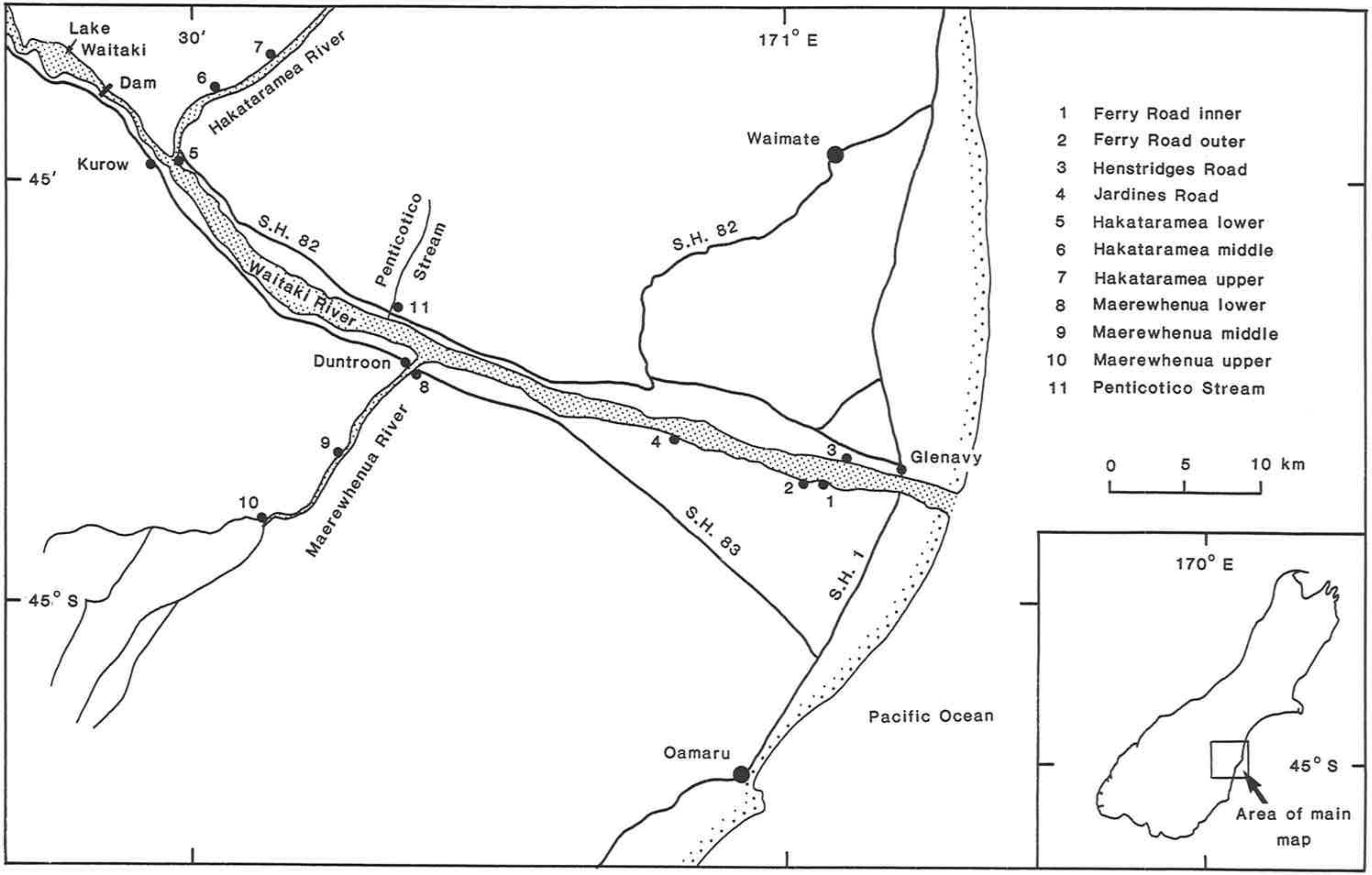


FIGURE 1. Lower Waitaki River system showing location of invertebrate sampling sites.

riffle where samples were taken was composed of 20% gravel (2-64 mm diameter) and 80% cobble (64-256 mm diameter). The presence of thick periphyton communities on the substrate surface reflected the general stability of the site.

2.1.2.2 Ferry Road Outer

The area sampled was located about 1 km upstream of the inner site and in a major braid of the main river (Fig. 1). Mean flow in the braid was estimated at 10-15 $m^3/s$. Substrate composition at the site was 90% cobble, and 10% gravel, with some siltation and periphyton development on the surfaces of stones.

2.1.2.3 Henstridges Road

This site was located on the north bank of the river about 8 km above the mouth (Fig. 1). Flow in this braid was estimated to average about 5 $m^3/s$. Substrate composition was 90% cobble and 10% gravel. On the substrate there was a thin layer of periphyton which had trapped a layer of silt.

2.1.2.4 Jardines Road

The area sampled was on the south bank about 20 km upstream from the river mouth at the point where Jardines Road meets the river (Fig. 1). Flow in the braid was about 5 $m^3/s$. Substrate composition was similar to that of Ferry Road outer and Henstridges Road, and there was a thin layer of silt and periphyton on the substrate surface.

## 2.2 Hakataramea River

### 2.2.1 General Features

The Hakataramea River rises in the Dalgety Range and follows a southerly course to its confluence with the lower Waitaki River opposite Kurow township (Fig. 1). The river is about 62.4 km long and has a mean discharge of 5.2 $m^3/s$. During the summer, sections of the riverbed are prone to drying when flows are reduced; floods generally occur during winter months. The substrate is a fairly consolidated bed of gravel and cobble with a few boulders and rock outcrops especially in the gorge areas. Water clarity and quality are good, and the river supports an abundant and diverse fish fauna (Wing 1978). The river is of considerable importance as a spawning and rearing area for quinnat salmon, brown trout, and rainbow trout. The Hakataramea is one of the most popular angling rivers in the district (Teirney, Richardson, and Unwin 1982).

### 2.2.2 Sampling Sites

Invertebrates were sampled at three sites in the Hakataramea River (Fig. 1). Sites were located at 0.2, 5, and 14 km above the confluence of the river with the Waitaki. Substrate composition at the riffles where samples were obtained was about 60% cobble and 40% gravel. A fairly thick (2-6 mm) growth of periphyton was evident at each site.

## 2.3 Maerewhenua River

### 2.3.1 General Features

The Maerewhenua River rises in the Kakanui Mountains and enters the Waitaki River near Duntroon township (Fig. 1). The mean flow is about 3.5 $m^3/s$. However, abstraction of water for irrigation in summer months reduces the flow and results in the occasional drying of lower reaches. Large floods occur periodically, for example the flow reached an unprecedented 700 $m^3/s$ in June 1980. A well sorted quartzite gravel is predominant through most of the lower reaches, whereas the upper reaches are characterised by a coarser cobble-gravel substrate with occasional boulders - especially in the gorge. The Maerewhenua, like the Hakataramea, is an important spawning area for brown and rainbow trout, but only a small number of quinnat salmon enter the river. Although few anglers fish the river, catch rates are high (Teirney, Richardson, and Unwin 1982).

### 2.3.2 Sampling Sites

Sampling sites were located about 3, 14, and 20 km above the confluence of the Maerewhenua and lower Waitaki Rivers (Fig. 1). Substrate composition at the lower site was about 80% gravel and 20% cobble whereas at the two sites further upstream it was about 60% cobble and 40% gravel. There was little periphyton development at the lower site, but moderate development (a 2-3 mm layer) at the middle and upper sites, where the substrate was more consolidated.

## 2.4 Penticotico Stream

### 2.4.1 General Features

The Penticotico is a small (mean discharge 0.1 $m^3/s$), fairly stable stream which originates in the Clarksfield Hills on the north bank of the Waitaki River (Fig. 1). The substrate is predominantly coarse gravel with areas of fine gravel and sand/silt, including some weed beds; the lower reaches are infested by willows. Brown trout and a small number of quinnat salmon utilize the stream as a spawning and juvenile rearing area. There is a large population of long-finned eels present. A few anglers fish the stream where it enters the Waitaki River.

### 2.4.2 Sampling Site

The sampling site in the Penticotico Stream was located about 20 m downstream of the S.H. 82 bridge (Fig. 1). Substrate composition at the site was about 70% gravel and 30% cobble. A thin brown film of diatoms was present on the substrate surface.

# 3. METHODS

Benthic invertebrates were sampled on a seasonal basis at the 11 riffle sites in the lower Waitaki River and tributaries from summer 1978 to spring 1980 (see Appendix I for dates). On a few occasions Waitaki River sampling sites were relocated when severe flow fluctuations or changes in the morphology of braids resulted in riffles being dewatered or flooded. Nearby riffles with similar characteristics were selected on such occasions. This problem did not occur in the tributary streams.

Large floods originating from the tributaries during winter 1980 precluded collection of samples at all sites.

Five replicate samples were taken from each riffle site using a 0.1 $m^2$ surber sampler fitted with a 0.25 mm mesh net. Water depth at sampling sites ranged from about 15 to 30 cm. Substrate was disturbed to a depth of at least 5 cm during the collection of each sample. Samples were preserved in 5-10% formalin in the field and transferred to the laboratory where they were sorted by hand and invertebrates identified and counted. Lack of expertise prevented identification of invertebrates to low taxonomic levels, hence some taxa were combined (e.g., the caddisflies *Pycnocentria* and *Pynocentrodes*). Abundance of invertebrates was expressed as percentage composition averaged over the five replicates taken during each sampling period. Mean percentage composition of each taxon for each of the 11 stations for the three years combined was also calculated (see Table 12). This gives an overall picture of the importance of each taxon in each sampling area.

# 4. RESULTS

## 4.1 Species Composition and Abundance

### 4.1.1 Lower Waitaki River

Over the 3 year sampling period a total of 23 taxa was recorded from the four lower Waitaki River sites. However, this number would be increased by 15-20 if Oligochaeta, Chironomidae, and Trichoptera were identified to lower taxonomic levels. Twenty-one taxa were recorded from each of Ferry Road inner, Ferry Road outer, and Henstridges Road, and 17 were recorded from Jardines Road (Tables 1, 2, 3, and 4).

TABLE 1. Relative abundance of benthic invertebrates (percent of total number) collected at Ferry Road inner, lower Waitaki River, summer 1978-spring 1980. Values are means of five replicate samples (- = not present; * = < 0.1%)

| Taxa | 1978 Sum | 1978 Aut | 1978 Win | 1978 Spr | 1979 Sum | 1979 Aut | 1979 Win | 1979 Spr | 1980 Sum | 1980 Aut | 1980 Spr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PLATYHELMINTHES | | | | | | | | | | | |
| *Cura* sp. | 0.8 | - | 1.4 | 4.8 | 7.5 | 13.4 | 3.9 | 12.0 | 4.2 | 0.3 | 7.1 |
| OLIGOCHAETA | | | | | | | | | | | |
| Oligochaetae (spp.) | 0.2 | 1.0 | 0.2 | 0.5 | 0.5 | * | 0.9 | 0.5 | 0.6 | 1.7 | 2.6 |
| MOLLUSCA | | | | | | | | | | | |
| *Potamopyrgus antipodarum* | 13.4 | 14.8 | 20.1 | 28.5 | 26.5 | 31.4 | 36.3 | 13.0 | 31.1 | 14.2 | 12.6 |
| *Physa acuta* | 0.5 | 12.6 | 6.9 | 6.0 | 0.9 | 1.9 | 1.6 | 0.4 | 0.3 | 0.3 | 0.7 |
| *Sphaerium novaezelandia* | - | - | - | 0.2 | 0.1 | - | - | - | - | - | - |
| EPHEMEROPTERA | | | | | | | | | | | |
| *Deleatidium* spp. | 11.4 | 4.6 | 2.9 | 3.3 | 1.7 | 5.6 | 17.4 | 17.7 | 10.1 | 5.7 | 40.2 |
| *Coloburiscus humeralis* | 27.4 | 7.2 | 14.9 | 11.2 | 16.5 | 1.7 | 1.3 | 4.3 | 7.1 | 6.9 | 4.7 |
| PLECOPTERA | | | | | | | | | | | |
| *Zealandobius* sp. | - | - | * | * | - | - | - | - | - | - | - |
| TRICHOPTERA | | | | | | | | | | | |
| *Pycnocentrodes* sp. and *Pycnocentria* sp. | 17.6 | 30.9 | 28.7 | 18.6 | 21.8 | 22.6 | 15.4 | 24.2 | 19.4 | 13.4 | 7.0 |
| *Olinga feredayi* | 1.2 | 3.1 | 2.7 | 1.3 | 2.7 | 1.8 | 0.8 | 2.2 | 0.9 | - | 0.7 |
| *Oxyethira albiceps* | - | - | - | - | - | - | * | 0.2 | - | 0.3 | - |
| *Aoteapsyche* spp. | 2.8 | 8.3 | 15.9 | 13.1 | 13.3 | 10.9 | 9.6 | 8.3 | 9.3 | 32.6 | 13.2 |
| *Polyplectropus* sp. | - | - | - | - | - | - | - | - | 0.2 | - | 0.6 |
| *Helicopsyche albescens* | - | - | - | - | * | - | - | - | * | - | - |
| Rhyacophilidae (spp.) | 12.3 | 1.1 | 0.1 | 0.6 | 1.3 | 0.1 | 0.6 | 1.0 | 4.2 | 3.5 | 0.5 |
| MEGALOPTERA | | | | | | | | | | | |
| *Archichauliodes diversus* | - | 0.2 | - | - | * | * | - | * | - | - | * |
| DIPTERA | | | | | | | | | | | |
| *Austrosimulium* spp. | - | 0.7 | - | * | - | - | * | 0.2 | 0.1 | 0.5 | - |
| Eriopterini (spp.) | - | 3.3 | 1.8 | 9.7 | 0.4 | 3.5 | 6.5 | 3.6 | 4.3 | 1.2 | - |
| Chironomidae (spp.) | - | - | - | - | * | 0.9 | 0.4 | 2.6 | - | - | 2.6 |
| COLEOPTERA | | | | | | | | | | | |
| Elmidae (spp.) | 12.2 | 12.2 | 4.3 | 1.9 | 2.1 | 5.2 | 3.5 | 8.8 | 7.9 | 11.3 | 5.8 |
| CRUSTACEA | | | | | | | | | | | |
| *Paracalliope fluviatilis* | - | - | - | - | * | 0.6 | 1.5 | 0.9 | 0.3 | 6.7 | 1.6 |
| MISCELLANEOUS | 0.2 | - | 0.1 | 0.2 | 0.7 | 0.1 | * | - | * | 1.3 | 0.2 |
| Mean no./$m^2$ | 4 490 | 1 529 | 4 214 | 5 054 | 9 194 | 9 672 | 4 714 | 8 430 | 9 446 | 2 934 | 4 918 |
| Number taxa | 11 | 13 | 13 | 15 | 17 | 15 | 16 | 17 | 15 | 14 | 15 |

TABLE 2. Relative abundance of benthic invertebrates (percent of total number) collected at Ferry Road outer, lower Waitaki River, summer 1978-spring 1980. Values are means of five replicate samples (- = not present; * = < 0.1%; N.S., not sampled)

| Taxa | 1978 Sum | Aut | Win | Spr | 1979 Sum | Aut | Win | Spr | 1980 Sum | Aut | Spr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PLATYHELMINTHES | | | | | | | | | | | |
| *Cura* sp. | - | - | - | N.S. | 4.6 | 0.3 | - | 0.7 | 1.2 | - | - |
| OLIGOCHAETA | | | | | | | | | | | |
| Oligochaetae (spp.) | - | - | 13.0 | | 0.9 | 1.1 | 63.6 | 1.4 | 0.5 | 3.1 | 4.0 |
| MOLLUSCA | | | | | | | | | | | |
| *Potamopyrgus antipodarum* | 5.3 | 13.1 | 6.5 | | 4.6 | 43.9 | 3.9 | 0.7 | 10.5 | 3.1 | 3.6 |
| *Physa acuta* | - | 5.4 | 3.9 | | - | 8.4 | - | - | 0.4 | - | - |
| *Sphaerium novaezelandiae* | - | - | - | | - | - | 1.3 | 0.7 | - | - | - |
| EPHEMEROPTERA | | | | | | | | | | | |
| *Deleatidium* spp. | 29.2 | 7.7 | - | | 7.0 | - | - | 2.0 | 25.3 | 69.2 | 5.5 |
| *Coloburiscus humeralis* | 15.6 | - | - | | 3.7 | - | - | - | - | - | - |
| TRICHOPTERA | | | | | | | | | | | |
| *Pycnocentrodes* spp. and *Pycnocentria* spp. | 25.3 | 23.1 | 7.8 | | 7.2 | 12.7 | - | 2.0 | 0.7 | 0.8 | 0.8 |
| *Olinga feredayi* | - | - | 1.3 | | 1.6 | 0.3 | - | - | - | 3.1 | - |
| *Oxyethira albiceps* | - | - | - | | - | - | - | 21.1 | - | - | 12.0 |
| *Aoteapsyche* spp. | 14.2 | 5.4 | - | | 19.2 | 1.6 | - | 3.4 | 4.7 | - | 2.3 |
| *Polyplectropus* sp. | - | - | - | | * | - | - | - | - | - | 3.6 |
| *Helicopsyche albescens* | - | - | - | | - | - | - | - | 0.2 | - | - |
| Rhyacophilidae (spp.) | 5.8 | 2.3 | - | | 4.8 | - | - | - | 4.1 | - | 0.4 |
| MEGALOPTERA | | | | | | | | | | | |
| *Archichauliodes diversus* | | - | - | | 0.5 | 0.8 | - | - | - | - | - |
| DIPTERA | | | | | | | | | | | |
| *Austrosimulium* spp. | - | - | - | | - | - | - | - | 0.4 | - | 3.4 |
| Eriopterini (spp.) | 0.6 | 2.3 | 35.1 | | 2.9 | 4.9 | - | 38.1 | 28.0 | 4.6 | - |
| Chironomidae (spp.) | - | - | - | | - | - | - | - | - | - | 0.4 |
| COLEOPTERA | | | | | | | | | | | |
| Elmidae (spp.) | 3.9 | 40.8 | 32.5 | | 42.6 | 26.0 | 29.9 | 29.3 | 23.3 | 15.4 | 59.3 |
| LEPIDOPTERA | | | | | | | | | | | |
| *Nymphula nitens* | - | - | - | | - | - | 1.3 | - | - | - | - |
| CRUSTACEA | | | | | | | | | | | |
| *Paracalliope fluviatilis* | - | - | - | | 0.3 | - | - | - | 0.7 | 0.8 | 4.6 |
| MISCELLANEOUS | - | - | - | | * | - | - | - | - | - | - |
| Mean no./$m^2$ | 513 | 130 | 154 | | 2 929 | 738 | 154 | 294 | 1 123 | 260 | 1 188 |
| Number taxa | 8 | 8 | 7 | | 14 | 10 | 5 | 10 | 12 | 8 | 12 |

TABLE 3. Relative abundance of benthic invertebrates (percent of total number) collected at Henstridges Road, lower Waitaki River, summer 1978-spring 1980. Values are means of five replicate samples (- = not present; * = < 0.1%)

| Taxa | 1978 Sum | 1978 Aut | 1978 Win | 1978 Spr | 1979 Sum | 1979 Aut | 1979 Win | 1979 Spr | 1980 Sum | 1980 Aut | 1980 Spr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PLATYHELMINTHES | | | | | | | | | | | |
| *Cura* sp. | - | - | 1.8 | 2.3 | 2.3 | 3.9 | 2.6 | - | 0.5 | - | - |
| OLIGOCHAETA | | | | | | | | | | | |
| Oligochaetae (spp.) | 0.6 | 1.6 | 41.1 | 0.4 | 0.7 | 1.6 | 6.5 | 3.1 | 0.3 | 14.9 | 4.7 |
| MOLLUSCA | | | | | | | | | | | |
| *Potamopyrgus antipodarum* | - | - | 1.8 | 4.1 | 4.0 | 30.4 | 29.8 | 0.3 | 9.1 | 9.1 | 1.8 |
| *Physa acuta* | - | 23.4 | - | 5.3 | 0.4 | 3.0 | - | 3.1 | 0.1 | - | - |
| *Sphaerium novaezelandiae* | | - | - | 0.2 | - | - | - | - | - | - | - |
| EPHEMEROPTERA | | | | | | | | | | | |
| *Deleatidium* spp. | 20.6 | 3.1 | - | 5.8 | 13.0 | 5.1 | 9.1 | - | 10.2 | - | 0.6 |
| *Coloburiscus humeralis* | - | - | - | 0.5 | 1.9 | 0.3 | - | - | - | - | - |
| *Nesameletus* sp. | - | - | - | - | - | 0.1 | - | - | - | - | - |
| PLECOPTERA | | | | | | | | | | | |
| *Zealandobius* sp. | - | - | - | 0.1 | - | - | - | 1.5 | - | - | - |
| TRICHOPTERA | | | | | | | | | | | |
| *Pycnocentrodes* sp. and *Pycnocentria* sp. | 14.4 | 25.0 | - | 65.7 | 44.8 | 12.4 | 2.6 | 6.2 | 13.0 | 3.3 | - |
| *Olinga feredayi* | 5.5 | - | 7.1 | 0.6 | 2.5 | 1.6 | - | 3.1 | 0.2 | - | 0.6 |
| *Oxyethira albiceps* | - | - | - | - | - | - | 2.6 | - | - | - | - |
| *Aoteapsyche* spp. | 2.7 | 3.1 | - | 2.1 | 10.7 | 13.8 | - | - | 4.1 | - | - |
| *Polyplectropus* sp. | - | - | - | - | - | - | - | - | 0.3 | - | - |
| Rhyacophilidae (spp.) | 25.4 | - | - | 0.2 | 1.5 | 2.0 | - | 7.7 | 1.0 | 3.3 | - |
| MEGALOPTERA | | | | | | | | | | | |
| *Archichauliodes diversus* | - | - | - | 0.1 | 0.1 | * | - | - | 0.2 | - | - |
| DIPTERA | | | | | | | | | | | |
| *Austrosimulium* spp. | - | 1.6 | - | - | - | - | - | - | 0.2 | - | 1.2 |
| Eriopterini (spp.) | 2.1 | 7.8 | 17.9 | 5.4 | 1.0 | 3.7 | 29.8 | 58.5 | 4.1 | 3.3 | - |
| Chironomidae (spp.) | 1.4 | - | 1.8 | - | 0.7 | 4.6 | - | - | - | 3.3 | 27.6 |
| COLEOPTERA | | | | | | | | | | | |
| Elmidae (spp.) | 26.7 | 34.4 | 28.6 | 5.4 | 16.2 | 17.4 | 14.6 | 13.8 | 55.5 | 62.8 | 62.4 |
| CRUSTACEA | | | | | | | | | | | |
| *Paracalliope fluviatilis* | - | - | - | - | - | * | 2.6 | - | 1.1 | - | 0.6 |
| MISCELLANEOUS | 0.6 | - | - | 1.5 | 0.1 | * | - | - | 0.1 | - | 0.6 |
| Mean no./$m^2$ | 486 | 128 | 112 | 1 882 | 3 260 | 5 590 | 155 | 136 | 4 404 | 121 | 340 |
| Number taxa | 9 | 8 | 7 | 15 | 14 | 16 | 9 | 9 | 15 | 7 | 8 |

TABLE 4. Relative abundance of benthic invertebrates (percent of total number) collected at Jardines Road, lower Waitaki River summer 1978-spring 1980. Values are means of five replicate samples (- = not present; * = < 0.1%)

| Taxa | 1978 Sum | Aut | Win | Spr | 1979 Sum | Aut | Win | Spr | 1980 Sum | Aut | Spr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OLIGOCHAETA | | | | | | | | | | | |
| Oligochaetae (spp.) | 0.2 | 11.0 | 21.3 | - | 0.1 | 6.8 | 11.6 | 0.7 | 2.5 | 4.4 | 1.8 |
| MOLLUSCA | | | | | | | | | | | |
| *Potamopyrgus antipodarum* | - | - | 45.5 | 3.1 | 4.9 | 3.1 | 26.3 | - | 1.2 | 1.9 | 0.4 |
| *Physa acuta* | 0.5 | - | 8.4 | 1.0 | 5.1 | 0.3 | 0.4 | - | - | - | - |
| EPHEMERODTERA | | | | | | | | | | | |
| *Deleatidium* spp. | 37.2 | - | 0.3 | 2.1 | 6.0 | 0.6 | - | 2.1 | 8.1 | 78.6 | 16.9 |
| *Coloburiscus humeralis* | 15.9 | 0.7 | - | - | - | - | - | - | - | - | - |
| PLECOPTERA | | | | | | | | | | | |
| *Zealandobius* sp. | - | - | - | 0.5 | - | - | - | - | - | - | - |
| TRICHOPTERA | | | | | | | | | | | |
| *Pycnocentrodes* sp. and *Pycnocentria* sp. | 8.1 | 4.1 | 5.5 | 2.6 | 1.0 | 0.6 | 0.8 | 0.9 | 2.5 | - | 0.6 |
| *Oxyethira albiceps* | - | - | - | - | - | - | - | 12.7 | 0.7 | - | - |
| *Aoteapsyche* spp. | 4.4 | 6.8 | 0.3 | 0.5 | 1.4 | 0.2 | - | 0.4 | 0.5 | - | 0.3 |
| *Polyplectropus* sp. | - | - | - | - | - | - | - | - | - | - | 0.3 |
| Rhyacophilidae (spp.) | 8.1 | 0.7 | 0.6 | 3.6 | 4.1 | - | - | 0.5 | - | - | 0.1 |
| MEGALOPTERA | | | | | | | | | | | |
| *Archichauliodes diversus* | - | - | 0.6 | - | 0.3 | - | - | 0.2 | - | - | 0.1 |
| DIPTERA | | | | | | | | | | | |
| *Austrosimulium* spp. | 0.2 | - | - | - | - | 0.2 | - | 0.4 | - | - | - |
| Chironomidae (spp.) | - | - | 0.9 | - | 0.2 | 0.6 | - | 53.0 | - | - | 50.3 |
| COLEOPTERA | | | | | | | | | | | |
| Elmidae (spp.) | 15.4 | 76.7 | 15.8 | 85.6 | 65.5 | 87.4 | 60.2 | 29.2 | 84.5 | 15.1 | 26.5 |
| LEPIDOPTERA | | | | | | | | | | | |
| *Nymphula nitens* | - | - | - | - | - | - | 0.4 | - | - | - | - |
| CRUSTACEA | | | | | | | | | | | |
| *Paracalliope fluviatilis* | - | - | - | - | - | - | 0.4 | - | - | - | 1.8 |
| MISCELLANEOUS | - | - | 0.9 | 1.0 | 11.4 | 0.1 | - | - | - | - | 0.9 |
| Mean no./m$^2$ | 1 350 | 482 | 695 | 390 | 2 128 | 1 932 | 518 | 1 118 | 812 | 318 | 1 364 |
| Number taxa | 9 | 6 | 10 | 8 | 10 | 9 | 7 | 10 | 7 | 4 | 11 |

On a seasonal basis, the lowest numbers of taxa occurred at Jardines Road, with a minimum of four recorded in autumn 1980 (Table 4). Ferry Road inner consistently recorded the highest numbers of taxa with a maximum of 17 in both summer and spring 1979 (Table 1). With the exception of Jardines Road, maximum numbers of taxa were recorded at all stations during either summer or autumn 1979 when flows were fairly low and stable. The number of taxa present showed large fluctuations from season to season (Tables 1, 2, 3, and 4); fluctuations were least pronounced at Ferry Road inner, which is a stable minor braid, except during large floods.

Of the 11 quarterly sample collections (each "sample" consisted of 5 replicates) taken at Ferry Road inner, the mollusc *Potamopyrgus antipodarum* was numerically dominant in 5 samples, and *Deleatidium* spp. and the caddisflies *Aoteapsyche* spp. dominated in 2 samples and 1 sample respectively. The caddisflies *Pycnocentria* and *Pycnocentrodes* dominated the fauna in the three remaining samples (Table 1). *Olinga feredayi* and species of the family Rhyacophilidae (free-living caddisflies) also occurred consistently, but they were less abundant. Elmid larvae occurred in all samples at Ferry Road inner, but they were never dominant (comprising 1.9-12.2% of the fauna) in contrast to the three other sites where they were often dominant and comprised up to 87.4% of the fauna (Jardines Road, summer 1979, Table 4). Other features distinctive of Ferry Road inner when compared to the three other lower Waitaki stations were the consistent occurrence and higher numbers of both Mollusca (predominantly *Potamopyrgus antipodarum*) and Platyhelminthes.

The numerically dominant invertebrates which occurred at the other three lower Waitaki sites varied considerably and without apparent relationship to either site or season (Tables 2, 3, and 4). At Ferry Road outer (Table 2) elmid larvae (comprising 3.9-42.6% of the fauna) and the dipterans Eriopterini spp., (comprising 0-38.1% of the fauna) predominated in three samples, and *Deleatidium* spp. predominated in two samples. Oligochaeta and the mollusc *P. antipodarum* were each predominant in one sample. Elmid larvae (comprising 15.1-85.6% of the fauna) were prevalent in six samples at Jardines Road, and chironomids and *Deleatidium* spp. predominated in two samples. The mollusc *P. antipodarum* was predominant in winter 1978 (comprising 45.5% of the fauna) (Table 4). At Henstridges Road, elmid larvae were dominant in five samples; Eriopterini spp., Oligochaeta, and *P. antipodarum* were dominant in one sample each; and the caddisflies *Pycnocentria* and *Pycnocentrodes* dominated in two samples. Eriopterini spp. and *P. antipodarum* were co-dominant in winter 1979 when each comprised 29.8% of the fauna.

A plot of mean daily flow in the lower Waitaki, Hakataramea, and Maerewhenua rivers (Fig. 2) shows that short term flow fluctuations of large magnitude are a persistent feature of the lower Waitaki. This makes it extremely difficult to draw any conclusions on the relationship between flow stability and numbers of benthic invertebrates (Fig. 3). Numbers of benthic invertebrates at the lower Waitaki sites showed a decline from summer (when flows were extremely low, Fig. 2) to autumn 1978, then they increased and reached an overall peak at all sites in either summer or autumn 1979. Maximum numbers of taxa were also recorded in the summer-autumn 1979 samples (Tables 1, 2, 3, and 4). Invertebrate numbers show a large decline at all sites in the winter 1979 sample, presumably as a result of high flows preceding sample collection. A general increase in numbers is then evident at all lower

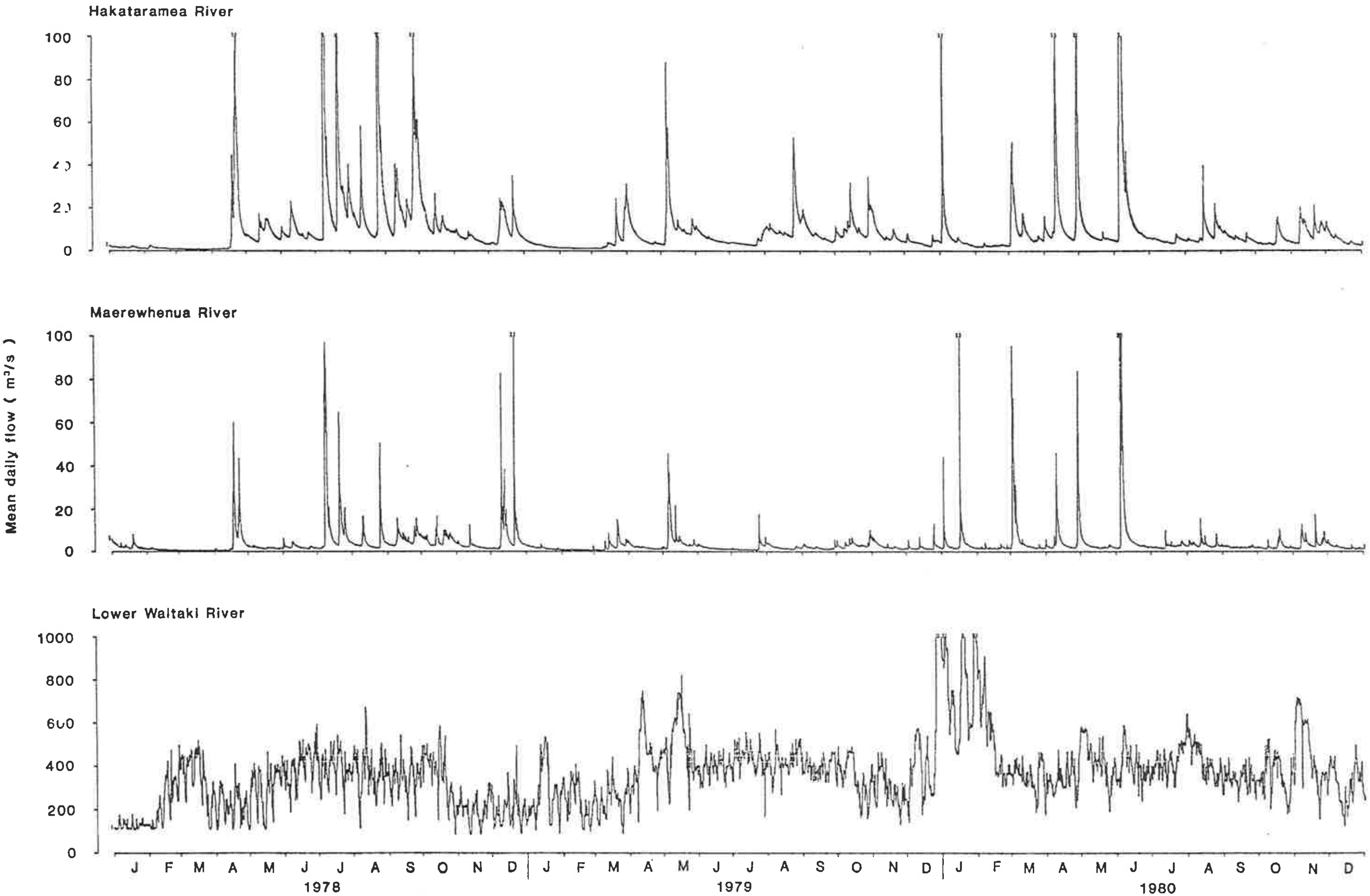


FIGURE 2. Mean daily flow in the lower Waitaki (at dam), Hakataramea, and Maerewhenua Rivers, 1978-80.

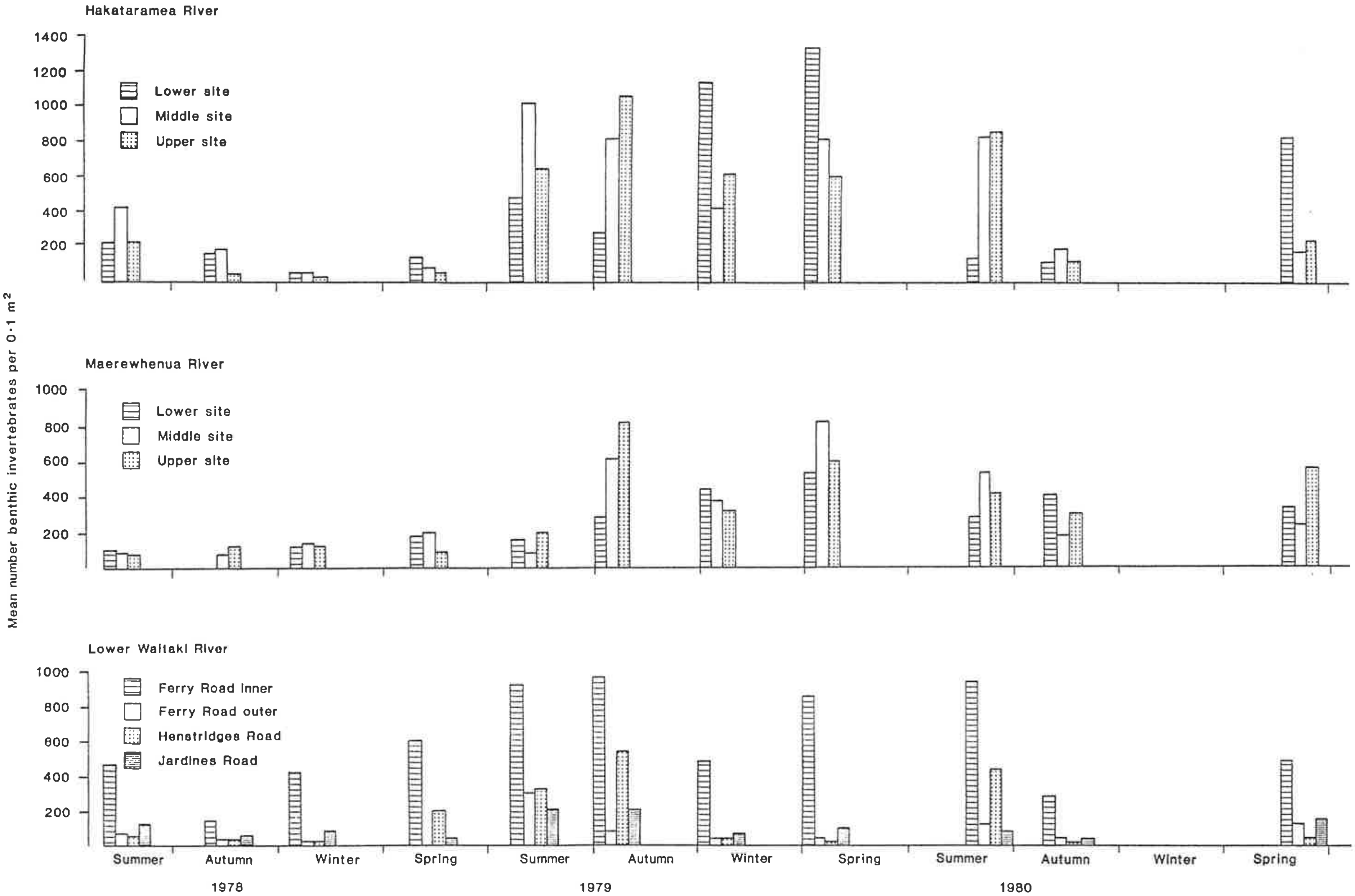


FIGURE 3. Mean numbers of benthic invertebrates per 0.1 $m^2$ in lower Waitaki, Hakataramea, and Maerewhenua Rivers, 1978-80.

Waitaki sites (with the exception of Jardines Road) and gives rise to a second peak in numbers in summer 1980. Invertebrate numbers show a marked decrease in the autumn 1980 sample, but in spring 1980 numbers showed an increase again. Large floods originating from the Maerewhenua and Hakataramea rivers (peaking at mean daily flows of 188 $m^3/s$ and 243 $m^3/s$ respectively) during June 1980 precluded sample collection at all sites.

Over the entire sampling period the highest numbers of invertebrates were recorded at Ferry Road inner in all 11 seasons. At this site invertebrates were about 2-60 times more abundant than at the other three sites, and reached a peak density of 9670/$m^2$ in autumn 1979. On only a few occasions did density exceed 2000/$m^2$ at the other lower Waitaki sites (Fig. 3).

### 4.1.2 Hakataramea River

#### 4.1.2.1 Lower Site

In total 20 taxa were recorded from this site. The number of taxa collected in any sample ranged from 10 in summer and spring 1980 to 18 in winter and spring 1979. Numbers of invertebrates were also at a maximum in winter and spring 1979 (Table 5, Fig. 3).

The caddisflies *Pycnocentria* and *Pycnocentrodes* were the most consistently abundant invertebrates (comprising 5.9-48.0% of the fauna). They were dominant in 5 of 11 sample collections and were co-dominant with the snail *P. antipodarum* in winter 1978 when each comprised 20.8% of the fauna. The net spinning caddisflies *Aoteapsyche* spp. dominated the fauna once in autumn 1979.

TABLE 5. Relative abundance of benthic invertebrates (percent of total number) collected at lower Hakataramea River, summer 1978-spring 1980. Values are means of five replicate samples (- = not present; * = < 0.1%)

| | 1978 | | | | 1979 | | | | 1980 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxa | Sum | Aut | Win | Spr | Sum | Aut | Win | Spr | Sum | Aut | Spr |
| OLIGOCHAETA | | | | | | | | | | | |
| Oligochaetae (spp.) | 0.1 | 1.2 | 2.9 | - | 0.6 | 0.6 | 0.8 | 0.3 | 2.8 | - | 0.6 |
| MOLLUSCA | | | | | | | | | | | |
| *Potamopyrgus antipodarum* | 19.6 | 9.4 | 20.8 | 0.6 | 0.5 | 0.8 | 0.9 | 0.5 | 12.8 | - | - |
| *Physa acuta* | - | 0.4 | 4.7 | - | 0.1 | 0.2 | * | * | - | - | - |
| EPHEMEROPTERA | | | | | | | | | | | |
| *Deleatidium* spp. | 4.8 | 6.3 | 17.4 | 9.7 | 3.5 | 14.6 | 29.1 | 29.9 | 8.2 | 50.2 | 23.2 |
| *Coloburiscus humeralis* | 4.2 | 1.0 | 0.4 | 1.1 | 0.2 | 0.2 | 0.7 | 1.1 | 0.1 | - | 0.6 |
| *Nesameletus* sp. | - | 0.2 | - | - | - | - | - | - | - | - | * |
| PLECOPTERA | | | | | | | | | | | |
| *Stenoperla prasina* | - | - | 2.9 | 1.5 | 0.7 | 0.2 | 0.2 | 0.2 | - | 1.8 | 0.7 |
| TRICHOPTERA | | | | | | | | | | | |
| *Pycnocentrodes* sp. and *Pycnocentria* sp. | 48.0 | 21.6 | 20.8 | 32.0 | 11.4 | 23.1 | 40.2 | 30.4 | 47.5 | 12.2 | 5.9 |
| *Olinga feredayi* | 11.3 | 6.5 | 12.7 | 5.0 | 1.7 | 1.1 | 2.3 | 1.1 | 4.6 | 1.9 | 1.2 |
| *Oxyethira albiceps* | - | - | - | - | - | - | 0.2 | 0.2 | 2.3 | - | - |
| *Aoteapsyche* spp. | - | 1.6 | 3.0 | 4.8 | 5.3 | 32.9 | 8.4 | 8.5 | 1.3 | 14.5 | 5.0 |
| *Polyplectropus* sp. | - | - | - | - | - | - | - | - | - | - | 0.6 |
| Rhyacophilidae (spp.) | 3.9 | 3.3 | 0.8 | - | 2.9 | 8.9 | 1.3 | 1.5 | - | 1.9 | * |
| MEGALOPTERA | | | | | | | | | | | |
| *Archichauliodes diversus* | 0.6 | 1.6 | - | - | * | 0.4 | 0.1 | * | 0.3 | 0.7 | 0.3 |
| DIPTERA | | | | | | | | | | | |
| *Austrosimulium* spp. | - | 0.2 | 0.8 | - | - | 0.9 | 3.5 | 10.1 | - | 0.2 | 2.9 |
| Tabanidae (spp.) | - | - | 0.4 | - | 1.3 | 0.5 | * | * | - | 1.2 | * |
| Eriopterini (spp.) | 1.1 | 10.4 | 0.4 | 0.9 | 0.8 | 1.3 | 2.3 | 1.7 | 5.8 | 0.4 | * |
| Chironomidae (spp.) | - | - | - | 30.5 | 55.3 | - | 1.9 | 4.1 | - | 1.2 | 42.1 |
| COLEOPTERA | | | | | | | | | | | |
| Elmidae (spp.) | 6.6 | 36.4 | 12.3 | 11.5 | 13.2 | 14.5 | 8.0 | 10.3 | 13.9 | 13.8 | 16.7 |
| CRUSTACEA | | | | | | | | | | | |
| *Paracalliope fluviatilis* | - | - | - | - | - | - | * | * | 0.4 | - | * |
| MISCELLANEOUS | - | - | - | 2.4 | 2.3 | - | * | * | - | - | - |
| Mean no./$m^2$ | 2 164 | 1 639 | 471 | 1 324 | 4 821 | 2 953 | 11 444 | 13 174 | 1 486 | 1 132 | 8 282 |
| Number taxa | 10 | 14 | 13 | 10 | 15 | 15 | 18 | 18 | 12 | 12 | 17 |

Although *Deleatidium* spp. larvae occurred in all samples they were dominant only once, in autumn 1980, when they comprised 50.2% of the fauna. The four dipteran taxa identified included Chironomidae, *Austrosimulium* spp., Eriopterini spp., and Tabanidae. Of these only Chironomidae occurred in large numbers and they were dominant in summer 1979 and spring 1980 when they comprised 55.3% and 42.1% of the fauna respectively. Elmid larvae occurred in all samples, but were dominant only once, in autumn 1978, when they formed 36.4% of the fauna; in the other samples they never made up more than 17.0% of the fauna. None of the taxa showed any obvious seasonal trends in abundance.

Invertebrate numbers were comparatively low in 1978 (Fig. 3, Table 5) when there was a series of large floods (Fig. 2). Mean daily flows exceeding 70 $m^3/s$ occurred in 4 months, with a maximum mean daily flow of 215.8 $m^3/s$ recorded in August and smaller floods in 4 other months (Fig. 2). Minimum numbers of invertebrates over the whole study period occurred in the winter sample of 1978 when a mean density of $471/m^2$ was recorded. During 1979 flows were comparatively stable with fewer floods of large magnitude; there were several minor floods of about 20 $m^3/s$. Large numbers of invertebrates were present in winter and spring 1979 when mean numbers of 11 $444/m^2$ and 13 $174/m^2$ respectively were recorded. In summer and autumn 1979 invertebrates were less abundant.

In the first 6 months of 1980 there were several large floods; the largest flood, with a mean daily flow of 242.4 $m^3/s$, occurred in June (N.Z. Ministry of Works and Development (MWD) TIDEDA data) and precluded collection of winter samples. Invertebrate numbers in summer and autumn 1980 did not exceed $1500/m^2$ in either sample (Fig. 3); floods preceded the collection of these samples (Fig. 2). By spring 1980, invertebrate numbers had increased to $8282/m^2$ (Table 5, Fig. 3).

4.1.2.2 Middle Site

All the taxa present at the lower Hakataramea site also occurred at this site, with the exception of *Oxyethira albiceps* and *Polyplectropus*, that is, a total of 18 taxa occurred here. In any sample the number of taxa recorded ranged from 8 (in autumn 1978) to 16 (in autumn and spring 1979) (Table 6).

The caddisflies *Pycnocentria* and *Pycnocentrodes* were the most consistently abundant invertebrates, (comprising 1.0-54.8% of the fauna). They were present in all 11 samples and were dominant in 5 (spring 1978 and from spring 1979 through to spring 1980). Another caddisfly *O. feredayi*, was dominant in winter 1978 when it comprised 43.8% of the fauna, but generally it was not abundant in the other samples.

*Deleatidium* spp. larvae also occurred in all samples. They comprised 4.2-39.3% of the fauna and were dominant in autumn 1978 and in autumn and winter 1979. Of the 4 dipteran taxa recorded only *Austrosimulium* spp. ever became dominant in summer 1979, when it made up 86.9% of the fauna. Elmid larvae occurred in all samples and comprised 2.6-27.6% of the fauna; they were dominant in summer 1978.

During 1978 the trend in invertebrate abundance at the middle Hakataramea site was generally similar to that of the lower site (Fig. 3). However, in summer and autumn 1979 invertebrate numbers at the middle site exceeded those at the lower site by a factor of about two, whereas the opposite was true in winter and spring. In summer 1980, invertebrate numbers were greater by a factor of about five at the middle site (8372/m$^2$) compared with the lower site (1486/m$^2$).

TABLE 6. Relative abundance of benthic invertebrates (percent of total number) collected at middle Hakataramea River, summer 1978–spring 1980. Values are means of five replicate samples (- = not present; * = < 0.1%)

| Taxa | 1978 Sum | Aut | Win | Spr | 1979 Sum | Aut | Win | Spr | 1980 Sum | Aut | Spr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OLIGOCHAETA | | | | | | | | | | | |
| Oligochaetae (spp.) | 0.7 | 0.2 | 0.8 | - | * | * | 2.3 | 0.7 | * | 0.3 | - |
| MOLLUSCA | | | | | | | | | | | |
| *Potamopyrgus antipodarum* | 1.4 | 4.3 | 9.2 | 1.1 | 0.2 | 0.5 | 1.3 | * | * | 0.6 | 0.1 |
| *Physa acuta* | - | - | - | - | * | 0.2 | * | * | - | 0.1 | - |
| EPHEMEROPTERA | | | | | | | | | | | |
| *Deleatidium* spp. | 13.0 | 38.1 | 10.0 | 20.7 | 4.2 | 38.8 | 39.3 | 35.2 | 13.7 | 25.2 | 21.1 |
| *Coloburiscus humeralis* | 4.0 | - | 1.2 | 1.9 | 0.3 | * | * | 0.1 | - | 0.2 | - |
| *Nesameletus* sp. | - | - | - | - | - | * | - | 0.1 | * | - | - |
| PLECOPTERA | | | | | | | | | | | |
| *Stenoperla prasina* | 2.7 | 0.2 | 9.6 | 4.8 | 0.3 | 0.8 | 0.9 | 0.5 | 0.2 | 0.9 | 2.0 |
| TRICHOPTERA | | | | | | | | | | | |
| *Pycnocentrodes* sp. and *Pycnocentria* sp. | 26.7 | 28.9 | 5.0 | 26.8 | 1.0 | 17.7 | 26.7 | 37.5 | 54.8 | 35.2 | 50.8 |
| *Olinga feredayi* | 15.4 | 19.7 | 43.8 | 5.0 | 0.8 | 1.3 | 1.3 | 1.3 | 3.9 | 0.6 | 3.7 |
| *Aoteapsyche* spp. | 5.7 | 5.3 | 6.5 | 10.1 | 0.8 | 25.0 | 10.1 | 6.8 | 3.3 | 7.0 | 5.7 |
| Rhyacophilidae (spp.) | 1.9 | - | - | - | 1.3 | 2.7 | 0.6 | 0.9 | 1.7 | 1.5 | 0.4 |
| MEGALOPTERA | | | | | | | | | | | |
| *Archicauliodes diversus* | .2 | - | 0.8 | 1.1 | - | - | 0.1 | - | 0.2 | - | 0.2 |
| DIPTERA | | | | | | | | | | | |
| Tabanidae (spp.) | 0.4 | - | - | - | 0.2 | * | - | * | 0.5 | 0.1 | - |
| *Austrosimulium* spp. | - | 0.8 | - | 18.4 | 86.9 | 1.0 | 1.1 | 5.5 | 1.0 | 2.3 | 3.6 |
| Eriopterini (spp.) | - | - | 2.3 | 0.3 | 0.3 | 1.3 | 3.5 | 2.5 | 0.3 | 0.9 | 0.2 |
| Chironomidae (spp.) | - | - | - | - | - | 1.7 | 1.0 | 2.2 | - | - | 6.9 |
| COLEOPTERA | | | | | | | | | | | |
| Elmidae (spp.) | 27.6 | 2.6 | 10.4 | 6.6 | 3.5 | 8.6 | 11.8 | 6.3 | 20.4 | 25.1 | 5.3 |
| CRUSTACEA | | | | | | | | | | | |
| *Paracalliope fluviatilis* | - | - | - | - | * | * | * | 0.1 | - | - | - |
| MISCELLANEOUS | - | - | 0.4 | 3.4 | * | - | - | - | * | - | - |
| Mean no./m$^2$ | 4 040 | 1 696 | 520 | 755 | 10 123 | 8 177 | 4 078 | 8 064 | 8 372 | 2 022 | 1 780 |
| Number taxa | 11 | 8 | 10 | 10 | 14 | 16 | 15 | 16 | 13 | 13 | 11 |

In autumn 1980, numbers were similar at both sites, but in spring 1980 numbers were much greater at the lower site (8282/$m^2$) than at the middle site (1780/$m^2$).

4.1.2.3 Upper Site

Nineteen taxa were identified at this site (Table 7). In any sample the number of taxa varied from 9 in spring 1978 to 16 in winter 1979. As at the two other Hakataramea River sites the highest numbers of taxa were recorded in the 1979 samples, when flows were the most stable over the 3 year sampling period.

Larvae of the mayfly *Deleatidium* spp. were present in all samples and comprised 11.9-75.5% of the invertebrate fauna. They were dominant in 6 of the 11 samples (autumn and spring in both 1978 and 1980, and in winter and spring in 1979). The caddisflies *Pycnocentria* and *Pycnocentrodes* occurred in all samples. They comprised 1.4-61.0% of the fauna and were dominant in three samples (summer 1978, autumn 1979, and summer 1980).

In summer 1979, *Austrosimulium* spp. were dominant and comprised 71.7% of the fauna; they were also dominant at the corresponding time at the middle site. The mollusc *P. antipodarum* was dominant in winter 1978, when it formed 24.8% of the fauna, and this coincided with its dominance at the lower site.

Trends in invertebrate numbers at the upper Hakataramea site over the study period were generally more similar to those of the middle site than to the lower site (Fig. 3). Numbers were low during the whole of 1978, but by autumn 1979 they had increased to a mean of 10 824/$m^2$.

TABLE 7. Relative abundance of benthic invertebrates (percent of total number) collected at upper Hakataramea River, summer 1978–spring 1980. Values are means of five replicate samples (- = not present; * = < 0.1%)

| Taxa | 1978 Sum | 1978 Aut | 1978 Win | 1978 Spr | 1979 Sum | 1979 Aut | 1979 Win | 1979 Spr | 1980 Sum | 1980 Aut | 1980 Spr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OLIGOCHAETA | | | | | | | | | | | |
| Oligochaetae (spp.) | 0.2 | 2.2 | 2.9 | - | * | 0.1 | * | 0.1 | - | 0.3 | 5.3 |
| MOLLUSCA | | | | | | | | | | | |
| *Potamopyrgus antipodarum* | - | 0.5 | 24.8 | - | * | * | * | - | 0.1 | - | - |
| *Physa acuta* | - | 0.5 | - | - | - | - | * | * | * | - | - |
| EPHEMEROPTERA | | | | | | | | | | | |
| *Deleatidium* spp. | 11.9 | 44.3 | 23.8 | 59.0 | 13.4 | 39.4 | 64.2 | 45.5 | 14.5 | 69.5 | 75.5 |
| *Coloburiscus humeralis* | 0.2 | 0.5 | 3.8 | 1.4 | - | - | * | 0.2 | - | - | - |
| *Nesameletus* sp. | - | 0.5 | - | - | - | * | - | - | - | - | - |
| PLECOPTERA | | | | | | | | | | | |
| *Stenoperla prasina* | 1.7 | 5.4 | 1.9 | 0.5 | - | * | * | * | 0.2 | 0.3 | * |
| TRICHOPTERA | | | | | | | | | | | |
| *Pycnocentrodes* sp. and *Pycnocentria* sp. | 48.4 | 7.0 | 16.2 | 23.3 | 4.9 | 46.9 | 13.1 | 34.2 | 61.0 | 5.6 | 1.4 |
| *Olinga feredayi* | 12.2 | 11.9 | 1.9 | 5.7 | 1.5 | 1.7 | 0.8 | 0.6 | 4.5 | 1.4 | 1.0 |
| *Paroxyethira* sp. | - | - | - | - | - | - | - | - | * | - | - |
| *Aoteapsyche* spp. | 5.7 | 6.5 | 13.3 | 2.9 | 1.9 | 6.0 | 4.5 | 1.5 | 3.2 | 2.6 | 1.0 |
| Rhyacophilidae (spp.) | - | 1.1 | 1.9 | - | 3.0 | 1.3 | 1.7 | 0.5 | 2.0 | 0.8 | 0.4 |
| MEGALOPTERA | | | | | | | | | | | |
| *Archichauliodes diversus* | 2.5 | 0.5 | - | - | * | 0.1 | 0.2 | 0.1 | 0.1 | - | - |
| LEPIDOPTERA | | | | | | | | | | | |
| *Nymphula nitens* | - | - | - | 0.5 | - | - | - | - | - | - | - |
| DIPTERA | | | | | | | | | | | |
| Tabanidae (spp.) | 0.3 | - | - | - | 0.2 | - | * | - | 0.2 | - | - |
| *Austrosimulium* spp. | - | - | - | - | 71.7 | 0.4 | 2.4 | 10.2 | 0.2 | 3.2 | 0.3 |
| Eriopterini (spp.) | 0.3 | 2.2 | 2.9 | - | 0.7 | 0.5 | 11.3 | 2.1 | 0.4 | 1.1 | 0.3 |
| Chironomidae (spp.) | - | - | - | 0.5 | - | 0.3 | 0.2 | 2.4 | - | - | - |
| COLEOPTERA | | | | | | | | | | | |
| Elmidae (spp.) | 16.5 | 16.8 | 6.7 | 6.2 | 2.4 | 3.0 | 1.3 | 2.0 | 13.3 | 15.0 | 14.8 |
| MISCELLANEOUS | - | - | - | - | 0.2 | 0.1 | * | 0.5 | * | 0.2 | - |
| Mean no./m$^2$ | 2 156 | 370 | 210 | 420 | 6 292 | 10 824 | 4 990 | 6 294 | 8 460 | 1 252 | 2340 |
| Number taxa | 11 | 14 | 11 | 9 | 12 | 14 | 16 | 14 | 14 | 10 | 10 |

Mean numbers had decreased to 4990/$m^2$ by winter 1979, but increased again to reach a second peak in summer 1980 when a density of 8460/$m^2$ was recorded. After summer 1980, invertebrate numbers declined to 1252/$m^2$ in autumn to a density of 2340/$m^2$ in the spring 1980 sample.

### 4.1.3 Maerewhenua River

#### 4.1.3.1 Lower Site

In total 20 taxa were identified from this site. The number of taxa present in any sample ranged from 8-17 (Table 8).

The mayfly *Deleatidium* spp. comprised 30.0-88.3% of the fauna and was dominant in all but the summer 1980 sample when elmid larvae were dominant and comprised 48.9% of the fauna.

Over the study period (1978-80) major flood events in the Maerewhenua River generally coincided with those in the Hakataramea River (Fig. 2). In 1978 floods occurred in April, July, August, and December. Invertebrate numbers were depressed from summer 1978 to summer 1979, presumably as a result of these floods (Fig. 3). As in the Hakataramea River, flows were fairly stable in the Maerewhenua River during 1979. Invertebrate numbers showed a steady increase through 1979 to reach a peak of 6034/$m^2$ in spring. The first 6 months of 1980 were exceptionally wet, there were floods during January, March, and April and these culminated on 5 June in a flood of unprecedented magnitude which peaked at about 700 $m^3$/s. Flows were fairly stable for the remainder of 1980. Invertebrate numbers declined to 2848/$m^2$ in the summer 1980 sample then increased to 3978/$m^2$ in the autumn sample. The large flood in June precluded the collection of a winter sample, but invertebrate numbers had reached 3278/$m^2$ by spring 1980.

TABLE 8. Relative abundance of benthic invertebrates (percent of total number) collected at lower Maerewhenua River, summer 1978-spring 1980. Values are means of five replicate samples (- = not present; * = < 0.1%); N.S. = not sampled)

| | 1978 | | | | 1979 | | | | 1980 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxa | Sum | Aut | Win | Spr | Sum | Aut | Win | Spr | Sum | Aut | Spr |
| OLIGOCHAETA | | | | | | | | | | | |
| Oligochaetae (spp.) | 5.7 | N.S. | - | - | 1.5 | - | 0.7 | - | - | 0.2 | 1.5 |
| MOLLUSCA | | | | | | | | | | | |
| *Potamopyrgus antipodarum* | - | | - | - | - | - | 0.6 | * | 0.2 | * | * |
| *Physa acuta* | - | | - | - | - | - | * | - | - | - | - |
| EPHEMEROPTERA | | | | | | | | | | | |
| *Deleatidium* spp. | 59.4 | | 87.3 | 76.4 | 47.2 | 47.8 | 54.6 | 67.9 | 30.0 | 55.3 | 88.3 |
| *Coloburiscus humeralis* | - | | - | 2.6 | 2.3 | 0.3 | 0.5 | 0.7 | 0.3 | 1.2 | * |
| *Nesameletus* sp. | - | | 0.2 | 0.1 | - | 0.4 | 0.8 | * | - | 0.3 | - |
| PLECOPTERA | | | | | | | | | | | |
| *Stenoperla prasina* | 0.7 | | - | - | 0.4 | 0.4 | * | 0.3 | 0.3 | * | - |
| TRICHOPTERA | | | | | | | | | | | |
| *Pycnocentrodes* sp. and *Pycnocentria* sp. | 1.6 | | 1.2 | 4.7 | 1.8 | 0.4 | 8.6 | 3.3 | 13.3 | 2.9 | 0.2 |
| *Olinga feredayi* | 2.0 | | 0.4 | 0.5 | 1.8 | 5.8 | 0.5 | 0.3 | 2.2 | 3.4 | - |
| *Oxyethira albiceps* | - | | - | - | - | - | 0.2 | - | - | - | - |
| *Aoteapsyche* spp. | 0.3 | | 3.5 | 1.7 | 3.6 | 1.2 | 2.0 | 3.0 | - | 10.7 | 0.3 |
| *Polyplectropus* sp. | - | | - | 0.2 | - | - | - | - | - | - | 0.1 |
| *Helicopsyche albescens* | - | | - | - | - | * | - | - | - | * | - |
| Rhyacophilidae (spp.) | 0.8 | | 0.4 | - | 1.8 | 5.1 | 4.4 | 1.9 | 2.9 | 1.7 | 2.2 |
| MEGALOPTERA | | | | | | | | | | | |
| *Archichauliodes diversus* | - | | - | 0.1 | 1.7 | 0.6 | * | * | 0.2 | 0.5 | * |
| DIPTERA | | | | | | | | | | | |
| *Austrosimulium* spp. | 0.3 | | - | - | 2.2 | 0.3 | 0.1 | 1.7 | 0.1 | 3.5 | 0.8 |
| Eriopterini (spp.) | - | | 3.4 | 0.2 | 0.2 | 10.6 | 3.8 | 6.3 | 1.3 | 0.3 | - |
| Tabanidae (spp.) | - | | - | - | 0.2 | - | * | * | 0.4 | 0.3 | - |
| Chironomidae (spp.) | - | | - | - | 1.8 | - | - | 10.1 | - | 0.4 | 3.8 |
| COLEOPTERA | | | | | | | | | | | |
| *Elmidae* spp. | 29.0 | | 3.7 | 11.6 | 31.3 | 26.8 | 22.9 | 4.3 | 48.9 | 19.4 | 2.4 |
| MISCELLANEOUS | - | | - | 1.7 | 1.0 | * | * | * | - | - | 0.2 |
| Mean no./m$^2$ | 977 | | 1 130 | 1 740 | 1 450 | 2 668 | 4 442 | 6 034 | 2 848 | 3 978 | 3 278 |
| Number taxa | 9 | | 8 | 10 | 14 | 13 | 17 | 15 | 12 | 17 | 12 |

#### 4.1.3.2 Middle Site

A total of 18 taxa was recorded from this site, 2 fewer than the lower site because of the absence of *O. albiceps* and *Physa acuta* (Table 9). The number of taxa recorded in any sample ranged from 9 to 16.

*Deleatidium* spp. (comprising 17.0-83.3% of the fauna) dominated in 9 of the 11 samples (Table 9). Elmid larvae were dominant in the other two samples and comprised 2.2-39.7% of the fauna.

The general pattern of invertebrate abundance at the middle site was similar to that of the lower site (Fig. 3). Invertebrate numbers were low from summer 1978 to summer 1979 and did not exceed 1900/$m^2$ during this time. In autumn 1979, numbers increased to 6064/$m^2$, but they declined to 3779/$m^2$ in the winter sample. Numbers increased to a maximum of 8010/$m^2$ in spring 1979, but decreased to 5465/$m^2$ in the summer 1980 sample and fell further to 1754/$m^2$ in the autumn sample then increased to 2452/$m^2$ in the spring sample.

#### 4.1.3.3 Upper Site

In total, 18 taxa were recorded from this site. The number of taxa recorded in any sample ranged from 9 in spring 1979 to 15 in winter 1979 and summer and autumn 1980 (Table 10).

As at the two other Maerewhenua sites the mayfly *Deleatidium* spp. was the most abundant taxon. It comprised 2.2-86.0% of the fauna and was dominant in 6 of the 11 samples. Chironomid larvae were dominant in two samples (spring 1978 and spring 1980) when they comprised 66.6% and 36.5% of the fauna respectively. Elmid larvae were dominant in the summers of 1978 and 1979 when they formed 24.0% and 27.3% of the fauna.

TABLE 9. Relative abundance of benthic invertebrates (percent of total number) collected at middle Maerewhenua River, summer 1978-spring 1980. Values are means of five replicate samples (- = not present; * = < 0.1%)

| Taxa | 1978 Sum | 1978 Aut | 1978 Win | 1978 Spr | 1979 Sum | 1979 Aut | 1979 Win | 1979 Spr | 1980 Sum | 1980 Aut | 1980 Spr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OLIGOCHAETA | | | | | | | | | | | |
| Oligochaetae (spp.) | 0.8 | 1.5 | 0.6 | - | 0.3 | - | * | * | * | 0.1 | * |
| MOLLUSCA | | | | | | | | | | | |
| *Potamopyrgus antipodarum* | 14.4 | 11.1 | 11.2 | 0.8 | - | 0.2 | 0.7 | 1.2 | 0.5 | 0.1 | - |
| EPHEMEROPTERA | | | | | | | | | | | |
| *Deleatidium* spp | 17.0 | 52.0 | 46.7 | 51.4 | 29.7 | 80.5 | 83.3 | 70.1 | 31.4 | 77.3 | 33.0 |
| *Coloburiscus humeralis* | 0.8 | 2.1 | 4.3 | 0.6 | 0.3 | 0.2 | 0.2 | 0.2 | 1.0 | 1.4 | 0.7 |
| *Nesameletus* sp. | - | - | - | 0.2 | - | 1.1 | 2.3 | 1.0 | - | - | - |
| PLECOPTERA | | | | | | | | | | | |
| *Stenoperla prasina* | 4.4 | 0.9 | 1.0 | 0.4 | 0.3 | - | 0.2 | 0.2 | * | 0.2 | * |
| TRICHOPTERA | | | | | | | | | | | |
| *Pycnocentrodes* sp. and *Pycnocentria* sp. | - | 0.9 | - | 5.7 | 16.4 | 0.3 | 0.7 | 3.7 | 2.5 | 1.0 | 13.9 |
| *Olinga feredayi* | 19.2 | 12.0 | 15.5 | 2.3 | 7.6 | 6.1 | 1.7 | 1.9 | 13.7 | 2.2 | 12.6 |
| *Aoteapsyche* spp. | 4.8 | 1.8 | 11.0 | 3.2 | - | * | 3.4 | 1.1 | 4.4 | 4.1 | 3.8 |
| *Polyplectropus* sp. | - | - | 0.1 | - | - | - | - | - | - | - | 0.2 |
| *Helicopsyche albescens* | - | 2.1 | - | - | - | 4.8 | - | - | - | 0.1 | * |
| Rhyacophilidae (spp.) | 1.4 | 2.1 | 3.6 | 1.3 | - | 2.9 | 2.8 | 2.5 | 3.7 | 1.9 | 0.6 |
| MEGALOPTERA | | | | | | | | | | | |
| *Archichauliodes diversus* | 3.0 | 1.2 | 1.4 | 0.5 | 2.2 | - | 0.2 | 0.2 | 0.2 | - | * |
| DIPTERA | | | | | | | | | | | |
| Tabanidae (spp.) | 3.7 | - | - | 4.3 | - | * | 0.1 | * | 0.7 | 5.2 | * |
| *Austrosimulium* spp. | 3.0 | - | - | - | - | 0.7 | 0.2 | 3.0 | 1.6 | 1.1 | 0.4 |
| Eriopterini (spp.) | 0.8 | 1.5 | 0.6 | 13.6 | 3.5 | 0.4 | 0.6 | 1.5 | 14.6 | 0.1 | - |
| Chironomidae (spp.) | - | - | - | 0.1 | - | 0.6 | - | 9.9 | - | - | 8.1 |
| COLEOPTERA | | | | | | | | | | | |
| Elmidae (spp.) | 26.9 | 10.8 | 3.9 | 15.4 | 39.7 | 2.2 | 3.6 | 3.5 | 25.3 | 4.8 | 23.8 |
| Mean no./$m^2$ | 903 | 666 | 1 430 | 1 852 | 634 | 6 064 | 3 779 | 8 018 | 5 465 | 1 754 | 2 452 |
| Number taxa | 13 | 13 | 12 | 14 | 9 | 14 | 15 | 16 | 14 | 14 | 15 |

TABLE 10. Relative abundance of benthic invertebrates (percent of total number) collected at upper Maerewhenua River, summer 1978-spring 1980. Percentage values are means of five replicate samples (- = not present; * = < 0.1%)

| Taxa | 1978 Sum | 1978 Aut | 1978 Win | 1978 Spr | 1979 Sum | 1979 Aut | 1979 Win | 1979 Spr | 1980 Sum | 1980 Aut | 1980 Spr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OLIGOCHAETA | | | | | | | | | | | |
| Oligochaetae (spp.) | 0.4 | - | - | 1.7 | 0.1 | - | * | - | * | * | 0.1 |
| MOLLUSCA | | | | | | | | | | | |
| *Potamopyrgus antipodarum* | 11.8 | 22.9 | 3.1 | 7.7 | 3.6 | 16.5 | 0.6 | 0.7 | 17.1 | 0.7 | - |
| *Physa acuta* | - | - | - | 2.5 | - | 3.8 | - | - | - | - | - |
| EPHEMEROPTERA | | | | | | | | | | | |
| *Deleatidium* spp | 16.4 | 42.4 | 75.8 | 2.2 | 20.5 | 51.6 | 86.0 | 70.5 | 24.8 | 74.7 | 31.3 |
| *Coloburiscus humeralis* | 1.3 | 8.6 | 4.0 | - | 1.4 | - | 1.0 | 1.8 | 1.7 | 0.4 | 0.9 |
| *Nesameletus* sp. | - | 0.2 | - | - | - | - | - | - | - | - | * |
| PLECOPTERA | | | | | | | | | | | |
| *Stenoperla prasina* | 1.3 | 1.4 | 1.2 | - | 1.5 | 0.3 | 0.5 | 0.2 | 0.2 | 0.5 | 0.8 |
| TRICHOPTERA | | | | | | | | | | | |
| *Pycnocentrodes* sp. and *Pycnocentria* sp. | 22.3 | 0.2 | 1.7 | - | 16.8 | - | 0.6 | 3.0 | 3.4 | 0.3 | 6.5 |
| *Olinga feredayi* | 10.1 | 8.1 | 2.6 | 0.3 | 16.9 | 16.0 | 5.0 | 8.0 | 26.7 | 4.7 | 1.7 |
| *Aoteapsyche* spp. | - | 3.0 | 5.2 | - | 1.1 | 0.6 | 2.3 | 0.9 | 2.5 | 4.1 | 7.8 |
| *Helicopsyche albescens* | 4.2 | 0.2 | 0.5 | - | 2.7 | - | * | * | 0.9 | 0.2 | - |
| Rhyacophilidae (spp.) | - | 1.2 | 1.9 | 0.3 | 0.1 | 2.2 | 1.5 | 0.9 | 4.7 | 1.8 | * |
| MEGALOPTERA | | | | | | | | | | | |
| *Archichauliodes diversus* | 5.1 | 1.9 | 1.2 | - | 2.4 | 0.7 | 0.1 | 0.5 | 0.4 | 0.3 | 0.4 |
| DIPTERA | | | | | | | | | | | |
| *Austrosimulium* spp. | - | - | 0.7 | - | - | * | 0.4 | 7.6 | * | 0.9 | 1.9 |
| Tabanidae (spp.) | 2.9 | 0.2 | 0.2 | - | 1.0 | * | 0.3 | - | 0.9 | 0.5 | 0.1 |
| Eriopterini (spp.) | 0.4 | 0.3 | - | 8.0 | - | - | 0.7 | - | 2.0 | - | - |
| Chironomidae (spp.) | - | - | - | 66.6 | 4.5 | 0.7 | - | 3.2 | - | 5.9 | 36.5 |
| COLEOPTERA | | | | | | | | | | | |
| Elmidae (spp.) | 24.0 | 9.5 | 1.7 | 10.8 | 27.3 | 7.7 | 0.8 | 2.6 | 14.5 | 4.9 | 11.7 |
| Mean no./$m^2$ | 791 | 1 142 | 1 148 | 724 | 1 964 | 8 314 | 3 138 | 5 794 | 4 232 | 2 991 | 5 542 |
| Number taxa | 12 | 14 | 13 | 9 | 14 | 12 | 15 | 13 | 15 | 15 | 14 |

The caddisfly *O. feredayi* was generally the most abundant of the five trichopterans recorded, and it dominated the fauna in summer 1980 when it comprised 26.7% of the fauna.

*P. antipodarum* occurred in 10 of the 11 samples and comprised up to 22.9% of the fauna; the other mollusc *Physa acuta* occurred in only 2 samples and never exceeded 4.0% in abundance.

Trends in invertebrate abundance at the upper Maerewhenua site followed closely those of the middle site and to a lesser extent those at the lower site (Fig. 3). Mean numbers were low in the first five samples and did not exceed 2000/$m^2$. They then increased to a peak of 8310/$m^2$ in autumn 1979, declined to 3138/$m^2$ in winter, and increased again to 5790/$m^2$ in spring. During summer and autumn 1980 invertebrate numbers declined, but increased to 5542/$m^2$ in the spring sample.

4.1.4 Penticotico Stream

In total 23 taxa were recorded from this site. The number of taxa present in any sample ranged from 10 in autumn 1979 to 17 in summer 1980 (Table 11). No single taxon dominated the fauna throughout the study. *Deleatidium* spp. larvae were present in all samples and comprised 4.0-51.4% of the fauna. They were numerically dominant in 5 of the 11 samples (winter and spring 1978 and 1979, and autumn 1980). Eriopterini spp. comprised 1.9-65.5% of the fauna and were dominant in the summer and autumn samples in 1978. In the remaining four samples *P. fluviatilis*, elmid larvae, and species of Rhyacophilidae and Chironomidae were each dominant in one sample, but were never consistently abundant in the other samples.

TABLE 11. Relative abundance of benthic invertebrates (percent of total number) collected at Penticotico Stream, summer 1978–spring 1980. Values are means of five replicate samples (- = not present; * = < 0.1%)

| Taxa | 1978 Sum | Aut | Win | Spr | 1979 Sum | Aut | Win | Spr | 1980 Sum | Aut | Spr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PLATYHELMINTHES | | | | | | | | | | | |
| *Cura* sp. | - | 0.5 | 0.3 | 0.6 | 1.2 | 1.3 | 2.0 | 2.0 | 1.2 | - | - |
| OLIGOCHAETA | | | | | | | | | | | |
| Oligochaetae (spp.) | 1.1 | 0.5 | 0.3 | 3.5 | 0.6 | 0.6 | 1.7 | 0.4 | 0.2 | 1.6 | - |
| MOLLUSCA | | | | | | | | | | | |
| *Potamopyrgus antipodarum* | 8.7 | 12.1 | 22.0 | 1.3 | 1.5 | 2.4 | 5.7 | 2.4 | 0.7 | 0.4 | * |
| *Physa acuta* | 3.1 | - | 0.5 | - | - | - | 0.1 | - | - | - | - |
| *Sphaerium novaezelandiae* | - | - | - | - | - | * | 0.1 | - | - | - | - |
| EPHEMEROPTERA | | | | | | | | | | | |
| *Deleatidium* spp. | 4.0 | 15.4 | 41.8 | 36.0 | 13.5 | 4.7 | 35.9 | 40.2 | 33.5 | 51.4 | 16.3 |
| *Coloburiscus humeralis* | - | - | 0.5 | - | - | - | - | - | - | - | - |
| PLECOPTERA | | | | | | | | | | | |
| *Zealandobius* sp. | - | - | - | - | 0.2 | - | - | - | - | - | - |
| TRICHOPTERA | | | | | | | | | | | |
| *Paroxyethira* sp. | - | - | - | - | - | - | - | - | 0.2 | - | - |
| *Pycnocentrodes* sp. and *Pycnocentria* sp. | 1.5 | 17.9 | 12.4 | 5.5 | 1.4 | 21.6 | 14.7 | 14.7 | 3.6 | 6.4 | 1.4 |
| *Olinga feredayi* | 0.3 | - | 1.8 | 3.9 | 2.7 | - | 0.3 | 0.4 | 0.3 | 1.8 | 1.5 |
| *Oxyethira albiceps* | - | - | - | - | - | * | - | - | 0.7 | - | - |
| *Aoteapsyche* spp. | - | 2.3 | 2.5 | 4.2 | 6.4 | 2.1 | 2.1 | 1.8 | 0.1 | 4.6 | 0.5 |
| *Polyplectropus* sp. | - | - | 0.5 | - | - | - | - | - | 0.2 | - | - |
| *Helicopsyche albescens* | - | 0.5 | - | - | - | - | 0.4 | * | * | - | - |
| Rhyacophilidae (spp.) | 2.9 | 2.0 | 2.2 | 0.3 | 20.6 | 3.3 | 2.9 | 1.0 | 1.7 | 5.2 | 3.4 |
| MEGALOPTERA | | | | | | | | | | | |
| *Archichauliodes diversus* | - | - | 0.4 | 1.6 | 1.9 | - | - | 0.1 | 0.1 | 1.1 | 0.3 |
| DIPTERA | | | | | | | | | | | |
| Tabanidae (spp.) | - | - | 0.8 | - | - | 0.6 | - | 0.3 | - | - | - |
| *Austrosimulium* spp. | - | - | - | - | 7.0 | 2.7 | 1.6 | 1.8 | 0.6 | 4.9 | 2.9 |
| Eriopterini (spp.) | 65.5 | 45.3 | 6.7 | 16.7 | 17.3 | 6.3 | 6.1 | 8.0 | 4.9 | - | 1.9 |
| Chironomidae (spp.) | 0.3 | - | - | - | 12.3 | 15.9 | 0.4 | 1.3 | - | 4.5 | 64.0 |
| COLEOPTERA | | | | | | | | | | | |
| Elmidae (spp.) | 1.2 | 3.5 | 7.1 | 6.6 | 9.5 | 7.6 | 8.0 | 6.4 | 37.0 | 17.6 | 2.3 |
| CRUSTACEA | | | | | | | | | | | |
| *Paracalliope fluviatilis* | 11.5 | - | - | - | 3.5 | 30.3 | 17.8 | 19.4 | 15.1 | 0.5 | 5.4 |
| MISCELLANEOUS | - | - | - | 19.6 | 0.4 | 0.4 | - | 0.1 | - | - | - |
| Mean no./$m^2$ | 2 488 | 794 | 1 190 | 622 | 1 808 | 3 456 | 1 986 | 3 989 | 5 938 | 2 232 | 4 696 |
| Number taxa | 11 | 10 | 15 | 11 | 15 | 15 | 16 | 16 | 17 | 12 | 12 |

At the Penticotico Stream the trend in mean numbers of invertebrates throughout the study period (Table 11) was generally similar to that observed at the Waitaki River sites. Thus, numbers declined from summer 1978 to a minimum in spring 1978, increased to a peak in autumn 1979, declined in winter 1979, and reached a second peak in summer 1980. During autumn 1980 numbers declined, but they increased in spring 1980. Invertebrate numbers in the Penticotico Stream generally exceeded those of the Waitaki River sites with the exception of Ferry Road inner.

No hydrograph is available for Penticotico Stream during the period of the study, but meteorological records show that heavy rainfalls in the area in autumn and winter 1978, winter 1979, and autumn 1980 coincided with lower invertebrate numbers during these periods. Therefore, it is considered that flow patterns probably influenced the numbers of invertebrates present during the study period.

## 4.2 Overall Features of the Fauna

To gain a picture of the overall importance of taxa at each site mean percentage composition for the 3 years combined is presented in Table 12. *Deleatidium* (comprising up to 61.4%) dominated the fauna at all three Maerewhenua River sites with Elmidae the next most abundant taxon then caddisfly larvae. *Deleatidium* was also the most abundant taxon at the Penticotico Stream and upper Hakataramea sites where it comprised 26.6% and 41.9% respectively. At the middle and lower Hakataramea sites *Pycnocentrodes* and *Pycnocentria* (comprising up to 28.3%) were the most abundant taxa, followed closely by *Deleatidium*, with Elmidae the next most abundant taxon.

TABLE 12. Mean percentage composition for each sampling location for the 3 years (1978-1980) combined.

| Taxa | Sampling locations FRI | FRO | HR | JR | LH | MH | UH | LM | MM | UM | PS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PLATYHELMINTHES | | | | | | | | | | | |
| *Cura* sp. | 5.5 | 0.7 | 1.2 | - | - | - | - | - | - | - | 0.8 |
| OLIGOCHAETA | | | | | | | | | | | |
| Oligochaetae (spp.) | 0.8 | 8.8 | 6.9 | 5.5 | 0.9 | 0.5 | 1.0 | 1.0 | 0.3 | 0.2 | 0.9 |
| MOLLUSCA | | | | | | | | | | | |
| *Potamopyrgus antipodarum* | 21.1 | 9.5 | 8.2 | 7.9 | 6.0 | 1.7 | 2.3 | * | 3.7 | 7.7 | 5.2 |
| *Physa acuta* | 2.9 | 1.8 | 3.2 | 1.4 | 0.5 | * | * | * | - | 0.6 | 0.3 |
| *Sphaerium novaezelandiae* | * | 0.2 | * | - | - | - | - | - | - | - | * |
| EPHEMEROPTERA | | | | | | | | | | | |
| *Deleatidium* spp. | 10.9 | 14.6 | 6.1 | 13.8 | 17.9 | 23.6 | 41.9 | 61.4 | 52.0 | 45.1 | 26.6 |
| *Coloburiscus humeralis* | 9.4 | 1.9 | 0.2 | 1.5 | 0.9 | 0.7 | 0.6 | 0.8 | 1.1 | 1.9 | * |
| *Nesameletus* sp. | - | - | * | - | * | * | * | 0.2 | 0.4 | * | - |
| PLECOPTERA | | | | | | | | | | | |
| *Zealandobius* sp. | * | - | 0.1 | * | - | - | - | - | - | - | * |
| *Stenoperla prasina* | - | - | - | - | 0.7 | 2.1 | 0.9 | 0.2 | 0.7 | 0.7 | - |
| TRICHOPTERA | | | | | | | | | | | |
| *Pycnocentrodes* sp. and *Pycnocentria* sp. | 20.0 | 8.0 | 17.0 | 2.4 | 26.6 | 28.3 | 23.8 | 3.8 | 4.1 | 5.0 | 9.2 |
| *Olinga feredayi* | 1.6 | 0.6 | 1.9 | - | 4.5 | 8.8 | 3.9 | 1.7 | 8.6 | 9.1 | 1.2 |
| *Aoteapsyche* spp. | 12.5 | 5.1 | 3.3 | 2.3 | 7.8 | 7.9 | 4.5 | 2.6 | 3.4 | 2.5 | 2.4 |
| *Polyplectropus* sp. | * | 0.4 | * | * | * | - | - | * | * | - | * |
| *Helicopsyche albesens* | * | * | - | - | - | - | - | * | 0.6 | 0.8 | 0.1 |
| Rhyacophilidae (spp.) | 2.3 | 1.7 | 3.7 | 1.6 | 2.2 | 1.0 | 1.2 | 2.1 | 2.1 | 1.3 | 4.1 |
| *Oxyethira albiceps* | * | 3.3 | 0.2 | 1.2 | 0.2 | - | - | * | - | - | * |
| *Paroxyethira* sp. | - | - | - | - | - | - | * | - | - | - | * |
| MEGALOPTERA | | | | | | | | | | | |
| *Archichauliodes diversus* | * | 0.1 | * | 0.1 | 0.4 | 0.2 | 0.3 | 0.3 | 0.8 | 1.2 | 0.5 |
| DIPTERA | | | | | | | | | | | |
| *Austrosimulium* spp. | 0.1 | 0.4 | 0.3 | * | 1.7 | 11.0 | 8.0 | 0.9 | 0.9 | 1.1 | 2.0 |
| Eriopterini (spp.) | 3.1 | 11.7 | 12.2 | - | 2.3 | 1.0 | 2.0 | 2.6 | 3.4 | 1.0 | 16.3 |
| Tabanidae (spp.) | - | - | - | - | 0.3 | 0.1 | * | * | 1.2 | 0.6 | 0.2 |
| Chironomidae (spp.) | 0.6 | * | 3.6 | 9.5 | 12.3 | 1.1 | 0.3 | 1.6 | 1.7 | 10.7 | 9.0 |
| COLEOPTERA | | | | | | | | | | | |
| Elmidae (spp.) | 6.9 | 30.3 | 30.7 | 51.1 | 14.3 | 11.7 | 8.9 | 20.0 | 14.5 | 10.5 | 9.7 |
| LEPIDOPTERA | | | | | | | | | | | |
| *Nymphula nitens* | - | 0.1 | - | * | - | - | * | - | - | - | - |
| CRUSTACEA | | | | | | | | | | | |
| *Paracalliope fluviatilis* | 1.1 | 0.6 | 0.4 | 0.2 | * | * | - | - | - | - | 9.4 |
| MISCELLANEOUS | 0.3 | * | 0.3 | 1.3 | 0.4 | 0.4 | * | 0.3 | - | - | 1.9 |
| Mean no./m2 | 5 872 | 748 | 1 510 | 1 010 | 4 450 | 4 520 | 3 964 | 2 854 | 3 002 | 3 253 | 2 655 |

Elmidae (comprising up to 51.1%) dominated the fauna at the three mainstem Waitaki River sites with *Deleatidium* the next most abundant taxon at two sites and Eriopterini spp. at the third site. The mollusc *P. antipodarum* (comprising 21.1%) dominated the fauna at the stable protected site at Ferry Road inner, but *Pycnocentrodes* and *Pycnocentria* were only slightly less abundant (comprising 20.0%), with *Aoteapsyche* and *Deleatidium* the next most abundant taxa.

After the main taxa outlined above, various taxa of Diptera (often chironomids or *Austrosimulium*) or Trichoptera were usually the next most abundant animals at each site.

## 5. DISCUSSION

### 5.1 Lower Waitaki River

The large braided rivers of the east coast of the South Island are ecosystems normally characterised by their instability. Floods of large magnitude frequently occur and cause the substrate to become mobile, resulting in dramatic changes to the morphology of the system of braided channels. Recent studies on the Rakaia River (Sagar 1983) and on the Waimakariri (Hirsch 1958; Winterbourn, Alderton, and Hunter 1971) indicate that the zoobenthos of these rivers is dominated (in terms of both abundance and biomass) by leptophlebiid mayflies of the genus *Deleatidium*. In fact, species of *Deleatidium* are probably the most widely distributed and abundant insects inhabiting stony streams in New Zealand (Winterbourn 1981). Sagar (1983) showed that *Deleatidium* is adapted to the unstable conditions prevailing in the Rakaia River so that populations recover rapidly even after major floods.

Results from the present study indicate that the zoobenthos of the lower Waitaki River is atypical when compared to the benthic fauna of relatively unmodified rivers such as the Rakaia. *Deleatidium* was numerically dominant in only 5 of a total of 32 samples taken over 3 years from major braids in the lower Waitaki. In contrast *Deleatidium* dominated in 49 of 50 sample collections taken from braids in the Rakaia (Sagar 1983). Overall mean numbers of *Deleatidium* per sample were 120/m$^2$ and 613/m$^2$ for the lower Waitaki and Rakaia Rivers respectively. Elmid larvae formed the major component of the lower Waitaki zoobenthos, they were dominant in 14 of the 32 samples collected from major braids of the Waitaki. Overall mean numbers of elmids per sample were 400/m$^2$ and 4.9/m$^2$ for the lower Waitaki and Rakaia Rivers respectively. In the remaining samples either cranefly larvae (Eriopterini spp.), caddisflies, chironomids, oligochaetes, or the mollusc *P. antipodarum* were numerically dominant.

Whereas *Deleatidium* remained dominant throughout the duration of the Rakaia study, often dramatic seasonal changes in community composition were evident at lower Waitaki sites (e.g., Ferry Road outer, 1979; Table 2). It is difficult to identify reasons for these changes; they do not appear to be related to seasonality in the life history cycles of invertebrates. It is possible that variations in several factors which are known to influence benthic invertebrate distribution (e.g., current velocity, substrate composition, periphyton accrual), brought about by changes in flow regime, were the cause. Graybill *et al.* (1979) suggested that in the Skagit River flow fluctuations (as a result of hydro-electric peaking) were responsible for changes in the community structure of benthic invertebrates.

Despite the fact that in the present study invertebrates were not resolved to low taxonomic levels (which would have increased the number of taxa by up to 20) mean taxonomic richness was still greater in the lower Waitaki (9.43 taxa per sample) than in the Rakaia (7.76 taxa per sample). Calculation of overall mean densities of invertebrates gives figures of 1100/$m^2$ and 899/$m^2$ for the lower Waitaki major braids and Rakaia respectively. In the Rakaia River the pattern of invertebrate abundance was found to coincide with the flow regime of the river so that maximum abundance and taxonomic richness occurred when flows were most stable. In the lower Waitaki the relationship between invertebrate abundance and flow regime was not clear. This is not surprising given the considerable short term flow fluctuations characteristic of the lower Waitaki (Fig. 2).

Since 1927 hydro-electric power development has considerably modified the flow regime of the lower Waitaki River. The major ongoing effects as far as the zoobenthos is concerned are (i) short term (diurnal) and weekly flow fluctuations (according to electricity demand and ED operating policy), (ii) the absence of regular large flood events and (iii) siltation of the substrate (severe in places) as a result of (i) and (ii). The net effect of modification has been an overall increase in substrate stability (see also Ward 1976, Blanz, Hoffman, Kilambi, and Liston 1969), as evidenced by the development of a silt/clay coating on up to one-third of the wetted area of the coarser gravel substrate in the lower river channel, with severe siltation in areas where velocities are low and depths fairly shallow (Jowett 1983). In the Rakaia River, frequent large floods flush the substrate clean of silt so that silt-covered substrates occur only around pools, where mayflies are least abundant (Pierce 1979).

Siltation of the substrate and the associated filling of interstices between larger particles that restricts access by invertebrates to lower, more sheltered surfaces (Ward 1976), is probably a major reason contributing to low *Deleatidium* populations in the lower Waitaki. It also seems likely that the large quantities of silt which become incorporated into the lower Waitaki periphyton would adversely affect the palatability of periphyton as food to *Deleatidium* and other invertebrates. In the lower Waitaki, persistent, rapid flow fluctuations which dewater the substrate and alter environmental conditions would also be likely to have an adverse affect on populations of *Deleatidium*. As a group mayfly larvae are particularly sensitive to modification of their natural environment and many authors have reported low mayfly populations in rivers regulated by impoundments upstream (e.g., Armitage 1976, 1978; Gore 1977; Graybill *et al.* 1979; Ward and Short 1978). Penny (1976) reported that elmid larvae (the most abundant taxon in the lower Waitaki) were tolerant of the accumulation of fine organic silt and to deoxygenation down to 40% of saturation. These characteristics could contribute to elmids relative "success" in the lower Waitaki River.

The basic response of the zoobenthos to modification of the flow regime in the lower Waitaki is considered to be consistent with the effects of enhanced substrate stability. This is seen in the greater taxonomic richness of the lower Waitaki compared with the Rakaia, and in the higher numbers of elmid larvae, molluscs, caddisflies, and dipterans, with fewer *Deleatidium* larvae. The presence of the amphipod *P. fluviatilis* and the mayfly *C. humeralis* in major braids of the lower Waitaki River (but not the Rakaia) provides further evidence of stable conditions. *P. fluviatilis* is normally characteristic of streams of low gradient with overhanging grass banks, aquatic macrophytes or coarse organic detritus (Winterbourn 1981). Wisely (1962) considered that the presence of *C. humeralis* was indicative of stable conditions not greatly affected by flooding, scouring, or periodical disappearance of surface water.

The mean density of benthic invertebrates in the lower Waitaki is greater than in the relatively unmodified Rakaia River. Ward (1976) reviewed the effects of flow on macroinvertebrates downstream of impoundments and concluded that, in general, flow constancy below impoundments results in enhanced numbers and/or biomass of benthic macroinvertebrates, even when short-term fluctuations are imposed on that type of flow regime. However, composition of the benthos is often greatly altered.

The zoobenthos of the stable minor side braid at Ferry Road inner was five times more abundant than that of the lower Waitaki major braids; mean densities of invertebrates for the minor and major braids were $5872/m^2$ and $1100/m^2$ respectively. The number of taxa recorded at each sampling period was also consistently higher at the minor braid site. Although all taxa recorded from the minor braid were also common to the major braids there were obvious differences in the relative abundance of particular taxa. For example, *C. humeralis* was fairly rare in the major braids yet was consistently abundant in the minor braid and formed the dominant taxon in the summer 1978 sample (Table 1). Although elmid larvae were the taxon most often numerically dominant in major braids (Tables 2, 3, and 4) they were never dominant in any of the 11 sampling seasons at the minor braid. Instead, either the mollusc *P. antipodarum* or caddisflies dominated the fauna. *Deleatidium* dominated the fauna once in spring 1980 after the advent of large winter floods.

Comparison of the zoobenthos of major and minor Rakaia braids by Sagar (1983) showed trends similar to those found in the present study.

Both taxonomic richness and invertebrate densities were greater at a stable minor Rakaia braid. In common with the present study, numbers of caddisflies (e.g., *Pycnocentrodes* and *Pycnocentria*) were greater at the more stable minor braids. Enhanced substrate stability at both the Rakaia and lower Waitaki minor braid sites was reflected in a higher degree of substrate compaction and fairly extensive coverings by periphyton.

In summary, the results of this study indicate that though the density of the fauna is comparable (mean densities of 1100/m$^2$ and 899/m$^2$ in lower Waitaki and Rakaia Rivers respectively), the composition of the lower Waitaki zoobenthos is substantially different from that reported in the Rakaia (Sagar 1983) and Waimakariri (Winterbourn, Alderton, and Hunter 1971). The mayfly *Deleatidium* which forms the dominant component of the fauna in the Rakaia and Waimakariri Rivers is present in relatively small numbers in the lower Waitaki where elmid larvae are most abundant and most often dominate the benthic invertebrate fauna. Siltation of the river bed and enhancement of bed stability through the effects of flow modification are considered of primary importance in accounting for these differences.

## 5.2 Tributary Streams

In the tributaries studied, benthic invertebrates were most abundant in the Hakataramea River, with an overall mean density of 4300/m$^2$ (compared with 1100/m$^2$ in lower Waitaki). Mean densities at the Maerewhenua River and Penticotico Stream were 3030/m$^2$ and 2660/m$^2$ respectively. Conoesucid caddisflies (i.e., *Pycnocentria*, *Pycnocentrodes*, and *Olinga*) usually dominated the fauna at the lower and middle Hakataramea sites, otherwise *Deleatidium*, dipteran larvae, or the mollusc *P. antipodarum* were dominant. At the upper site, which was considered to be the least stable, *Deleatidium* dominanted. Likewise, *Deleatidium* dominated the fauna at the lower and middle Maerewhenua River sites, where the substrate consisted mostly of quartzite gravel that was very unstable. Further upstream the substrate became progressively more stable with cobbles and boulders more predominant. At the upper site *Deleatidium* was dominant in about half of the samples; chironomids, elmid larvae, or the caddisfly *Olinga* dominated in the remaining samples.

Studies on the zoobenthos of Rakaia River tributaries (Sagar 1983) revealed findings in common with the present study. The stable Glenariffe Stream supported large populations of conoesucid caddisflies and, similarly, these were abundant at the middle and lower Hakataramea sites, where the substrate is well consolidated and interstitial spaces (where most invertebrates occur) are reduced. Larval conoesucids (especially *P. evecta*) are well adapted to these conditions; they are often found in large numbers on the upper surfaces of stones (Winterbourn 1981). The fauna of a less stable Rakaia tributary, Boundary Stream, was dominated by *Deleatidium* which was also dominant at the more unstable middle and lower Maerewhenua sites.

The invertebrate benthos of the Penticotico Stream was the least abundant of the tributaries studied with a mean density of $2660/m^2$. However, it was the most rich taxonomically with 23 taxa recorded compared with 20 taxa and 21 taxa recorded from the Maerewhenua and Hakataramea Rivers respectively. *Deleatidium* dominated the Penticotico fauna in five samples, otherwise a wide variety of taxa including Eriopterini spp., *P. fluviatilis*, elmid larvae, chironomids, and rhyacophilid caddisflies were dominant during the study period. The presence of large numbers of the amphipod *P. fluviatilis* (especially during 1979) was a noted feature of the Penticotico zoobenthos. No amphipods were recorded from the Maerewhenua River and only a few from the Hakataramea. Provision of cover in the form of aquatic macrophytes and overhanging grass banks in the Penticotico Stream favours the establishment of large numbers of *P. fluviatilis* which then colonise the stream bed.

Monthly sampling and the absence of frequent floods in small Rakaia River tributaries allowed Sagar (1983) to examine the seasonal abundance of the total invertebrate fauna and individual taxa. For the Glenariffe Stream the major findings were that invertebrate density decreased by about 50% over December-March, indicating emergence of adults, and densities increased during April probably as a result of the occurrence of newly hatched larvae. In the present study samples were taken too infrequently, and floods were too prevalent, to draw any conclusions regarding the effects of life cycle seasonality on patterns of invertebrate abundance. However, a general relationship between flow stability and both the total abundance of invertebrates and the number of taxa in the benthos was evident in all three tributaries studied. Large floods, which occurred frequently in 1978 and in the first 6 months of 1980 (when flows exceeded 700 $m^3/s$ in the Maerewhenua River and 240 $m^3/s$ in the Hakataramea River) had the general effect of reducing invertebrate abundance and the number of taxa. However, during 1979, when flows in tributaries were more stable, invertebrates reached high densities and the numbers of taxa were at a maximum.

Resolution of invertebrates to low taxonomic levels was outside the scope and resources of the present general survey with the result that a total of only 25 taxa were recorded from lower Waitaki tributaries.

More intensive sampling and taxonomic resolution to the levels achieved by Sagar (1983) would probably yield double this figure and bring it close to the 51 taxa recorded from Rakaia tributaries. Intensive studies on the faunas of small forested New Zealand streams have resolved up to 182 taxa (Cowie 1983).

In conclusion, it appears that the benthic invertebrate communities of lower Waitaki tributaries are typical of small New Zealand rivers which contain high quality water (Winterbourn 1981). Although the composition and abundance of the fauna differed between the three tributaries studied, all three supported communities more dense and of greater taxonomic richness than that of the main Waitaki River.

## 5.3 Role of Benthic Invertebrates in the Biota of the Lower Waitaki River

Studies of the diet of native fish (McDowall 1965, Burnet 1969, Hopkins 1970, Sagar and Eldon 1983) and introduced salmonids (Allen 1951, Burnet 1969, Hopkins 1970, McLellan and MacMillan 1984) show that benthic invertebrates form the bulk of the diet of most fish species inhabiting New Zealand rivers and streams. Diet studies show that in the lower Waitaki River both native and introduced species are dependant on benthic invertebrates as their major food source.

Data collected to date (FRD unpublished data) show that larval, pupal, and adult forms of aquatic insects comprise the bulk of the diet of lower Waitaki juvenile quinnat salmon and brown trout. Taxa that featured most prominently in the diet included *Deleatidium* larvae, hydroptilid caddisflies, chironomids, and the net spinning caddis *Aoteapsyche*. Insects of terrestrial origin (e.g., hymenopterans and hemipterans) and zooplankton were also eaten by quinnat salmon, but they did not form an important component of the diet. Molluscs (*Potomopyrgus* and *Physa*), caddisflies (*Pycnocentria*, *Pycnocentrodes*, and *Aoteapsyche*), and *Deleatidium* larvae were found to comprise the bulk of the diet of adult trout. The native fish examined (common bully, torrentfish, black flounder) had been feeding predominantly on chironomid and caddisfly larvae.

Despite the abundance of elmid larvae in the lower Waitaki benthos, only a small number occurred in the diets of fish species examined. Allen (1951) and Witherow and Scott (1984) also reported a disproportionately small number of elmids in the diet of brown trout, compared with their abundance in the benthos. However, *Deleatidium* larvae featured prominently in the diet of the lower Waitaki juvenile quinnat salmon, though only small numbers of *Deleatidium* were typical in samples of benthic invertebrates. Allen (1951) found the same to be true in regard to the diet of 0+ brown trout in the Horokiwi Stream. The relative abundance of *Deleatidium* in the diet of trout was found to be up to 11.3 times (i.e., forage ratio of 11.3) that of *Deleatidium*'s relative abundance in the benthos. These differences can be accounted for in terms of the availability of elmids and *Deleatidium* to fish.

Elmid larvae live fairly deep in the substrate so despite their abundance in the benthos they probably are not often accessible to fish as a food item, either in the drift or on the substrate surface from which they could be foraged. Therefore, it seems likely that the large amount of benthic invertebrate production which elmids represent in the lower Waitaki River is not readily available to fish. However, *Deleatidium* larvae are highly mobile animals that are associated strongly with the substrate surface, they therefore have a high propensity to drift and are readily available to fish as food (even though in some rivers they may comprise only a small proportion of the zoobenthos). Its soft-bodied nature probably also makes *Deleatidium* (both larvae and adults) highly palatable to fish (especially drift-feeding juvenile salmonids and the smaller native fish e.g., bullies) and could result in active selection for *Deleatidium*.

Diet studies of small fish in the Rakaia River (Sagar and Eldon 1983) showed that the dominant taxon in the benthos, *Deleatidium* spp., also provided the bulk of fish food. Thus most of the Rakaia's invertebrate production is readily accessible as fish food whereas in the lower Waitaki, elmid larvae (though frequently the most abundant taxon) are not readily accessible. Therefore, energy flow pathways to higher trophic levels may differ between the lower Waitaki and Rakaia rivers.

There is no strong evidence to suggest that food supply is limiting fish production in the lower Waitaki. At present the lower Waitaki supports substantial populations of native fish and introduced salmonids (anglers have been estimated to creel about 8000 trout and up to 10 000 salmon annually, FRD unpublished data). In addition to providing food for fish, benthic invertebrates also provide food for the lower Waitaki avifauna. Eighty-one bird species have been recorded from the lower Waitaki catchment (Robertson *et al*. 1984). Of these, 48 species are adapted to using aquatic habitats. Benthic invertebrates form an important component of the diet of several birds (e.g., black-billed gull, black-fronted tern, wrybill) and supplement the diet of other species.

## 5.4 Implications for Benthic Invertebrates in a Residual River

Should power development proceed on the lower Waitaki River, FRD has suggested a development option that plans a residual river, power canal, and floodway as holding the greatest potential for maintenance of the qualities of the present river (Graynoth, Pierce, and Wing 1981). As benthic invertebrates will form the major source of fish food in a residual river it will be essential to maintain high levels of invertebrate production.

The structure of benthic invertebrate communities in a residual river will depend primarily on the flow regime and substrate conditions present. It seems likely that if a stable flow regime is maintained in a residual river the siltation problems evident in the lower Waitaki would be exacerbated by enhanced stability and would lead to the excessive accumulation of silt and silt-laden periphyton. If this did occur in a residual river then benthic invertebrate and fish production could be adversely affected. There is considerable evidence that excessive accumulations of fine organic and inorganic particles lower the abundance of benthic invertebrates and alter the community structure (see reviews by Iwamoto, Salo, Madej, and McComas 1978, Milner, Scullion, Carling, and Crisp 1981).

Therefore, urgent attention should be given to the solution of potential siltation problems in a residual river. Possible solutions could include the removal of silt from lower Waitaki water feeding a residual river, or the regular flushing of the channel to mobilise silt and periphyton accumulations. However, the feasibility or effectiveness of such measures in a residual river are unknown and require further research.

Besides the importance of maintaining suitable substrate conditions for benthic invertebrates, there are several other features which should be incorporated into residual river design to maximise invertebrate production. It is generally recognised that wide, unshaded, shallow, swift riffles provide the habitat most likely to achieve maximum invertebrate production (Milner *et al.* 1981). Obviously, such areas should be incorporated into the design of channel morphology in a residual river. Studies in the lower Waitaki demonstration channels on insect availability at the water surface (Power 1985) also indicate that wide, open channels are likely to provide more insects per unit area than tree shaded channels. However, benthic invertebrates could derive some benefit from the provision of allochthonous material (e.g., willow, leaves, and catkins) which would augment autochthonous food.

To facilitate utilisation of benthic invertebrates by fish, pools would be an essential feature in a residual river. Fish densities in riffles (where benthic production is usually highest) are often low because of lack of cover and high water velocities. Fish tend to occupy suitable pools or the quieter water below riffles where they can utilise incoming drifting invertebrates (originating from the riffles), whether they take them from the drift or by foraging on the bottom after the drift has settled (Waters 1972).

## 6. CONCLUSIONS

The fauna of the lower Waitaki River is comparable in terms of density with that of the relatively unmodified Rakaia River, but the composition of the fauna is different. Although *Deleatidium* dominates the Rakaia River fauna (and that of most other New Zealand braided river systems), elmid larvae most often dominated the lower Waitaki fauna, with caddisflies, dipteran larvae, oligochaetes and molluscs dominant at other times. It is considered that siltation of the river bed and enhanced substrate stability as a consequence of upstream hydro-electric development account for these differences. The benthic invertebrate fauna of lower Waitaki tributaries is similar to that of other small, stony bedded New Zealand rivers which contain high quality water.

In a residual river (should further power development proceed) there appears to be the potential to support large benthic invertebrate populations with the provision of clean substrate conditions and large areas of riffle habitat (where invertebrate production is maximised).

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APPENDIX I. Sampling dates for collection of benthic invertebrates.

| Year | Season | Date Sampled |
|---|---|---|
| 1978 | Summer | 16/1/78 |
| | Autumn | 26/4/78 |
| | Winter | 25/6/78 |
| | Spring | 11/10/78 |
| 1979 | Summer | 8/1/79 |
| | Autumn | 8/3/79 |
| | Winter | 5/6/79 |
| | Spring | 12/9/79 |
| 1980 | Summer | 22/2/80 |
| | Autumn | 14/4/80 |
| | Winter | not sampled owing to floods |
| | Spring | 17/11/80 |

MAF Fisheries Research

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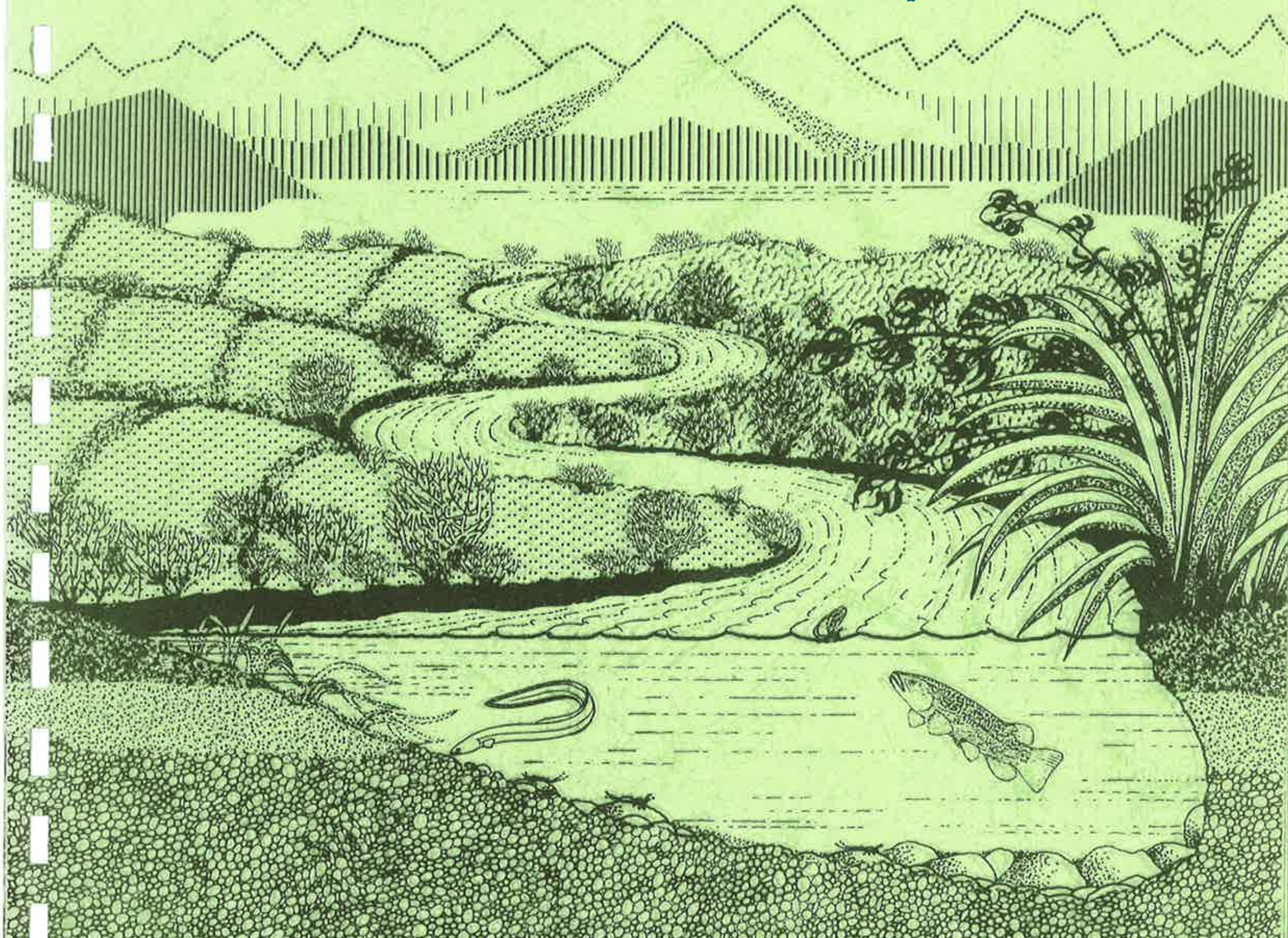

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