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METHODS

1. Chemical and Physical Factors

(a) Dissolved oxygen concentration (D.O.)

The concentration of dissolved oxygen in water samples was determined by the Alsteberg (sodium azide) modification of the Winkler method (Standard Methods, 1965). Water samples were taken close to the substratum in mid-stream wherever possible, and the initial steps of the Winkler techniques were carried out immediately in the field. Triplicate titrations were made on each sample and values given are means of these.

(b) Biochemical oxygen demand (B.O.D.)

B.O.D.'s were determined by comparing the dissolved oxygen concentration in samples analysed immediately after collection with replicate samples which were kept in the dark for 5 days at 20°C. Samples from heavily polluted areas were diluted with distilled water and/or aerated prior to incubation.

(c) pH, conductivity and salinity

Water samples for the determination of these factors were taken at the same time as samples for oxygen determinations. Measurements of pH were made with a Metrohm, Model E488 pH meter immediately after returning from the field (i.e. within 3-4 hours of collection). Conductivity was measured with a Radiometer, type CDM 2e mains operated conductivity meter and salinity (at stations affected by tidal movements) with an "Autolab" model 601, Mk III salinometer.

(d) Turbidity

Turbidity measurements were made to give some indication of the amount of fine particulate matter present in the water. The optical density (O.D.) of a subsample of water taken from a thoroughly shaken stream water sample (200 ml) was measured at a wave-length of 350 mu with a "Spectronic 20" colorimeter. Distilled water was used as a blank. Because particularly large particles of organic material were present in some water samples, O.D.s of single samples could vary over a wide range as the particles settled in the colorimeter tube. Readings were therefore made over a 30 second period, and the maximum, minimum and mean values were all recorded.

(e) Temperature and current velocity

Water temperatures were measured 5-10 cm below the water surface and surface current velocities by determining with a stop-watch the time taken by a cork float to travel a distance of 1 m. All velocities given are means of three trials.

2. Biological Methods

Sampling was carried out from mid November to late January, the streams being examined in the following sequence:

(a) North Branch: 24 November - 7 December

(b) South Branch: 7 - 24 December

(c) Northbrook Drain and R. Cam: 10 - 20 January

Initially, the sampling stations used by Hirsch (1958) were located. Most were re-established and a number of additional stations were also set up, giving a total of 25 sampling points (Appendix 1, Fig. 1).

In each river a "baseline" station was established upstream of all pollution sources and at these stations extensive bottom fauna sampling was undertaken from as wide a range of substrata as possible. At all other stations samples were taken from substrata most "typical" of the station, and included stone-gravel substrata whenever possible. In most cases these provided the best comparative data on the effects of organic pollution between stations.

In flowing water and on coarse sediments bottom fauna samples were taken with a Surber sampler (area sampled 900 cm^2; mesh diameter 0.5 mm), but on soft substrata (sand and mud) and where little flow was found, sediment cores (area 38.5 cm^2) were taken to a depth of 5 cm. The fauna of submerged plants was sampled by removing complete plants (3-12 g dry weight) which were quickly and carefully transferred to containers. Few animals appeared to be lost during this process. To provide some measure of sample variation, three samples were taken from each substratum at each station. All samples of bottom fauna were kept alive prior to sorting by keeping them in plastic bags of stream water at 4^oC.

In the laboratory, samples were washed through a seive (mesh size 0.5 mm) to remove excess sediment and to facilitate sorting. Although some small animals (particularly Chironomidae and Oligochaeta) were lost during this process it is not considered to be a major source of error. Animals were separated into different taxa (Appendices 6-8) and stored in vials of 70% alcohol. Densities of animals in Surber and core samples are expressed as no./0.1 m^2 and those in weed samples as no./10 g dry weight of weed.

In addition to quantitative samples, general collections of bottom fauna were made to obtain animals for gut content analysis. These samples were preserved immediately in the field with 10% formalin.

Dry weights of animals in each sample were determined to the nearest 1 mg on a Mettler balance, but as all specimens had been preserved in 70% alcohol for up to 4 weeks, the biomass values obtained were probably slightly lower than those expected with fresh material. Prior to weighing animals were placed in pre-weighed aluminium foil containers, dried for 4 days at 80°C and cooled in a desiccator. Shells of molluscs were decalcified with dilute HCl, and larval caddis cases which contained inorganic sediments were removed before weighing. The secreted cases of Olinga feredayi which are made of fibrous proteins (Rudall and Kenchington, 1971) were not removed.

Dry weights of plants were obtained in a similar way, and were determined to the nearest 0.01 g.

3. Diversity indices

The faunal diversity of a community can be expressed by means of a diversity index in which numbers of individuals and species present are inserted in a simple mathematical formula. In the present study, the index of Margalef (1958) has been used. This states:

$$D = \frac{(S-1)}{\mathrm{Log}_e N}$$

where S = a number of species, N = a number of individuals, and D = diversity.

A diversity index provides one expression of the structural organisation of a community and a fall in the index can often be related to some outside influence (e.g. pollution) upsetting the system. When large numbers of species and individuals are present the index is high, but when a community is dominated by a few species it is low.

THE NORTH BRANCH SYSTEM

Three streams, the Cust Main Drain, Ohoka Stream and the North Branch of the Waimakariri River (= Eyre River) converge northwest of Kaiapoi to form the Kaiapoi River. Wastes from a fell mongery where sheep skins are cured, and a dairy farm (including milking shed) are emptied into the North Branch and form an important source of organic pollution. The North Branch is 5-8 m wide in the part studied and had a stable bed composed of shingle, stones and sand. Above the fellmongery, aquatic weeds including the oxygen weed Elodea canadensis and the water milfoil Myriophyllum propinquum were abundant and formed extensive beds. Below the fellmongery and upstream of the milking shed the shingle bed was covered by a soft, uncompacted layer of mud and fine organic matter up to 15 cm deep. Below the milking shed (station 3) the stream gradient and flow velocity increased and fine organic matter was no longer deposited to such an extent. From here to the mouth of the North Branch many of the more stable stones were encrusted with algae including Chaetophorales and diatoms of the genera Achnanthes and Gomphonema or to a lesser extent "sewage fungus". Substrata at the mouths of the Ohoka Stream, North Branch and Cust Main Drain were very similar, although more fine sediments including sand were present in the latter which has a shallow gradient. Filamentous algae were apparently absent from the Ohoka stream, but were abundant in the Cust Main Drain. All three of these stream mouth stations are affected by tidal movements in the Kaiapoi River, and although saline water does not penetrate this far (Appendix 14) fresh water banks up against the advancing sea water. Consequently the depth of water at the three stations varies within a range of about 60 cm during each tide cycle and current velocities in mid stream range from maximum rates of up to 200 cm/sec to still water or even reversed flow.

1. The Bottom Fauna

Station 1 (Neeves Road bridge)

Samples were taken in nine subhabitats varying in current velocity, vegetation type and substratum (Appendix 2A). The largest numbers and biomasses of animals were found on soft sediments particularly where decaying plant material was present. In these conditions the fauna was dominated by oligochaete worms and smaller numbers of larvae of the midge Chironomus zealandicus. On clean shingle the fauna was markedly reduced in numbers (20-30 times fewer individuals) and biomass (5-10 times smaller) and was dominated by larvae of the mayfly Deleatidium sp. and several species of caddisfly, notably Pycnocentria evecta, Helicopsyche sp. and Hydrobiosis parumbripennis. Here oligochaetes (Lumbriculus variegatus and Tubificidae) comprised only about 11% of the numbers found.

The faunas inhabiting two submerged macrophytes were examined. Of these Myriophyllum supported slightly larger numbers and weights of animals per gram dry weight of plant than did Elodea, in both fast and slow flowing water. The weed faunas were dominated by the amphipod Paracelliope fluviatilis, caddis larvae, notably those of Pycnocentria, and the gastropod Potamopyrgus antipodarum. Smaller numbers of oligochaete and chironomid larvae were also present.

Station 2 (Below the fellmongery)

Here the river had a hard gravel bed coated with mud and soft deposits derived from the fellmongery. The fauna was dominated by larvae of Chironomus zealandicus (at densities which sometimes exceeded 6000/0.1 m^2) and smaller numbers of oligochaetes. Mean biomass values obtained were over twice the greatest values obtained at Station 1.

Station 3 (At the ford below the cowshed)

Samples were taken from substrata of sand, silt and gravel at two different current velocities, and on a sandy bed with the pondweed Potamogeton present. All samples were dominated by oligochaetes. At the sampling point where the current was slowest the faunal biomass was comparable to that found below the fell- mongery, but where the flow was greater less fine organic material was deposited on the bed and both the numbers and biomass of bottom fauna were reduced. In these conditions large numbers of the snail Potamopyrgus and a chironomid Orthocladius publicus were also present on the hard substrata. Where the weed Potamogeton was present the most stable bed conditions and greatest deposits of fine sediments were found. This was reflected in the huge numbers of Chironomus present and their relatively greater importance here compared with other substrata.

Station 4 (Mouth of North Branch)

This station provided unusual conditions for stream animals owing to the tidal influence which regularly affects the depth and flow of the stream. The river bed and its fauna showed little difference from that found in reasonable flow at Station 3. At the stream margins a band of mud was alternately submerged and exposed according to the tide, and was colonized by oligochaetes, Chironomus and Orthocladius.

Stations 5 & 6 (Ohoka Stream and Cust Main Drain)

Samples were taken at the mouths of the Ohoka Stream and Cust Main Drain where they converge with the North Branch. Both were affected by the rising tide in the same way as the North Branch. The bottom fauna on stones in the Ohoka Stream were poorer than that of the North Branch in comparable conditions (about 1/5 the numbers and 1/3 - 1/4 biomass) and was dominated by *Potamopyrgus* rather than chironomids and worms, which were present only in very small numbers. At its mouth the Cust Main Drain also possessed very poor fauna which was probably limited by the unfavourable sandy substratum occurring at this point.

Station 7 (Kaiapoi River)

Samples were taken close to the north bank of the Kaiapoi River about 700 m below the confluence of the three tributaries. This station was also affected by tidal movements but saline water did not penetrate to it. The composition and density of the fauna was similar to that at the mouth of the Ohoka Stream.

2. Diversity

At the baseline station diversity and species numbers were highest on a clean, shingle bottom and within beds of *Elodea* in rapidly flowing water. The diversity index fell in areas of reduced flow and in finer, softer sediments.

Lowest values were found immediately below the fellmongery and they then rose gradually towards the mouth. Faunal diversity in the Ohoka Stream and Cust Main Drain were notably higher than at the mouth of the North Branch.

3. Water sampling results

(a) Diurnal oxygen study

Water samples were taken from seven stations in the North Branch system over a 24 hr period on 1-2 February 1971. Seven sets of samples were taken from close to the stream bed and in mid-stream at 4-hourly intervals, except in the Kaiapoi River where samples were obtained about 1 m from the northern bank. As the sampling was undertaken in mid-summer and during a prolonged dry spell, the water level was close to its lowest level and water temperatures must have been near maximal. The major source of pollution on the North Branch, the fellmongery, was in operation and the milking shed below it was also in use. Thus, during the sampling period the combined effects of these factors should have been to produce some of the lowest oxygen conditions that occur in the North Branch.

In general dissolved oxygen (D.O.) concentrations were higher during the day than at night at all stations (Appendix 10).

Above the fellmongery (station 1) D.O.s ranged from 5.6-8.4 mg/L (57-87% saturation at temperatures ranging between 15 and 18°C). The D.O. level fell drastically below the fellmongery, and the lowest day-time readings were obtained at the mouth (station 4). At stations 2 and 3 the water in 6 a.m. samples was totally deoxygenated.

Both the Ohoka Stream and Cust Main Drain were well oxygenated (5.4 - 9.4 mg/l, 54-98% saturation, and 5.5-11.2 mg/l, 60-130% saturation). The Kaiapoi River samples exhibited a wide range in values between day and night.

Dissolved oxygen determinations made on water samples taken during the day (between 10 a.m. and 2 p.m.) on two other occasions are given in Appendix 12. These either fell within or slightly above the range of values obtained in the diurnal study. Higher values found can be explained as primarily a temperature effect, the water temperatures during these subsidiary samplings being lower than those on the day of the diurnal series so that a higher saturation level would be expected.

B.O.D. measurements made on day-collected water samples taken on one or two occasions during January and February 1971 are also given in Appendix 12. At the times these samples were taken, little or no effluent was being released into the river. Following the convention of the Royal Commission on Sewage Disposal (1958) (Cameron, 1970), water at the baseline (station 1) would be considered "very clean" (BOD $<$ 1), that in the Ohoka Stream and Cust Main Drain, "clean", the Kaiapoi River "fairly clean" and all stations in the North Branch below the fellmongery would be "doubtful".

(b) pH, conductivity and turbidity

Measurements of pH were made on water samples collected in December and February. In December alkaline pH's were obtained at all stations, ranging from 7.1 at the baseline to 9.2 below the fellmongery. In February the pH range was compressed from 6.8 at the baseline to 7.7 below the fellmongery.

Conductivities were determined on a series of diurnal water samples collected concurrently with those used for oxygen determinations in January. Over the 24 hr period values were relatively low and constant above the fellmongery ($<$130 μmho) but were slightly higher in the Ohoka Stream and Cust Main Drain. The highest readings (indicating an increased ionic content of the water) and the greatest fluctuations in values were found at the three lower stations on the North branch. Increases in conductivity recorded were probably related to the times when effluents were emptied into the stream. A second series of conductivity measurements made on single day-collected water samples from each station showed similar relationships between the stations (Appendix 12).

In order to compare the amount of suspended particulate matter, both organic and inorganic, occurring in the water, turbidity measurements were made on water samples collected as part of the diurnal programme (Appendix 12). This "turbidity index" was low at the baseline station, and high below the fellmongery and the ford, although the index values obtained at these stations were only about half those found below the freezing works outfalls on the South Branch. Intermediate values were obtained at the junction stations and in the Kaiapoi River. The occurrence of fine suspended matter in this section of the river is probably related to the tidal situation existing there. This may prevent the removal of some fine material further downstream and also inhibit the settling out of particulate matter.

In the North Branch, a strong correlation was found between maximum conductivity and maximum turbidity over the 24 hr period.

THE SOUTH BRANCH

The South Branch of the Waimakariri River was the largest of the streams studied. At the uppermost sampling station, immediately above the weir downstream from the Groynes pool the stream was about 10m wide and had a stable bed of stones lying on a base of sand and gravel. Some filamentous algae were growing on the uppermost stones and large beds of rooted vegetation were also present. A considerable amount of organic detritus, much of it decaying aquatic weed, was present on the stream bed. Lower down, at stations 2 and 3, the stream was very swift-flowing and had a bed of clean gravel and stones; no algae were present. About 120 m below the Dickey's Road bridge, freezing works washings are emptied into the water and a second pipe also discharges effluent a further 50 m downstream. In this region the stream gradient is shallower and consequently the current velocity falls. Here the bed was composed of sand, stones and shingle coated with fine organic "ooze", which was up to 5-10 cm deep at the margins. Sewage fungus was abundant. Similar conditions prevailed down to the mouth of the South Branch.

The main Waimakariri River is large with an unstable bed. Sampling was carried out close to the southern bank, above and below the entry of the South Branch. Upstream, the bed of stones and sand was clean and some algae were present. Downstream the bed was similar, but covered with an abundance of slime algae and "sewage fungus".

The small drain entering the South Branch above the Dickey's Road Bridge appeared to have changed in character since 1958. This was probably related to the extensive development of land that has occurred in its vicinity. The bed of the drain consisted mainly of silt and willow root debris, and there was little indication of organic pollution.

1. <u>The Bottom Fauna</u>

<u>Station 1</u> (Below the Groynes)

The baseline station was located below the "Groynes" pool where the water velocity was very constant at about 30 cm/sec and considerable growth of weed was present. Samples were taken from three subhabitats, weed (<u>Myriophyllum</u>), gravel and algal coated stones, and gravel with sand and organic detritus (largely decaying <u>Myriophyllum</u> stems and leaves).

Far higher densities of animals were found where detritus was present than on the cleaner substrata but little variation in biomass was found. In fine sediments oligochaetes were abundant (84% numbers) and smaller numbers of amphipods (<u>Paracalliope</u>) and caddis larvae (<u>Oxyethira</u> sp.) occurred. Small numbers of <u>Potamopyrgus</u> and <u>Chironomus</u> were also found.

On the harder, stony substrata, greater faunal diversity occurred, the most abundant species numerically being <u>Potamopyrgus</u> and the insects <u>Deleatidium</u>, <u>Oxyethira</u>, <u>Orthocladius</u> and <u>Maoridiamesa</u>. Oligochaetes were present in reduced numbers and only occasional larvae of <u>Chironomus</u> were seen.

Myriophyllum was colonised by Paracalliope, Potamopyrgus, larvae of the chironomids Orthocladius and Maoridiamesa and a variety of larval caddisflies, notably Oxyethira and Pycnocentria evecta. The invertebrate biomass on Myriophyllum was comparable with that found on Myriophyllum and Elodea in the North Branch, and the major groups inhabiting the plants (Amphipoda, Gastropoda and Trichoptera) were similar.

Stations 2 & 3

These stations, above and below Dickey's Road bridge had water velocities 2-3 times those recorded below the "Groynes". Weed beds were restricted to stretches of deeper, more sheltered water at the stream margins, and less organic detritus was found on the bed in mid-stream. The invertebrate fauna was very similar in composition and density at the two stations, and the inflow of water from a small ditch had no apparent effect on the stream. The dominant animals were Potamopyrgus, Deleatidium and larvae of two caddis species, Pycnocentrodes aureola and Olinga feredayi. Small numbers of oligochaetes were found, but few chironomid larvae of any kind.

Stations 4 & 5

Below Dickey's Road bridge, freezing works effluents are poured into the river from two separate pipes. Station 4 was located between the pipes and station 5, 20 m below the second outlet. In this stretch, the stream gradient falls off considerably and the water velocity was reduced from about 80-90 cm/sec at Dickey's Road to only about 30 cm/sec between the outlets. As a result, fine organic materials entering the stream in the effluent was deposited on the bed in this area of reduced flow and the whole character of the stream bed was drastically altered. In addition to this "organic sediment" which lies upon and fills interstices between stones, "sewage fungus" was found on the surface of stones and at the sides of the stream. Below the second outfall, much of the stony bed was coated with a fine, amorphous "ooze" which reached depths of 5-10 cm in places at the stream margins.

Oligochaetes composed over 95% of the fauna at these stations and the only other animals present were larvae of Chironomus. Worm densities of over 40,000/0.1 m^2 were recorded here and an invertebrate biomass of over 40 g/0.1 m^2. This compares with biomass values of less than 0.4 g/0.1 m^2 in soft, "detritus-enriched" areas with an oligochaete-dominated fauna at station 1 and less than 1.6 g/0.1 m^2 in comparable non-polluted areas of the North Branch.

Station 6

At the mouth of the South Branch fine organic matter was no longer being deposited in significant quantities, but the bed supported a well developed growth of "sewage fungus". Only a very sparse fauna was present although its diversity had increased slightly with the addition of small numbers of Potamopyrgus, Oxyethira and Orthocladius.

Stations 7 & 8 (Main Waimakariri River)

Sampling was carried out close to the south bank in the main channel, above and below the entry of the South Branch. The river bed was very unstable and did not support a rich fauna. Above the South Branch, the bed was clean and 75% of the fauna consisted of Deleatidium larvae. Downstream the stones were coated with algal slime and "sewage fungus" and only oligochaetes were found.

2. Diversity

In gravel at the baseline station below the Groynes, the number of species and the diversity index were similar to those found in a similar situation in the North Branch. Reduced diversity was found on Myriophyllum and in soft sediments. High values were maintained above and below Dickey's Road and the entry of a small drain had no noticeable effect on the benthic community. Between and below the freezing works effluent outfalls, diversity fell abruptly but it increased again slightly at the mouth. This increase was probably associated with a reduction in the amount of fine sediment deposited on the bed.

The main Waimakariri River provides a harsh environment for the invertebrate bottom fauna owing to its instability, and consequently species diversity is not high. These harsh physical conditions combined with the enriched water discharged from the

South Branch have produced an impoverished fauna at station 7, with a low diversity comparable to that immediately below the effluent discharge points.

3. Water Sampling Results

(a) Diurnal oxygen study

Water samples were taken at 4-hourly intervals from five stations on the South Branch and two stations in the main river over a 24 hour period on 25-26 January 1971. The river level was low at this time, water temperatures were high and the freezing works was in operation and pumping "washings" into the stream.

At all stations consistently higher oxygen values were obtained during the day than at night (Appendix 11). The mean dissolved oxygen concentration over the 24 hr period showed a gradual decrease at each station downstream from the Groynes to the mouth of the South Branch. The higher readings obtained at the Groynes, compared with Dickey's Road are probably the result of greater photosynthetic activity at the former where large weed beds were present.

Immediately below the second outfall dissolved oxygen levels ranged between 2.3 and 6.9 mg/L (24-72% saturation) and at the mouth were reduced to 1.9-3.5 mg/L (20-36% saturation). Water entering the main river from the South Branch stayed close to the south bank of the river, and water samples taken at the Northern Motorway bridge below the entrance of the South Branch had low levels of dissolved oxygen (2.5-5.3 mg/L), comparable to those occurring in the lower reaches of the South Branch. By contrast, close to the North bank of the main river opposite the mouth of the South Branch, oxygen values were high and approaching saturation at all times.

Dissolved oxygen determinations were made between 10 a.m. and 2 p.m. on two other days during the summer and are included in Appendix 12. Oxygenation of the water on these days was similar to that found on 25-26 January.

B.O.D.s were determined at all stations in February (Appendix 12). "Clean" values (<2) were recorded above the effluent outfalls and in the main river opposite the South Branch, but extremely "bad" values (B.O.D. = 40-65) were obtained below the outfalls and near the south bank of the main river at the motorway bridge.

(b) pH, conductivity and turbidity

The pH measurements were made twice in the South Branch (in December and February) and once in the main river (February).

A slight increase in pH was found immediately below the outfalls in December, but this was not so evident in February.

Conductivities were determined on a series of diurnal water samples collected in February along with those taken for oxygen analyses. Values were low and almost constant (<90 μmho) above the effluent outfalls and in the main river. Below the outfalls and on the south side of the main river conductivities were considerably higher (increase up to 5 times those recorded upstream), and exhibited considerable diurnal fluctuations. The highest values and most severe fluctuations were recorded immediately below the second effluent outfall. A second series of conductivity measurements made in February on water samples collected during the day, gave values consistent with those obtained in the diurnal series (Appendix 12).

Turbidity measurements taken to provide an indication of the amount of suspended particulate matter present in the river were made on water samples collected as part of the diurnal programme. Low turbidity values were obtained above the outfalls and on the north side of the main river. Highest values were obtained below the second effluent outfall, and the turbidity remained high down to the mouth of the South Branch, and on the southern side of main river at the motorway bridge. This indicates that not all the particulate matter was being settled out below the outfall and much was being carried into the main river.

A strong positive correlation between turbidity and conductivity was found in the South Branch suggesting that the two are related. Highest readings of both parameters occurred during the day (when the effluent was flowing into the stream) and they fell markedly at night.

NORTHBROOK DRAIN

The Northbrook Drain is a tributary of the Cam River south-east of Rangiora. Domestic wastes from a septic tank are discharged into the stream near its headwaters and two small tributaries drain into the stream before its confluence with the Cam. In the headwater, above the septic tank outflow, the stream was about 1.3 m wide and deeply entrenched. Grass (*Glyceria* sp.) and water cress (*Rorippa microphylla*) grew in the water at the sides and the bed consisted principally of clay, sand and mud with accumulated organic debris, leaves and twigs. Below a septic tank outflow the stream widened to a maximum of 5-6 m, was less entrenched and the bed was composed of coarser gravels and stones. Clumps of submerged *Glyceria* were rooted to the substrata throughout the length of the stream which had a generally clean appearance.

1. The bottom fauna

No baseline conditions could be established, as above the main source of pollution (septic tank outfall) the flow rate was considerably slower than that downstream and much of the bed was composed of different materials; no stony substrata were present at station 1.

(a) Soft substrata (Stations 1 and 2)

At Station 1 samples were taken from sand and mud substrata, with and without accumulated detritus. These habitats contained large numbers of oligochaetes (over 90% total numbers). Where detritus had accumulated the fauna was more diverse and included numbers of amphipods (*Paracalliope*), chironomids and *Potamopyrgus*.

Below the septic tank outfall (Station 2) in sand and mud the fauna was about six times greater in numbers and had four times the biomass of that at Station 1. Oligochaetes were again predominant but large numbers of chironomids (18%) including *Chironomus* were also present.

(b) Water cress (*Rorippa microphylla*) (Stations 1, 2, 4)

At Station 1, *Potamopyrgus* was the most important animal colonizing cress, and there were smaller numbers of amphipods and *Orthocladius*. The biomass of the invertebrate fauna was comparable to that occurring on *Myriophyllum* and *Elodea* in non-polluted areas of the South and North Branches.

At Station 2 the biomass was over four times as great as that at Station 1 and although similar numbers of *Potamopyrgus* were found, huge numbers of *Orthocladius* were also present and represented 78% of the numbers. Downstream at Station 4 biomass values were lower than those occurring at Station 1. *Potamopyrgus* and *Orthocladius* were still the two most important species found.

(c) Grass (*Glyceria* sp.) (All Stations)

Submerged rooted grasses were present in flowing water at all stations.

The water velocity at Station 1 was only half that at Stations 2-5 and one quarter that at Station 6 and some of the faunal differences observed were probably related to these differences in flow rate. Thus, amphipods were only important at Station 1 whereas at Station 6 larvae of the two caddisflies *Pycnocentria* and *Pycnocentrodes* constituted 56% of the grass fauna.

The biomass of the grass fauna at Station 1 was less than that found on water cress at the same station, and the composition of the fauna differed in having relatively more *Orthocladius* larvae and less Gastropoda which, together were the most abundant groups. The biomass per g grass was greater at all other stations, the highest values occurring at Station 3 where large numbers of oligochaetes made an important contribution to this increased biomass.

(d) *Stones and Gravel*

Hard substrata were not present at Station 1. At Stations 2-5 oligochaetes and gastropods (*Potamopyrgus* and *Physa*) were the dominant invertebrates, the former being particularly abundant at Station 3. *Deleatidium* occurred at the three lower stations and caddis larvae (notably *Hydropsyche*, *Pycnocentria* and *Pycnocentrodes*) were dominant in the swift current at Station 6.

2. Diversity

Diversity was generally lowest at the two upstream stations, and was consistently high at Stations 3-6 on all substrata. The low values obtained at Stations 1 and 2 were probably related to the presence of soft sediments and slow stream flow at these stations, as well as organic enrichment from septic tank outflows in the case of Station 2. The effect of this enrichment can be seen by comparing the faunal diversity on *Glyceria* at each station. Diversity is significantly lower at Station 2 than at all others. The effects of pollution on community structure in this stream appear to be very localised.

CAM RIVER

The upper reaches of the Cam River above the entry of the Northbrook Drain were examined. Effluents from a small septic tank and a candied peel factory enter this section of the stream. Above the factory, the stream bed consists of stones and gravel with clumps of *Glyceria* growing in the bed. Below the factory organic debris derived mainly from pine trees was present on the gravel bed and many of the larger, more stable stones were coated with filamentous algae. At the lowest sampling station algal covered stones were also found and the bed was strewn with broken bricks and glass.

1. The bottom fauna

Two main habitats were considered in the Cam, the stony bed and submerged rooted grasses (*Glyceria*).

(a) Hard substrata

Above the septic tank outflows the most abundant invertebrates were elmid larvae (Coleoptera) (also found in the Waimakariri River above the entrance of the South Branch), and larvae of the two caddis flies *Hydropsyche* and *Pycnocentria*. Few oligochaetes were present among the coarse sediments, and no chironomid larvae were seen.

At Station 2 where algae were present the fauna was composed almost exclusively of Gastropoda (65%) and Oligochaete, and the total biomass was about twice that found at Station 1. Areas in which mud and debris had accumulated had reduced water flow and a dense oligochaete population. *Potamopyrgus* was also fairly abundant along with lesser numbers of dipteran larvae, including *Ch. zealandicus*. Although nominally a hard substratum the accumulation of finer materials has allowed the development of a dense primarily burrowing fauna.

At Station 3 oligochaete densities were much reduced, and gastropods (mainly *Potamopyrgus*) formed 95% of the fauna. Larvae of *Pycnocentria* which were fairly common at Station 1 but absent at Station 2, reappeared here.

(b) Grass (Glyceria)

At Station 1 the grass fauna was poorly developed and was of a similar composition to that present on the adjacent stones and gravel. Downstream, however, it was comparatively well established and composed almost exclusively of gastropods and oligochaetes. Biomass values and numerical densities were highest at Station 2.

2. Diversity

Medium diversity values were found in most situations in the Cam. Highest values were recorded above the septic tank outlet and the lowest ones immediately below it. Recovery of the community structure was occurring at Station 3.

3. Water Sampling Results

Northbrook Drain and Cam River

One series of chemical measurements was made in each of these streams in February when water levels were low and temperatures high. Dissolved oxygen levels were high at all stations (7.7-9.5 mgO_2/L; 74-92% saturation) and B.O.D.s determined on water samples collected at the same time indicated that the streams were fairly clean (Appendix 15, 16). The highest B.O.D. (4.4) was obtained from below the septic tank outfall on the Northbrook Drain, and the highest B.O.D. recorded on the Cam (2.0) was also from below a septic tank outfall.

The pH was almost constant throughout the Northbrook Drain (6.9-7.0) but varied a little more in the Cam (6.6-7.1). Conductivity and turbidity were low throughout both streams and comparable to values obtained at the baseline stations on the North and South Branches.

DISCUSSION

1. A comparison with Hirsch's 1956-57 Survey

In an attempt to evaluate the level of pollution occurring in the lower Waimakariri River system, Hirsch (1958) carried out a bottom sampling programme at 29 stations in the North and South Branches, Cam River and Northbrook Drain during 1956-57. In addition, he noted briefly substrate condition, the presence or absence of algae and "sewage fungus", and took "spot" oxygen and temperature readings on a number of occasions.

His sampling in the Cam and Northbrook Drain was carried out using non-quantitative methods but in the North and South Branches quantitative bottom samples were taken with a Surber sampler. Unfortunately, too little information is provided on the sampling techniques and situations sampled to allow a useful comparison of numerical densities to be made with those obtained in the present study. However, a comparison of the relative abundance of different invertebrate groups at each station can be made.

(a) Bottom Faunas

(1) North Branch

Hirsch (1958) took samples in August 1956 and February 1957 but comparisons will be made with his February data only so as to reduce differences which may be introduced by seasonal factors.

Similar faunas were found at the baseline station (Station 1) in both studies. This fauna was dominated by Trichoptera (notably *Olinga* and *Pycnocentria*) and Ephemeroptera (*Deleatidium* dominant) and exhibited considerable diversity. *Potamopyrgus* was relatively more abundant in 1957 than in the present study.

Below the ford and at the stream mouth in 1957 the fauna was dominated by molluscs (*Potamopyrgus* and *Physa**) and oligochaetes, but very few chironomidae were found. In 1971, however, oligochaetes and two species of chironomid were abundant and very few molluscs were found. Those present were almost all *Potamopyrgus*.

Hirsch records the substratum at this station as shingle and sand with abundant algae, and the results of the present study suggest that increasing quantities of fine material have been deposited amongst the larger sediments in the last 13-14 years. This would help to account for the increased importance of the burrowing component of the fauna. Of the Chironomidae, larvae of

*No *Physastra* were found in any of the streams in 1970-71, only *Physa*. It seems probable that this snail was misidentified by Hirsch.

Chironomus burrow into the soft sediments whereas the larvae of *Orthocladius* occupy the upper surfaces of stones on which they construct permanent tubes from the fine sediments.

Changes in composition of the bottom fauna have also occurred in the Ohoka Stream and Cust Main Drain. These changes cannot be attributed to pollution from a well defined source but are probably a consequence of gradual enrichment by nutrients derived from agricultural fertilizers, etc., in the catchment area. Whereas Ephemeroptera, sericostomatid caddis larvae and oligochaetes predominated in 1957, *Potamopyrgus* and oligochaetes were dominant in 1971. Ephemeroptera and sericostomatids were absent in 1971. A similar, if less extreme change has occurred in the Cust Main Drain. Whereas the mayfly *Deleatidium*, sericostomatids, *Hydropsyche* and chironomids were abundant in 1957, a few *Deleatidium* or caddis were found in this suudy and the fauna was composed largely of oligochaetes, chironomids and molluscs (including *Potamopyrgus*, *Physa* and *Planorbis*).

The changes which have occurred in these three streams were reflected downstream in the Kaiapoi River. Here also, *Potamopyrgus* and oligochaetes were the most important groups occurring and caddis larvae were absent, whereas in 1957 larval sericostomatids (notably *Pycnocentrodes*) and oligochaetes were dominant and even *Deleatidium* was present. Although the limited amount of information given by Hirsch indicates that the structure of the stream bed was probably fairly similar then to now, subtle differences in the composition of the microflora produced by nutrient changes of the water may be partially responsible for the observed changes in the bottom community. Thus, Allen (1960) notes that with an increased supply of nutrients in the water the initial thin film of diatoms and blue-green algae on the stones is replaced by an increasing heavy mat of diatoms and filamentous forms, and as a consequence of this animals such as ephemeropterans and sericostomatids which typically live on exposed surfaces browsing the thin diatom film are replaced by burrowers and creepers on the algal felt (e.g., *Potamopyrgus*).

(2) South Branch

Hirsch's observations were made in June 1956 and March 1957, but comparisons here are made with the latter only. Below the Groynes and at Dickey's Road the bottom community has shown little change since 1957. It was dominated by *Potamopyrgus*, sericostomatids, *Hydropsyche* and the mayfly *Deleatidium*. Below the freezing works outfalls the community structure was also essentially the same now as in 1957 with oligochaetes dominant and larvae of *Chironomus* occurring in lesser numbers. Hirsch's quantitative values suggest, however, that numerically both groups have increased enormously, (perhaps up to 30 times) since 1957, and this could be expected if fine organic matter was continually being deposited and accumulated on the river bed. Little change in the oligochaete dominated community was found at the mouth of the South Branch but near the south bank of the main Waimakariri River below the entry of the South Branch an oligochaete-dominated fauna was found in 1971 compared with a *Deleatidium* (and oligochaete) dominated one in 1957. This suggests that the effect of the polluted water issuing from the South Branch is greater now than it was in 1957. Above the mouth of South Branch a *Deleatidium* dominated fauna was present in both years and few oligochaetes were present.

(3) Northbrook Drain

Observations were made by Hirsch in October 1956, February 1957 and December 1957. The 1971 data are compared with his February results. At Station 1, Hirsch described the stream bed as shingle, sand and detritus, whereas in 1971 samples were taken in clay, mud, sand, and detritus, as shingle was not an important material on the stream bed. Differences in the composition of the fauna found on the two occasions may be largely associated with this difference in substratum. Hirsch found large numbers of amphipods (*Paracalliope*), oligochaetes, *Deleatidium* and caddis larvae, whereas in 1971 the dominant groups were oligochaetes, turbellarians (flatworms) and *Potamopyrgus*. At Station 2, below the septic tank outlet, chironomids and oligochaetes were most abundant in 1957. In 1971 a more diverse fauna was found with large numbers of snails as well as chironomids and oligochaetes being the main groups present. This suggests a possible improvement in water quality at this station and this is also indicated by the presence of *Deleatidium* which was not found by Hirsch.

At the lower stations little change in fauna has occurred since 1957 except at Station 5 (Station 6 of Hirsch) where large numbers of *Potamopyrgus* and chironomid larvae now occur. Formerly they were unimportant and the fauna was dominated by sericostomatids, oligochaetes and *Deleatidium*. The nature of this change in the bottom community suggests that it is probably associated with an increase in the amount of fine sediment present (and probably a consequent change of microflora), but the cause of this change is not clear.

(4) Cam River

Only a single series of samples was taken by Hirsch; in April 1957. Minor changes in the fauna at Station 1 since then may be associated with an increase in fine sediment or an increase in available nutrients leading to a decrease in the importance of mayflies and an increase in the molluscan population. At Station 2 the species diversity was reduced, but oligochaetes and molluscs remained the most important groups and at Station 3 a similar situation was found.

(b) Oxygen Levels

In general, a comparison of the oxygen levels recorded by Hirsch (1958) with those obtained in the present study confirm the results of the faunistic surveys (Appendix 16). In the South Branch comparable saturation levels were found at each station in the two surveys although at the mouth they were even lower in 1970-71. Oxygen levels in the North Branch were significantly lower than in 1957 when the water at all stations was nearly saturated with oxygen. This suggests that the level of pollution has increased since then, probably through the accumulation and decomposition of organic matter. Respiration by the increased microflora and fauna associated with this could account for the reduction in oxygen levels.

Levels close to 100% saturation occurred in the Ohoka Stream but widely fluctuating levels were found in the Cust Main Drain, including supersaturation on two occasions. The photosynthetic activity of mats of filamentous algae and Elodea could account for this. Little change in oxygen levels was found in the Kaiapoi River where the saturation level was quite high.

Oxygen levels were consistently higher at all stations in the Northbrook Drain in 1971 than in 1957, and ranged from 74-90% saturation. As Hirsch did not make oxygen measurements on water from the Cam River, no comparison could be made. However, saturation levels obtained in the present study were comparable to those found in the Northbrook Drain and were not indicative of significant pollution.

(c) The Oligochaeta

Oligochaete worms belonging to the families Tubificidae and Lumbriculidae were abundant in the Waimakariri River system and in addition smaller numbers of the introduced lumbricid *Eiseniella tetraedra* were found at the Groynes in the South Branch. Smaller worms belonging to the Naididae also occurred and were frequently abundant but were not considered in this study.

Lumbriculus variegatus is the only lumbriculid recorded from New Zealand (and in fact from the Southern Hemisphere (Brinkhurst, 1971)) and the lumbriculids found in this study fitted Brinkhurst's description of this species. The tubificids could not be identified. Hirsch does not record the presence of lumbriculids at all in his study and it is assumed that he considered them to be Tubificidae.

The relative abundance of the two families at different stations in the four streams is compared in Table 1.

In the Cam immediately below the septic tank outflow where numbers were high, just over half the oligochaetes were Tubificidae, whereas lower downstream where numbers were greatly reduced, 90% were Lumbriculidae.

In the Northbrook Drain, which has a similar pollution source to the Cam, a fairly similar distribution of the two groups was found. Tubificids were most abundant above and immediately below the effluent outflow whereas at all stations further downstream lumbriculids were dominant and represented 87-97% of the worms taken.

Tubificidae were dominant at all stations in the North Branch, Ohoka Stream and Cust Main Drain but some Lumbriculids occurred at all stations, their largest numbers being below the ford and at the mouth of the North Branch.

Lumbriculidae dominated the fauna throughout most of the South Branch and the main river below the South Branch entrance. They were present in exceptionally high numbers below the freezing works outfalls. Few oligochaetes were found in the rapidly flowing water near Dickey's Road bridge, but 95% of those present were Tubificidae. The two groups existed in roughly equal proportions below the Groynes.

The difference in relative abundance of the two groups are not easy to explain in terms of water quality, substrate differences or extent of pollution, but it is clear that both groups are tolerant of enriched or polluted water where together they represent the major group in the bottom fauna.

(d) The Chironomidae

Larvae of seven chironomid species were found during this study and are listed below:

Chironomus zealandicus Hudson (Chironominae)

Polypedilum pavidus (Hutton) (Chironominae)

Tanytarsus sp. (Chironominae)
Pentaneura sp. (Tanypodinae)
Maoridiamesa harrisi Pagast (Diamesinae)
Orthocladius publicus Hutton (Orthocladiinae)
Orthocladiinae sp.

Of these the larvae of *Ch. zealandicus* are well known (Robb, 1966) but apart from *M. harrisi* the others have not been described.

Larvae of *Ch. zealandicus* and *Orthocladius publicus* were important inhabitants of polluted waters, whereas the others were less abundant and mainly confined to cleaner waters.

TABLE 1 RELATIVE ABUNDANCE OF TUBIFICIDAE AND LUMBRICULIDAE IN THE LOWER WAIMAKARIRI RIVER SYSTEM

Stations	Sample Size	Percentage Tubificidae	Percentage Lumbriculidae
R. Cam			
2	26,699	56	44
3	145	8	92
Northbrook Drain			
1	2,919	66	34
2	7,642	75	25
3	3,784	13	87
4	528	11	89
5	1,809	3	97
North Branch			
1	11,974	90	10
2	971	95	5
3	21,629	57	43
4	2,859	67	33
5	16,192	>99	<1
Ohoka	40	87	13
Cust	234	>99	<1
South Branch			
1	960	40	60
2 & 3	58	95	5
4	1,095	18	72
5	92,048	12	88
6	158	10	90
Main River	206	13	87

In the Cam River chironomid larvae were present in very small numbers except for those of Chironomous which were common in mud and organic debris at Station 2. Likewise, larvae of Chironomus were abundant in the organically enriched sand and mud at Station 2 in the Northbrook Drain but otherwise were present only in small numbers. Orthocladius and Maoridiamesa were important components of the fauna in the Northbrook Drain and their distribution could be correlated with changes in degree of enrichment (or pollution). This is clearly seen by considering the distribution and abundance of the two species on the grass, Glyceria throughout the drain (Appendix 8). Orthocladius was present at all stations but was most abundant below the septic tank outfall (Station 2). Maoridiamesa was present at Station 1, but was not present below the outfall or at Station 3. However, further downstream where the effects of the effluent were no longer apparent it reappeared and was the dominant chironomid at Station 6. By contrast, numbers of Orthocladius declined downstream.

In the North Branch, Chironomus was important in fine, detritus-enriched sediment at the baseline station and was very abundant in the thick layer of fine material deposited below the fellmongery. At the tidal junction high numbers were found in the rich mud at the stream margins. Few Orthocladius larvae were found at the baseline station but large numbers were found on hard substrata below the ford and at the stream mouth where the increased water flow had dispersed the fine particulate matter which was deposited below the fellmongery. Perhaps significantly, fewer larvae of this species were found in the Ohoka Stream or Cust Main Drain, where apart from reduced artificial enrichment, conditions similar to those at the mouth of the North Branch prevailed. Maoridiamesa was not found in the North Branch.

Chironomid larvae were not abundant in the South Branch. Small numbers of *Chironomus* were present at the "Groynes" but very few were found in the vicinity of Dickey's Road where current velocities were rapid and little organic matter was deposited. Large numbers occurred in the soft sediments below the effluents and in pockets of fine sediment in the main river below the entry of the South Branch. *Orthocladius* and *Maoridiamesa* were present below the Groynes on stones and *Myriophyllum* but few were found elsewhere.

The presence of *Chironomus* larvae seems to be determined initially by the presence of soft sediments in which they can burrow. Substrata of this kind are not found only in organically polluted waters, but they are frequently abundant in such places where fine particulate matter present in the effluent is often deposited on the stream bed. Deposits of this type are typically rich in nutrients which can be utilised directly or indirectly by the larvae. As larvae and pupae of this species are tolerant of low oxygen conditions and wide variations in water chemistry (e.g. salinity) (Robb, 1966), these substrata can be and are colonised extensively. The larvae of *Orthocladius* and *Maoridiamesa* were found mainly on stones and macrophytes. *Orthocladius* was tolerant of low oxygen conditions but it seems probable that *Maoridiamesa* is not. This is suggested by the distributions of the two species and by the ease (or difficulty) with which they could be kept alive when removed from the stream. Most larvae of *Maoridiamesa* died within an hour of collection when kept in a closed bag of stream water with other aquatic insects, (perhaps as a result of an increase in water temperature or a decrease in dissolved oxygen) whereas many larvae of *Orthocladius* remained alive under these conditions for several days after collection.

(e) Community Structure and Diversity

In both the North and South Branches a decrease in the species diversity index was found with an increase in pollution. This response of the fauna is typical of organically polluted streams and rivers (Hynes, 1963) and normally involves the elimination of species (particularly insects) which are less tolerant of the lower levels of oxygen found in enriched or polluted waters, and an increase in the numbers of tolerant forms, notably oligochaete worms.

In this study, as well as comparing stream bottom faunas in areas varying in degree of organic pollution, comparisons were made between the communities of macro-invertebrates inhabiting different substrata above the main sources of pollution. At the clean-water stations on the North and South Branches the largest numbers of species and the highest species diversities were found on hard substrata of stones and shingle in fairly rapidly flowing water, and the lowest diversities (which were comparable to those occurring in polluted sections of the streams) occurred amongst mud, silt and sand. The former habitat is structurally more diverse than the latter, being composed of particles of varying sizes. It possesses a relatively large surface area for colonization and many cracks and crevices of varying sizes which can be occupied by members of the bottom fauna. The larger stones also lie on a base of compacted fine sediments which provide a further definable habitat with a characteristic burrowing fauna.

Fine sediments provide a more uniform habitat than coarse ones, and related to this reduction in structural diversity is a reduction in biological diversity. The fauna of fine sediments typically is a burrowing one as opposed to that of coarse sediments which is a surface dwelling one, and the burrowing macro-invertebrate faunas of uniform fine sediments tend to be dominated by large numbers of a few relatively large species. Where coarse detritus accumulates in fine sediments, as it frequently does in still waters, the substrate diversity increases and an associated increase in species diversity is also found. As fundamentally different types of faunas can be expected on different types of substrata, this must be taken into account when attempting to evaluate the effects of pollution on the bottom fauna.

In the North and South Branches the kinds of pollution that occur have altered the nature of the substratum by depositing fine particulate matter on the stream beds, and they also reduce the oxygen level of the water. The accumulation of fine material on an initially "diverse" stream bed has made it more uniform, and the fine sediments created are suitable for colonization by a burrowing rather than a surface-dwelling fauna. Within the fine sediments of a stream bed, a rapid reduction in the oxygen concentration of the interstitial water occurs in the top few centimetres or even millimetres (Eriksen, 1966), and the burrowing fauna is composed largely of species which are able to tolerate a reduced supply of oxygen, or possess adaptations for obtaining it from above the sediment (e.g. some Tubificidae). This is in contrast with most surface dwellers, particularly insects which have a high oxygen demand. The open water in polluted reaches of streams of the Waimakariri River system is frequently partially deoxygenated, and this, in addition to alterations of the substratum undoubtedly prevents many species from occupying the surface of the stream bed.

The soft sediments deposited below the pollution sources in these streams differ from those found in clean waters in origin and in compactness. In both the North and South Branches the soft sediments of polluted waters consist largely of light, organic particles which are not compacted on the stream bed as are primarily inorganic sediments such as silt and sand.

As a result, partially oxygenated water can probably diffuse through them to a greater depth and they are colonised to a greater depth by members of the burrowing invertebrate fauna. The primarily organic origin of these soft sediments also provides a rich nutrient pool which can be used by the burrowing fauna directly or indirectly via the decomposer system. The importance of these differences is reflected in the development of an enormously increased burrowing fauna in polluted areas whose species composition, however, differs little from that found in soft sediments at unpolluted stations.

Also associated with the decrease in habitat and species diversity (from hard to soft substrata, or from clean to polluted water) is a simplification of the food web. In fine sediments little living plant material occurs and the invertebrates present (oligochaetes, chironomids, sometimes molluscs) ingest the sediments themselves. Where hard substrata are present, a variety of diatoms, filamentous algae, fine sediments and larger decaying plant fragments are commonly found, and all are ingested by the bottom fauna to some extent (Table 2). A similar simplification of the food web is found in polluted areas where a stony substratum is found. In such situations a heavy growth of algae is frequently found on the upper surfaces of the stones, but the dominant animals (e.g. *Orthocladius*; Gastropoda) seem to be primarily fine particle feeders. Animals which commonly feed on algae (e.g. several species of larval Trichoptera) are normally absent, probably because they are intolerant of the low levels of oxygen that occur there.

TABLE 2 Results of Gut content analyses of 18 invertebrates from unpolluted stations in the North Branch, South Branch and Northbrook Drain. The presence of materials is indicated by a cross. Where a species ingests a wide variety of materials the most abundant are indicated by two crosses.

Species	No. examined	Decaying plant fragments	Fine sediments	Grit	Diatoms	Filamentous algae	Arthropod fragments
TRICHOPTERA							
Pycnocentria	14	xx	x	x	x	x	
Pycnocentrodes	4	xx	x	x	x	xx	
Hudsonema	6	xx	x	x	x	xx	
Olinga	7	xx				x	
Hydropsyche	9	x	x	x		x	x
Polyplectropus	2		x		x		
Hydrobiosis parumbripennis	16	x					xx
H. frater	3						xx
Neurochorema	3		x				
Psilochorema	4		x				
EPHEMEROPTERA							
Deleatidium	28		xx	x	xx	x	
Coloburiscus	8	x	xx	x	x		
CHIRONOMIDAE							
Chironomus	8		xx	x			
Orthocladius	9		xx	x			
Maoridiamesa	4		xx	x	x		
COLEOPTERA							
Elmidae	6		x	x	xx	x	
AMPHIPODA							
Paracalliope	3		xx	x	x		
OLIGOCHAETA							
Lumbriculus + Tubificidae	9		xx	x			

SUMMARY AND CONCLUSIONS

1. Effluents from a fellmongery and a milking shed are pollution sources on the North Branch. Fine particulate matter from the former settles on the stream bed and has changed the nature of the substratum. A high proportion of this fine material is confined to a short stretch of stream immediately below the fellmongery where the stream gradient is shallow and the water flow slow. This alteration in the nature of the stream bed has been accompanied by a change in the composition of the fauna which is now dominated by burrowing forms, particularly oligochaete worms and chironomid midge larvae.

In addition to changing the nature of the bed, an increased supply of nutrients is added to the stream. This has undoubtedly resulted in an increase in numbers of benthic invertebrates. Respiration of these organisms results in oxygen depletion of the water, and particularly low values (including total deoxygenation) have been recorded at night. Washings from the milking shed undoubtedly aggrevate this situation further.

Some leaching of nutrients from farmland in the stream catchment area must also contribute to general enrichment of the water throughout the length of the stream and also in the Ohoka Stream and Cust Main Drain. The composition of the bottom faunas found in the latter two streams was considerably changed since 1957, these changes being of the kind to be expected through gradual enrichment (Allen, 1960; Hynes, 1969).

2. The lower course of the South Branch is heavily polluted by freezing works effluents which have had a similar effect to those from the fellmongery in the North Branch, smothering the stream bed with soft, particulate matter (much probably originating from stomach contents). This has resulted in similar changes in the composition and abundance of the fauna and a reduction in the oxygen content of the water, particularly at night. The effects of effluent discharges into the South Branch are harmful throughout the length of the stream, and continue well into the main Waimakariri River. In addition to their effect on the bottom fauna, effluents discharged into the South Branch give the stream

a disgusting appearance and smell. These factors have effectively destroyed it as a recreational facility. Perhaps it is "unfortunate" that many people only see the lower Waimakariri River during weekends when the freezing works are not in operation and its appearance is somewhat more favourable!

3. Pollution sources in the Northbrook Drain and Cam River were septic tanks, but their effects on the streams were minor. Small changes in composition of the bottom fauna were found below the outfalls, but these were very localised. High oxygen levels were found throughout both streams.

4. A comparison with the results of Hirsch's 1956-57 survey suggests that the effects of organic pollution are greater now in both the North and South Branches than they were in 1957, but that little change has occurred in the Northbrook Drain or the upper Cam River.

5. A complete clean up of the stream should be possible if no effluents are emptied into them. Failing this, considerable improvement in the North and South Branches could be achieved through greater treatment of wastes before their release. Specifically, if all particulate matter including very fine materials was settled out, deleterious changes to the stream beds through smothering could be prevented. Consequently, the huge increase in the burrowing fauna and other decomposer organisms whose respiration leads to severe oxygen depletion in the water at times, would be reduced. In addition, more efficient treatment of wastes to produce a cleaner effluent would improve the aesthetic appearance of the rivers and make them into more desirable recreational facilities.

6. In this study a considerable body of information on the biology of the four Waimakariri tributaries has been accumulated, and this should provide a firm basis for future comparative studies following the introduction of pollution control measures, if and when these are undertaken. In making such a follow-up study it would be desirable to use the same procedures carried out here and to make the study at the same time of year so that changes in fauna brought about by seasonal factors are minimised.

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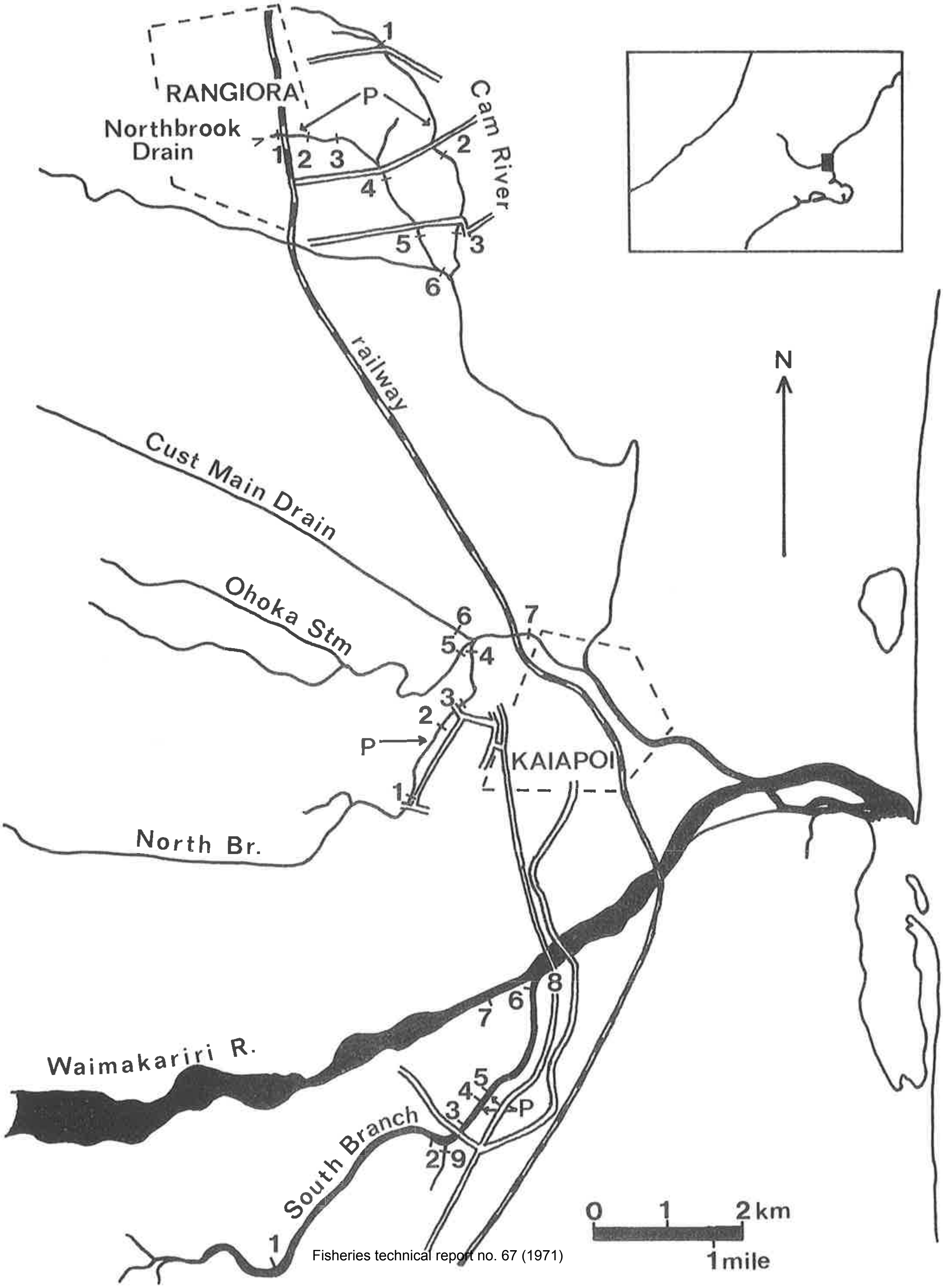
FIGURE 1


RANGIORA
Northbrook Drain
P
Cam River
1
2
3
4
5
6
railway
N
Cust Main Drain
Ohoka Stm
7
KAIAPOI
North Br.
P
Waimakariri R.
8
South Branch
P
9
0 1 2 km
1 mile

APPENDIX 1 Locations of sampling stations on the 4 stream systems. Map references are to NZMS 1 Sheet S76 (Kaiapoi).

1. North Branch

Station No.	Hirsch's Station No.	Map Reference	Distance from station above (m)	Descriptive Location
1	1	995728		Neeve's Road bridge
2	-	001741	1.6 Km	Below fellmongery
3	3	002742	40 m	Ford
4	4	005753	960 m	N. Br. mouth
5	6	004753		Ohoka mouth
6	7	004754		Cust mouth
7	5	011754	700 m	Kaiapoi R., railbridge
2. South Branch				
1	1	980661		Below Groynes
2	2	003677	3.5 Km	Above Dickey's Rd
3	5	004678		Below Dickey's Rd
4	-	005679	120 m	Between effluents
5	6	006680	50 m	Below effluents
6	8	014702	2.62 Km	S. Br. mouth
7	11	002696		Main River above S. Br.
8	12	018704	500 m	" " below "
9	3	003677		Drain above Dickey's Rd
3. Northbrook Drain				
1	1	978830		Below bridge N. Belt Rd
2	2	983828	525 m	Above trib. drain
3	3	985828	40 m	Below trib. drain
4	4	990824	800 m	Below bridge, Boys Rd
5	6	995815	1.14 Km	Marsh Rd
6	7	998809	700 m	Mouth of Drain
4. Cam River				
1	1	989842		Rangiora-Woodend Rd
2	2	997829	1.8 Km	Below Boys Rd
3	3	002816	1.6 Km	Below Marsh Rd

APPENDIX 2A

Physical and biological features at Station 1 on the North Branch.

Substation	a	b	c	d	e	f	g	h	i
Fauna									
(a) No./0.1m^2	167	3073	5757	3689	1207				
No./g weed						375	185	122	119
(b) mg/0.1m^2	105	575	1529	603	286				
mg/g weed						153	66	78	36
No. of species	20	5	3	6	7	14	14	18	6
Diversity index	3.53	0.50	0.23	0.61	0.94	2.19	1.88	3.54	1.04
Current (cm/sec)	50	52	52	6	6	53	6	52	6
Substratum	Shingle	Sand Silt Mud Detritus	Mud Silt	Mud Silt Detritus	Mud Silt	*Myriophyllum*	*Myriophyllum*	*Elodea*	*Elodea*

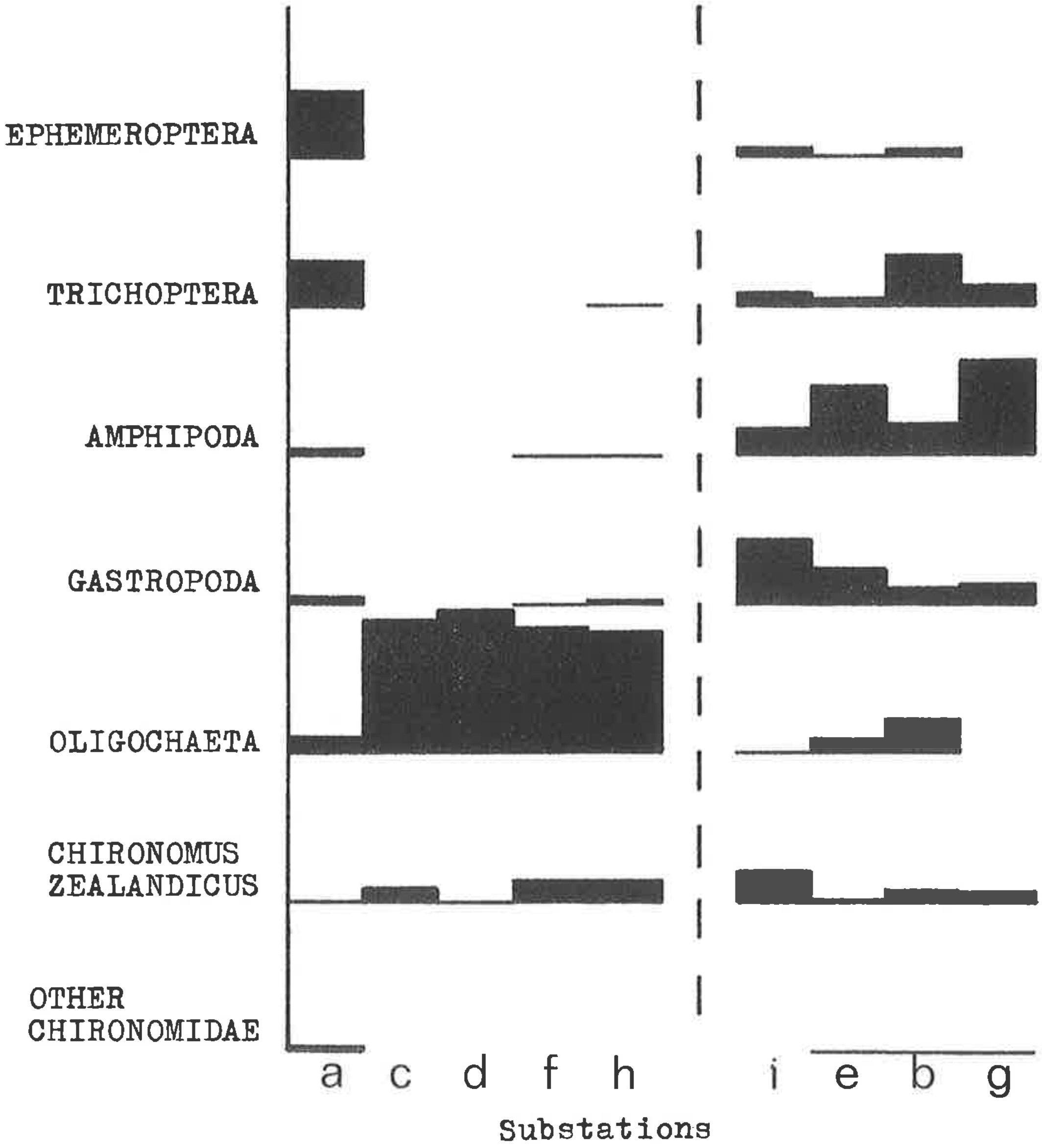


FIGURE 2

(Refer Appendix 2A)

APPENDIX 2B Physical and biological features at Stations 2-7 of the North Branch system

Station	2	3a	3b	3c	4a	5a	6	7	4b	5b
Fauna										
(a) No./0.1m^2	7090	11552	14763	1646	2066	406	89	782	4151	16172
(b) mg/0.1m^2	3322	3108	5971	751	741	228	22	406	1473	2020
No. of species	4	6	8	8	11	15	13	8	4	2
Diversity index	0.34	0.54	0.73	0.95	1.31	2.32	2.68	1.05	0.36	0.10
Current (cm/sec)	28	23	50	50	200*	140	30	?	-**	-**
Substratum	Mud Muck	Sand Silt Gravel	Sand Silt *Potamogeton*	Sand Gravel Shingle	Shingle	Shingle	Shingle Sand	Shingle Sand	Mud	Mud

* Low tide value. At high tide water is still or even reversed flow.

** Exposed mud at all times except at high tides.

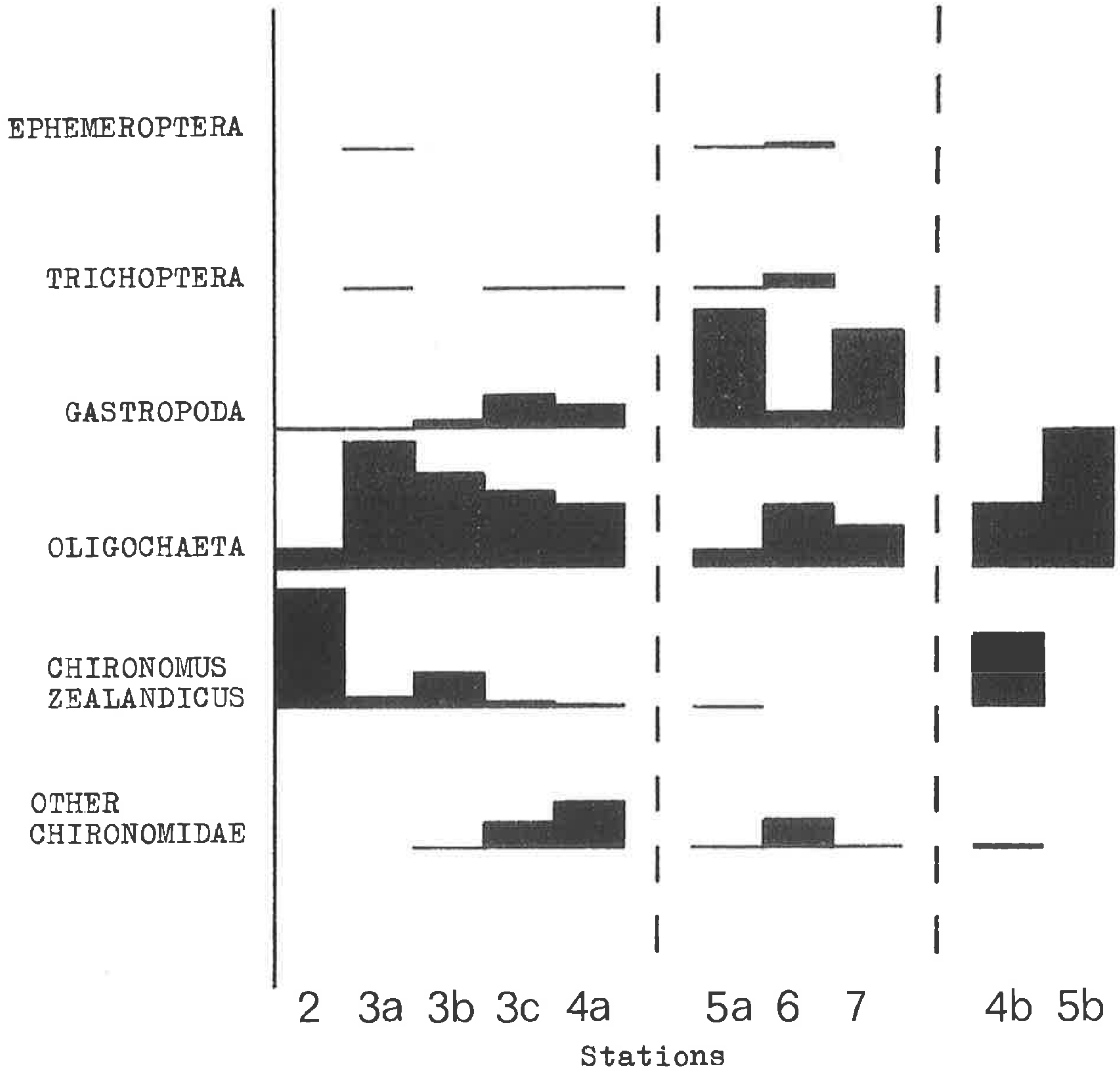


FIGURE 3

(Refer Appendix 2B)

APPENDIX 3A Physical and biological features at stations above the pollution source on the South Branch

Station	1a	1c	2	3	1b
Fauna					
(a) No./0.1m^2	378	1110	351	305	
No./g weed					538
(b) mg/0.1m^2	306	394	154	143	
No./g weed					68
No. of species	24	8	17	18	17
Diversity index	3.87	1.00	2.72	2.97	2.54
Current (cm/sec)	30	30	90	80	30
Substratum	Gravel Algae	Gravel Sand Detritus	Gravel	Gravel	*Myriophyllum*

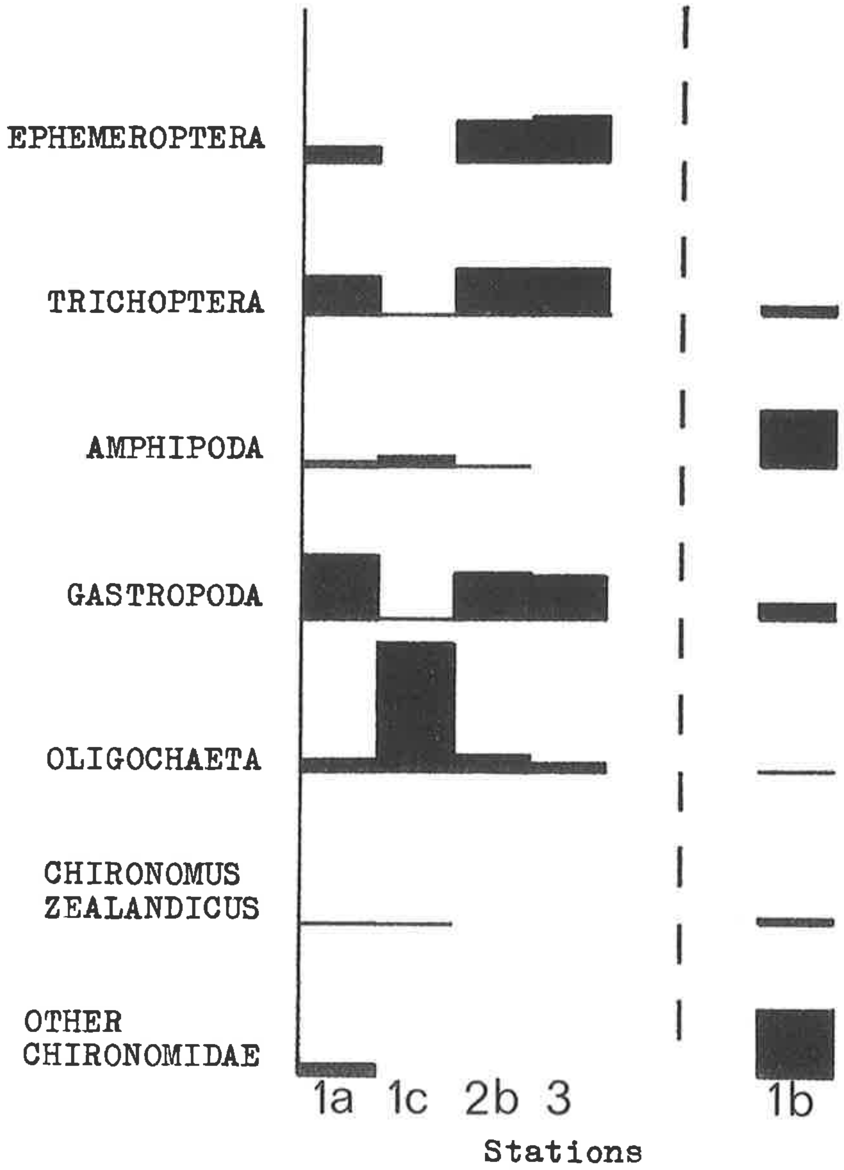


FIGURE 4

(Refer Appendix 3A)

APPENDIX 3B Physical and biological features at stations below the pollution source on the South Branch and in the main Waimakariri River

Station	4	5a	5b	5c	6	8	7	9a	9b
Fauna									
(a) No./0.1m^2	1156	37596	9948	45110	165	207	48	28400	40
(b) mg/0.1m^2	1741	30010	5415	43955	118	88	33	5600	73
No. of species	3	3	3	3	8	3	8	1	5
Diversity index	0.28	0.19	0.22	0.19	1.15	0.37	1.80	0	1.08
Current (cm/sec)	30	45	30	0	30	30	40	45	30
Substratum	Sand Gravel Organic Sediment Sewage fungus	Gravel 'ooze' (mid-stream)	'Ooze' 5-10cm deep (side stream)	Sewage Fungus	Gravel Sewage fungus	Sand Stones Sewage fungus	Sand Stones	Silt Organic debris	Gravel

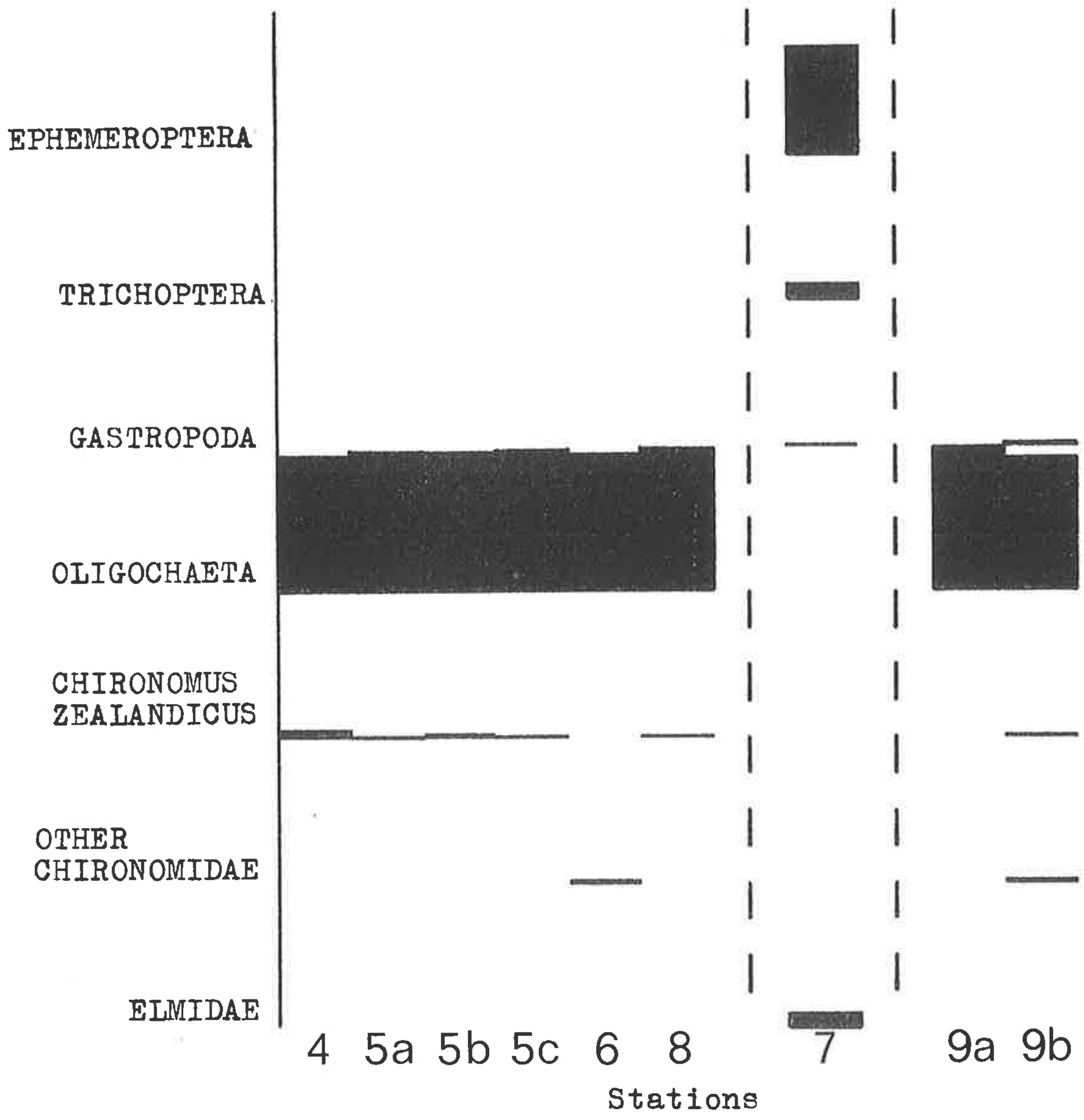


FIGURE 5

(Refer Appendix 3B)

APPENDIX 4A Physical and biological features at sampling stations with soft and hard substrata in the Northbrook Drain

Stations	1a	1c	2d	2c	3a	4b	5a	6a
Fauna								
(a) No./0.1m^2	1621	1454	8418	1462	3883	683	2583	399
(b) mg/0.1m^2	1489	913	4780	932	2011	440	1247	634
No. of species	8	4	6	13	13	20	16	18
Diversity index	0.95	0.41	0.55	1.66	1.46	2.92	1.91	2.84
Current (cm/sec)	24	24	45	45	52	50	50	100
Substratum	Clay Sand Mud Detritus	Sand Mud	Sand Mud	Gravel	Gravel Sand	Gravel Algae	Gravel	Gravel Sand

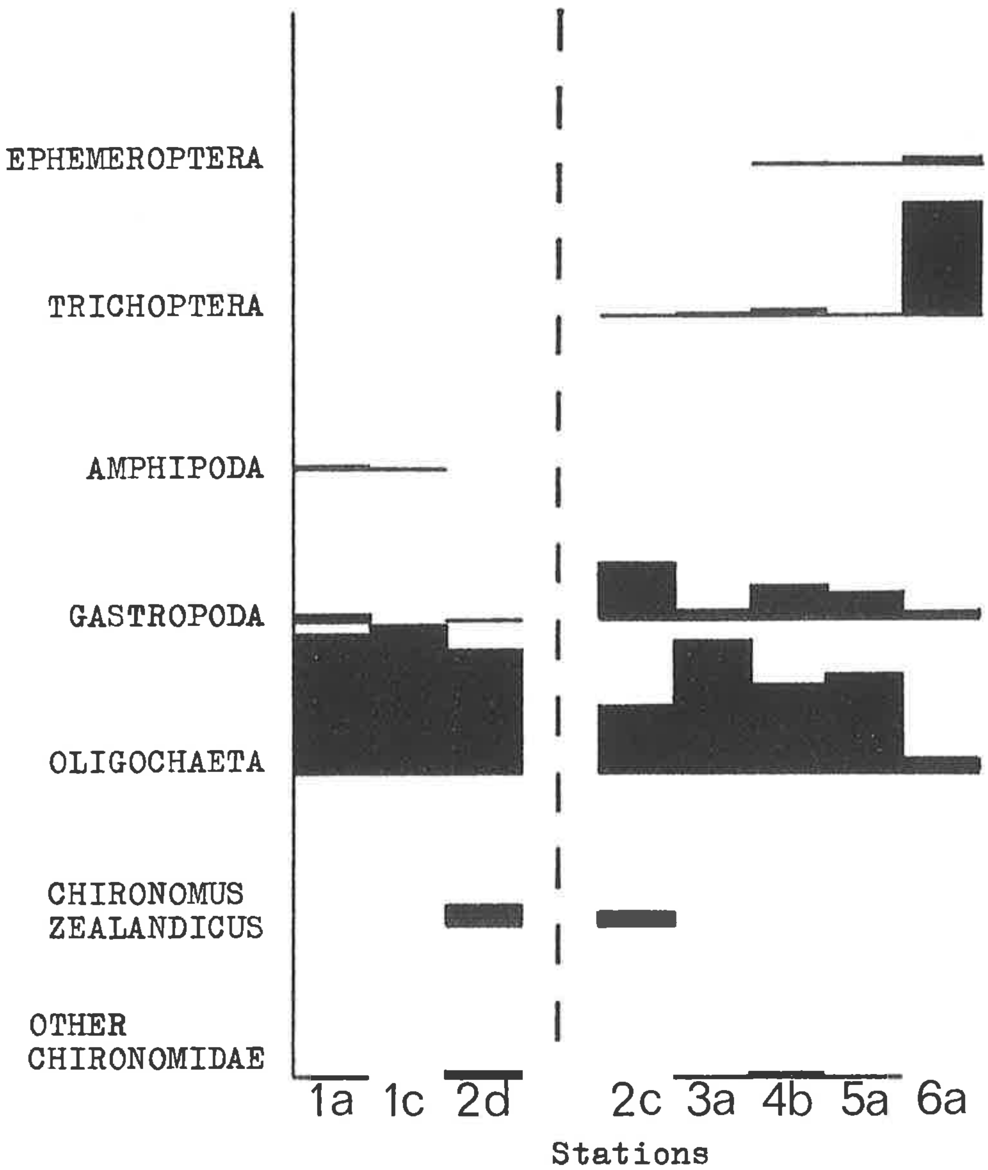


FIGURE 6

(Refer Appendix 4A)

APPENDIX 4B Physical and biological features at sampling stations with the macrophytes *Glyceria* and *Rorippa* in the Northbrook Drain

Stations	1d	2a	3b	4a	5b	6b	1b	2b	4c
Fauna									
(a) No./g weed	350	1231	1135	557	713	310	378	1429	155
(b) mg/g weed	48	212	379	185	450	190	78	355	46
No. of species	12	8	18	18	16	20	9	10	19
Diversity index	1.97	0.99	2.42	3.26	2.36	3.31	1.35	1.24	3.57
Current (cm/sec)	24	45	52	50	50	100	24	45	0
Substratum	*Glyceria*	*Glyceria*	*Glyceria*	*Glyceria*	*Glyceria*	*Glyceria*	*Rorippa*	*Rorippa*	*Rorippa*

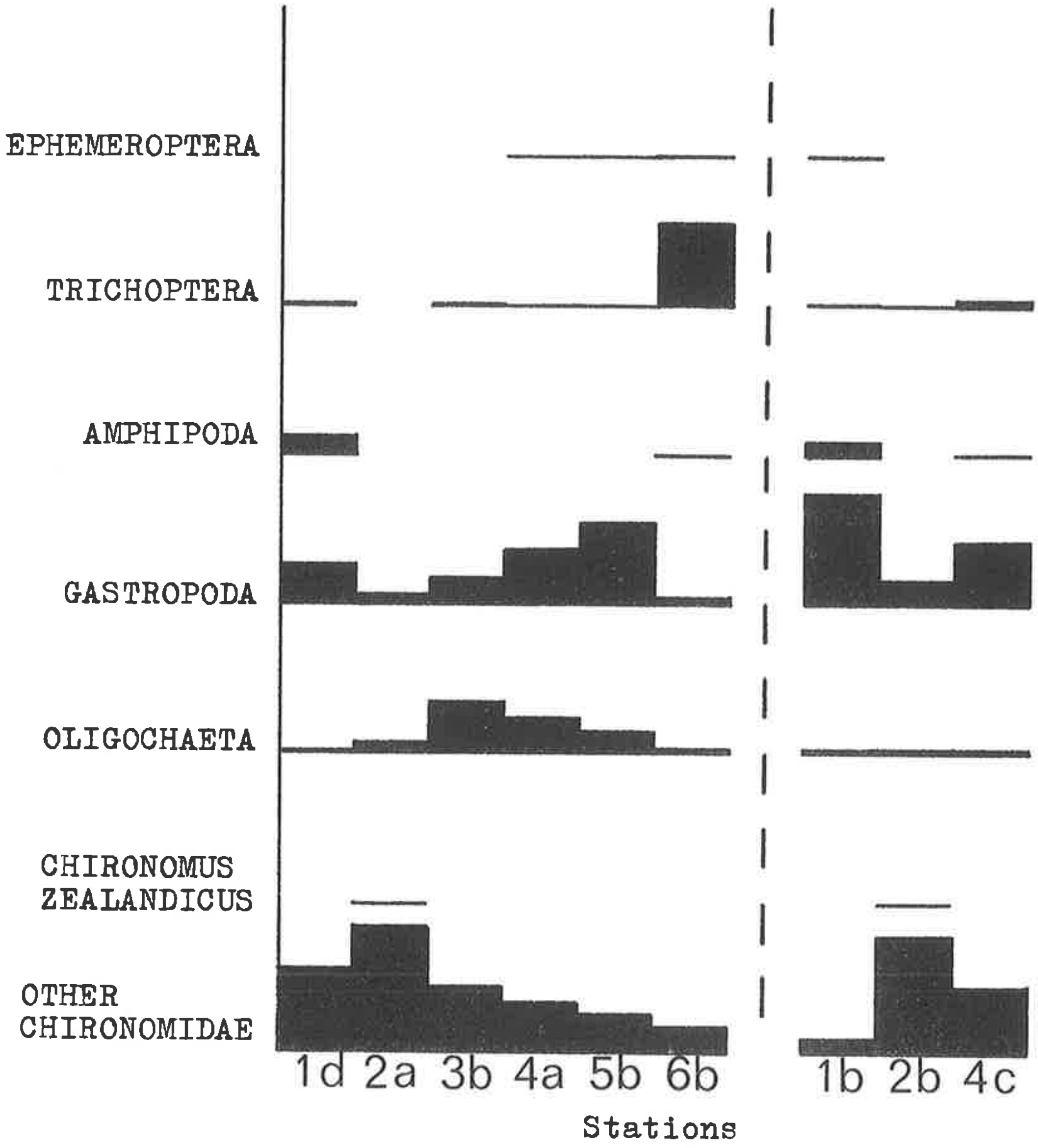


FIGURE 7

(Refer Appendix 4B)

APPENDIX 5 Physical and biological features at all stations on the Cam River

Stations	1a	2a	2c	3a	1b	2b	3b	2d
Fauna								
(a) No./0.1m^2	260	25740	1923	2717				
No./g weed					31	1137	127	469
(b) mg/0.1m^2	191	11237	916	2732				
mg/g weed					25	435	202	249
No. of species	12	5	8	10	17	5	6	7
Diversity index	1.98	0.65	0.93	1.14	3.56	0.57	1.76	0.98
Current (cm/sec)	83	33	126	144	83	33	144	126
Substratum	Gravel	Mud and pine debris over gravel	Gravel Algae	Gravel Algae Glass Bricks	*Glyceria*	*Glyceria*	*Glyceria*	Filamentous algae

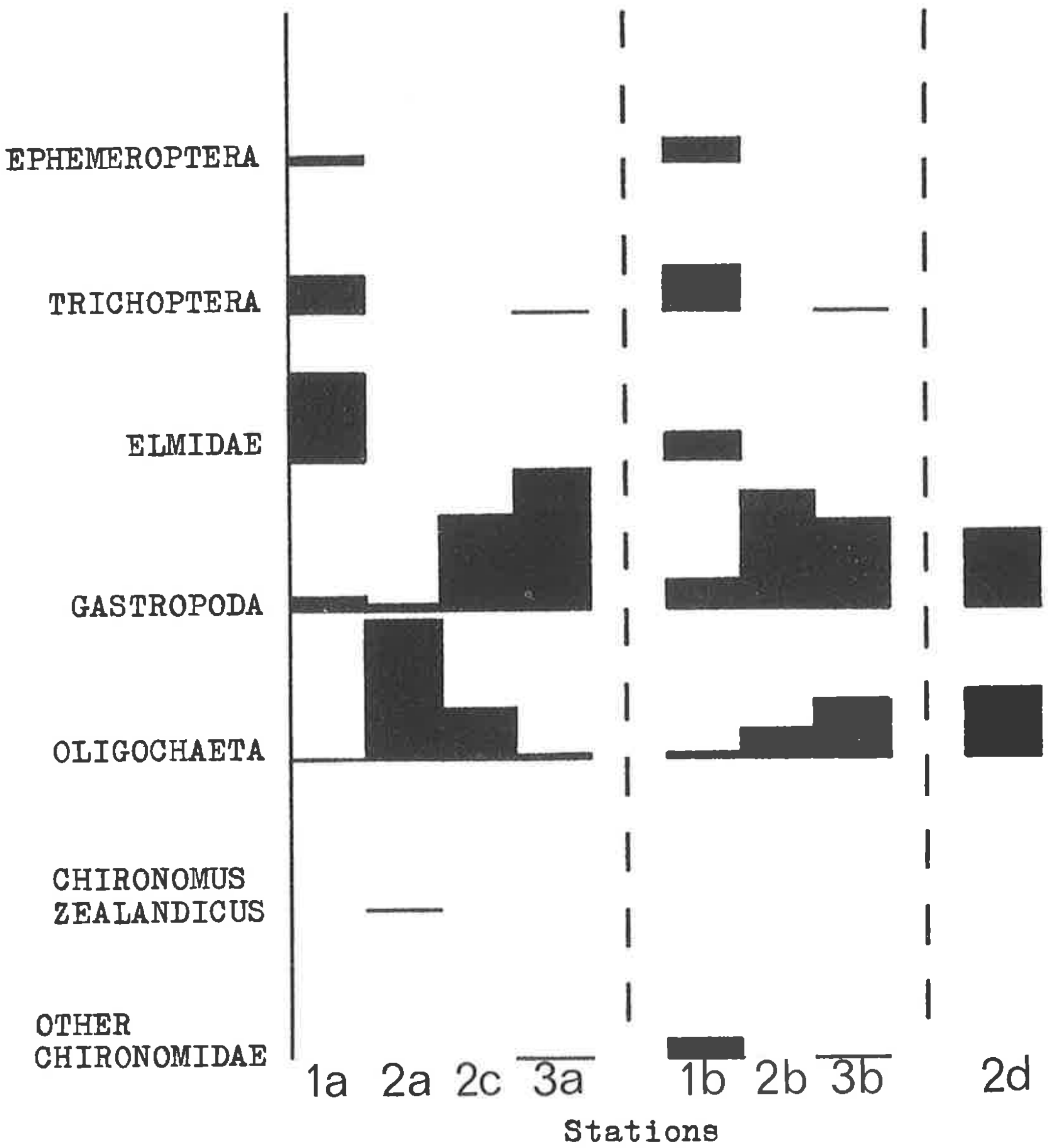


FIGURE 8

(Refer Appendix 5)

APPENDIX 6 North Branch, Waimakariri River and tributaries: Quantitative sampling. Mean numbers of animals per 0.1m2 (or per g dry wt weed where indicated by an asterisk). Each value given is the mean of 3 samples. Sampling was carried out between 24 November and 7 December 1970.

Station Number -	1a	1h*	1b	1c	1g*	1d	1i*	1e	1f*	2	3a	3b	3c	4a	4b	5a	5b	6	7
EPHEMEROPTERA																			
Deleatidium sp.	75	6.3	-	-	3.3	-	-	-	23	-	8.6	-	-	-	-	0.3	-	2.3	-
Coloburiscus humeralis									4.6										
COLEOPTERA																			
Elmidae	0.3															0.3		0.3	
Antiporus sp.	0.3																		
TRICHOPTERA																			
Hydropsyche sp.	7.7								1.6										
Helicopsyche sp.	14								0.6										
Olinga feredayi	0.6	5							4.6										
Pycnocentria evecta	17.3	28			5		17.3		24										
Pycnocentrodes aureola	1.3	0.3									33.6								
Hudsonema amabilis	0.6	0.6																	
Oxyethira sp.	4.3													0.3		0.3		8	
Polyplectropus sp.		5.6			3.3			8.6	1.3										
Hydrobiosis clavigera	0.6															0.3			
H. parumbripennis	6															0.3			
Psilochorema bidens	2.3								0.3							0.6			
CRUSTACEA																			
Paracalliope fluviatilis	5.3	26.6			87.3	14	76.5	17.3	62.6							1.3			
Ostracoda		0.3			3.3													4.6	
MOLLUSCA																			
Potamopyrgus antipodarum	8.6	8.6	9.6		30.3		13	8.6	64.3	8.6	43.3	848	397	307		338		9.6	540
Physa sp.		4.3	0.3		14	8.6	1.6	17.3	100.3			26		8		1.6		1.3	3
Planorbis corunna										1		8.6	0.3	22				0.3	3
Sphaeriidae		0.3			3	14			6.6			8.6				2			

North Branch (contd)

Station Number -	1a	1b*	1c	1d	1e*	1f	1g*	1h	1i*	2	3a	3b	3c	4a	4b	5a	5b	6	7
OLIGOCHAETA																			
Tubificidae	6.6	2.6	2305	5411		2777		320	3	919	10539	1421	274	339	1586	43.8	16120	36.3	232
Lumbriculus variegatus	11.6	19.6	355	303	19.3			69		52	147	8627	621	622	312	16.3	52	4	2
HIRUDINEA																			
Glossiphonia sp.		0.3														0.3			
PLATYHELMINTHES																			
Cura pinguis	0.3	2			4									0.3		3.6		1.6	
DIPTERA																			
Chironomus zealandicus	1	10	313	43	6	503	10	165	78	6110	780	3720	64.6	59	2149	3			
Tanypodinae sp.		1			0.6								1.3	1.3				10	
Orthocladius publicus							1.3					104	288	707	104	1		10	0.5
Orthocladiinae sp.	6																		
Syrphidae														0.7					
Austrosimulium sp.																			
ODONATA																			
Xanthocnemis zealandica	7																	1	
TOTAL	167	122*	3073	5757	185*	3689	119*	1207	375*	7090	11552	14763	1646	2066	4151	406	16172	89	782

APPENDIX 7 South Branch, Waimakariri River: Quantitative sampling. Mean numbers of animals per $0.1m^2$ (or per g. dry wt. weed in the asterisked sample). Each value given is the mean of 3 samples. Sampling was carried out between 7-24 December 1970.

Station Number -	1a	1b*	1c	2	3	4	5a	5b	5c	6	7	8	9
EPHEMEROPTERA													
Deleatidium sp.	39	0.6		95	88.6	-	-	-	-	-	36	-	-
Coloburiscus humeralis	-	-		0.3	0.6	-	-	-	-	-	-	-	-
COLEOPTERA													
Elmidae											5		
TRICHOPTERA													
Hydropsyche sp.				4.6							1		
Helicopsyche sp.				9.6	11								
Olinga feredayi	2	1.3		11	30.6								
Pycnocentria evecta	0.6	10.3		3.3	0.3								
Pycnocentrodes aureola	4.6			70.3	44.6						0.5		
Hudsonoema amabilis	1	1.3		1.6	1								
Oxyethira sp.	68.6	16	52		0.3					0.3	2.5		
Paroxyethira sp.		2											
Polyplectropus sp.	0.6	2											
Hydrobiosis parumbripennis	1	1.3		1	1								
H. frater				0.3	1						2		
Psilochorema bidens	7.6			2.3	0.6								
Neurochorema confusm	3.6			1									
CRUSTACEA													
Paracalliope fluviatilis	13.6	197	78	0.6									
Ostracoda	1.6	1.3	26										
MOLLUSCA													
Potamopyrgus antipodarum	159	31		111	104								
Physa sp.	0.6	27.6			0.6					0.6	1		
Planorbis corinna	3	1.6	8.6										

South Branch (Contd)

Station Number -	1a	1b*	1c	2	3	4	5a	5b	5c	6	7	8	9
OLIGOCHAETA													
Tubificidae	9.6		373	38.6	16.3	308	4780	5841	450	15	0.5	31	28400
Lumbriculus variegatus	14	1.3	563	1	2.3	787	32781	3986	44210	143		175	
Eiseniella tetraedra	7.3			0.3									
HIRUDINEA													
Glossiphonia sp.	1.3												
PLATYHELMINTHES													
Cura pinguis	1.6				0.3								
Rhabdocoela										2			
DIPTERA													
Chironomus zealandicus	2.3	17.3	8.6		0.3	61	34.6	121	450	0.6		1	
Tanypodinae sp.	1												
Orthocladius publicus	30	164	0.3							3			
Maoridiamesa harrisi	1	65			1								
Tanytarsus sp.		1											
Limnophora sp.										0.5			
TOTAL	378	538*	1110	351	305	1156	37596	9948	45110	165	48	207	28400

APPENDIX 8 Northbrook Drain: Quantitative Sampling. Mean numbers of animals per $0.1m^2$ (or per g dry wt weed where indicated by an asterisk). Each value given is the mean of 3 samples. Sampling was carried out between 10-20 January 1971.

Station Number -	1a	1b*	1c	1d	2a*	2b*	2c	2d	3a	3b*	4a*	4b	4c*	5a	5b*	6a	6b*
EPHEMEROPTERA																	
Deleatidium sp.							0.6				1.6	8	0.3	22	6	18	4.5
COLEOPTERA																	
Elmidae														1.3		1	0.5
TRICHOPTERA																	
Hydropsyche sp.									57	1		0.6	1.6	8.6	1.3	193	36
Olinga feredayi				2												3.6	1
Pycnocentria evecta							0.6		9	2.3	1.6	9	0.3	1.3	1.3	27	101
Pycnocentroaes aureola							3.3		17		1.3	8				34	32
Hudsonema amabilis																	1
Oxyethira sp.				1.5		1				0.3	3		4	4	2.6		1
Polyplectropus sp.		6.6							1.3								
Hydrobiosis frater										0.6	0.3						
H. parumbripennis										0.3	0.6	2		5.6	1.3	3.3	
H. umbripennis													0.6				
Psilochorema bidens							0.6					1.6	1.6				
Helicopsyche sp.																36	1.5
CRUSTACEA																	
Ostracoda								17		3.3	1	10	0.3		0.3		
Paracalliope fluviatilis	26	37	8	39							0.3		0.6		0.6	1.3	3.5
MOLLUSCA																	
Potamopyrgus antipodarum	61	256		91	4	14	466		183	19	30	68	4.6	397	324	25	8.5
Physa sp.		25		4	68	232	107	34	34	175	178	100	60	89	68	1.3	5
Planorbis corinna													0.3				
Sphaeriidae					4		113		111	4		46	0.3	262	19	11	7

Northbrook Drain (Contd)

Station Number -	1a	1b*	1c	1d	2a*	2b*	2c	2d	3a	3b*	4a*	4b	4c*	5a	5b*	6a	6b*
OLIGOCHAETA																	
Tubificidae	632	7	1282	5	6.6	1	313	5440	495	10	0.3	56	0.3	56	4	23	3
<u>Lumbriculus variegatus</u>	831	4.5	156	2	89	44	316	1433	2886	393	128	338	5	1648	101	18	6.5
<u>Eiseniella tetraedra</u>	43		8				0.6		13			1.3				0.6	
PLATYHELMINTHES																	
<u>Spathula</u> sp.	11			3.5							2	4		7	0.3		2
DIPTERA																	
<u>Chironomus zealandicus</u>					11	5.3		1078		0.6		0.6					
Tanypodinae sp.	8.6	13				1.6						0.6	0.3				
<u>Orthocladius publicus</u>	8.6	27.6		189	1019	1117	138	416	72	485	177	26	71	17	104		18
<u>Maoridiamesa harrisi</u>				9							4		1	58	79	0.6	71
<u>Austrosimulium</u> sp.		1.3		1.5	29	12	2		2.6	33	26	1.3	2.3	3	8.6	2	8.5
<u>Limnophora</u> sp.				1.5		1	2.3			3.6	2	0.6	1.6	4		0.3	0.5
Empididae sp.									2.6	10	0.3						
Muscidae sp.										2.3							
TOTAL	1621	378*	1454	350	1231*	1429*	1462	8418	3883	1135*	557*	683	155*	2583	713*	399	310*

APPENDIX 9 Cam River: Quantitative sampling. Mean numbers of animals per 0.1m^2 (or per g dry wt weed where indicated by an asterisk). Each value given is the mean of 3 samples. Sampling was carried out between 10-20 January 1971.

Station Number	1a	1b*	2a	2b*	2c	2d*	3a	3b*
EPHEMEROPTERA								
Deleatidium sp.	10	3.3						
Coloburiscus humeralis		1.3						
COLEOPTERA								
Elmidae	155	5						
TRICHOPTERA								
Hydropsyche sp.	28	1.6						
Olinga feredayi	8							
Pycnocentria evecta	24	59					12	
Pycnocentrodes aureola	3	1.3						
Hudsonema amabilis	0.6	0.3						
Oxyethira sp.				5				
Hydrobiosis parumbripennis	2	1						1
Unidentified pupae								
CRUSTACEA								
Paracelliope fluviatilis		0.3			0.6			
MOLLUSCA								
Potamopyrgus antipodarum	25	6	121	643	1203	241	2390	66
Physa sp.	0.3			252	45	3	201	9
Sphaeriidae					6	2	4	
OLIGOCHAETA								
Tubificidae	0.6	0.3	14681	3	260	16	4.5	8
Lumbriculus variegatus		0.3	10887	234	405	203	92	41
Eiseniella tetraedra	4				2	4	4.5	
PLATYHELMINTHES								
Spathula sp.		0.3			1	0.3	0.5	
DIPTERA								
Chironomus zealandicus			17					
Orthocladius publicus		2.3					2	2.3
Maoridiamesa harrisi		1.6						
Austrosimulium sp.		6						
Limnophora sp.		0.3	34					
TOTAL	260	31*	25740	1137*	1923	469*	2717	127*

APPENDIX 10 North Branch: Diurnal Water Sampling Results (1-2 Feb.)

(a) Temperature (°C), Oxygen (mg/L), oxygen % saturation

Station	2p.m. T	2p.m. O_2	2p.m. %S	6p.m. T	6p.m. O_2	6p.m. %S	10p.m. T	10p.m. O_2	10p.m. %S	2a.m. T	2a.m. O_2	2a.m. %S	6a.m. T	6a.m. O_2	6a.m. %S	10a.m. T	10a.m. O_2	10a.m. %S	2p.m. T	2p.m. O_2	2p.m. %S
1	17.5	8.2	84.8	18	7.7	80.7	16.5	5.8	58.9	16.5	5.64	57.1	15	6.0	59.0	15	7.3	71.8	17.5	8.4	87
2	16.5	4.2	42.7	17.5	5.30	54.8	17	3.6	36.9	16.5	3.66	37.1	16	0	0	16.5	3.04	30.9	17	4.24	43.4
3	16.5	4.0	40.6	17.5	4.8	49.7	17	3.7	38.0	16.5	3.60	36.5	15	0	0	17	3.4	34.9	17	4.1	42.1
4	19	3.56	38.1	17.5	2.86	29.6	17	2.64	27.1	16	2.0	20.1	16	3.44	34.6	18	0.9	9.4	19	2.9	31.0
5	17.5	9.30	96.5	16.5	8.8	89.8	16	6.12	61.5	15.5	5.4	53.7	16.5	5.74	58.1	17.2	8.16	84.2	18	9.4	98.4
6	18.8	5.6	60.0	24	7.5	88.0	20	5.5	60.0	17	6.66	68.4	15.5	7.5	74.5	19.5	10.9	118	23.5	11.2	130
7	20.5	8.94	98.5	20	8.1	88.2	18	3.68	38.6	17.5	6.72	69.7	18	4.4	46.1	20	7.74	84.3	20	6.94	75.6

(b) Turbidity (OD350), Conductivity (μmho)

Station	2p.m. T	2p.m. C	6p.m. T	6p.m. C	10p.m. T	10p.m. C	2a.m. T	2a.m. C	6a.m. T	6a.m. C	10a.m. T	10a.m. C	2p.m. T	2p.m. C
1	.01	122	.005	120	.01	120	.006	115	.007	120	.01	120	.01	120
2	.015	172	.008	128	.011	120	.01	120	.13	325	.03	290	.028	250
3	.015	181	.012	135	.013	120	.01	121	.1	346	.025	306	.025	240
4	.03	264	.01	170	.01	130	.011	125	.01	125	.03	310	.03	270
5	.015	140	.04	140	.042	140	.045	137	.043	145	.048	147	.045	143
6	.025	210	.04	135	.04	152	.025	145	.03	148	.03	138	.03	134
7	.03	162	.03	170	.03	150	.025	162	.025	140	.045	180	.04	187

(c) Mean values per station over 24 hour period and range of values

	Oxygen		Temperature		Conductivity	
1	7.0	(8.4 5.64)	16.6	(18 15)	119.5	(122 115)
2	3.43	(5.3 0)	16.7	(17.5 16)	201	(325 120)
3.	3.34	(4.8 0)	16.65	(17.5 15)	207	(346 120)
4	2.61	(3.56 0.9)	17.5	(19 16)	199.5	(310 125)
5	7.56	(9.4 5.4)	16.74	(18 15.5)	141.7	(147 137)
6	7.84	(11.2 5.5)	19.76	(24 15.5)	151.7	(210 134)
7	6.65	(8.94 3.68)	19.1	(20.5 17.5)	165	(187 140)

APPENDIX 11 South Branch: Diurnal Water Sampling Results (25-26 Jan.)

(a) Temperature (°C), Oxygen (mg/L), Oxygen % Saturation

Station	10a.m. T	10a.m. O_2	10a.m. %S	2p.m. T	2p.m. O_2	2p.m. %S	6p.m. T	6p.m. O_2	6p.m. %S	10p.m. T	10p.m. O_2	10p.m. %S	2a.m. T	2a.m. O_2	2a.m. %S	6a.m. T	6a.m. O_2	6a.m. %S	10a.m. T	10a.m. O_2	10a.m. %S
1	15	9.9	97.5	18	10.8	113	19.5	10.0	108	18	6.72	70.3	15.5	6.50	64.6	15.5	7.66	76.3	14.5	8.52	83.2
3	15	9.0	88.8	17	9.12	93.7	17	7.78	80.0	17	4.2	43.1	16	5.46	54.7	15	5.10	50.2	14.5	8.02	78.3
4	15.5	8.12	80.8	17.5	7.64	79.2	17.5	7.42	77.0	17.5	3.06	31.7	16	6.14	61.7	15.5	4.92	49.0	15	7.38	72.7
5	16	5.50	55.3	18	5.54	58	17.5	6.94	71.8	18	2.28	23.8	16	4.44	44.5	15.5	3.80	37.8	15.5	3.76	37.4
6	16.5	3.50	35.5	18.5	3.12	33	17.8	3.22	33.7	18	1.88	19.7	16	2.64	26.5	15.5	2.18	21.7	15.5	2.78	27.7
8	18.5	5.34	56.4	21	3.2	35.6	20	4.36	47.5	17	3.50	35.9	16	2.86	28.7	15.5	2.48	24.7	16.0	4.16	41.8
7	21	8.96	99.6	24	8.32	97.5	22.5	8.24	94	19.5	8.12	87.8	17.5	7.64	79.0	17	7.72	79.2	17.5	9.28	96.2

(b) Turbidity (OD 350), Conductivity (µmho)

Station	10a.m. T	10a.m. C	2p.m. T	2p.m. C	6p.m. T	6p.m. C	10p.m. T	10p.m. C	2a.m. T	2a.m. C	6a.m.	10a.m. T	10a.m. C
1	0	80	0	80	0	80	0	87	0	80	-	.005	80
3	.01	90	.01	86	.008	84	.01	85	.01	85	-	.01	84
4	.025	142	.03	173	.035	158	.02	161	.022	121	-	.015	145
5	.12	300	.09-.32	330	.045-.04	188	.18 .04	180	.12-.02	140	-	.165 .155	425
6	.07 .06	192	.07	222	.11 .06	265	.07 .045	198	.13 .045	138	-	.075 .055	185
8	.025	148	.04	168	.03	269	.02-.101	144	.02 .01	139	-	.025	138
7	.105	80	.145	80	.03	77	.035	86	.05	78	-	.065 .06	78

(c) Mean values per station over 24 hour period and range of values

Station	Oxygen			Temperature			Conductivity		
1	8.6	10.8	6.5	16.57	19	14.5	81.2	87	80
3	6.95	9.12	4.2	15.9	17	14.5	85.6	90	84
4	6.38	8.12	3.06	16.36	17.5	15	150	173	121
5	4.61	6.94	2.28	16.64	18	15.5	260.5	425	180
6	2.76	3.50	1.88	16.54	18.5	15.5	200	265	138
8	3.70	5.34	2.48	17.7	21	15.5	167.6	269	138
7	8.33	9.28	7.64	19.8	24	17	79.8	86	77

APPENDIX 12 North and South Branch water sampling results (excluding diurnal cycle data). All samples taken between 10a.m. and 2p.m. - = no reading.

(a) North Branch

Station	Month	Temp.	O_2 (mg/L)	O_2 (%Sn)	BOD (5-day)	pH	Conductivity (μmho)	Turbidity (OD 350)
1	Dec	12	9.6	92.2	-	7.1	-	-
	Feb	14.5	10.1	102	0.1	6.8	122	0.01
2	Dec	12.7	6.4	62.7	-	9.2	-	-
	Feb	14.5	8.5	86.4	5.4	7.7	392	0.08
3	Dec	13.0	6.6	64.5	-	9.1	-	-
	Feb	14.5	8.0	81	6.3	7.4	402	0.09
4	Dec	13.5	4.6	45.5	-	8.6	-	-
	Feb	14.8	3.7	38.2	7.1	7.4	280	0.03
5	Dec	12.5	10.7	104	1.2	8.7	-	-
	Feb	14.0	10.3	103	1.1	7.0	143	0.05
6	Dec	15.0	12.2	124	2.2	8.0	-	-
	Feb	17.5	10.4	112	1.3	7.0	148	0.05
7	Feb	16.0	7.5	78	4.9	7.0	297	0.04

(b) South Branch

1	Dec	15.5	9.76	97.0	0.95	6.6	-	-
	Feb 1	15	9.30	91.7	1.6	7.2	83	0
	Feb 2	-	9.56	-	1.6	-	-	-
3	Dec	15	8.20	80.7	-	6.5	-	-
	Feb 1	15	8.16	80.5	2.4	7.2	86	0.01
	Feb 2	-	8.76	-	2.0	-	-	-
4	Dec	16	6.16	62.0	-	7.8	-	-
	Feb 1	15	6.80	67.0	>16.8	7.4	248	0.04
	Feb 2	-	8.22	-	42.9	-	-	-
5	Dec	16	4.40	44.2	-	8.1	-	-
	Feb 1	15	4.86	48.0	>16.0	7.8	288	0.14
	Feb 2	-	4.44	-	>62.7	-	-	-
6	Dec	16.5	2.18	22.1	-	6.6	-	-
	Feb 1	15	3.17	31.2	>17	7.2	230	0.09
	Feb 2	-	3.0	-	>65.3	-	-	-
8	Dec	17.5	3.22	33.2	-	-	-	-
	Feb 1	16	5.55	55.7	>16.6	7.4	167	0.04
	Feb 2	-	5.38	-	40.6	-	-	-
7	Dec	19	9.60	102.5	0.68	-	-	-
	Feb 1	17.5	9.90	102.5	0.5	8.5	77	0.01
	Feb 2	-	10.54	-	1.9	-	-	-

APPENDIX 13 A comparison of oxygen saturation values recorded in the lower Waimakariri River system in 1970-71 compared with similar months in 1957. All values quoted from the present study were obtained between 10a.m. and 3p.m. and those for 1957 are assumed to be daytime records.

Station	1957* Temp. °C	1957* % sat.	1970-71* Temp. °C	1970-71* % sat.
(a) South Branch				
1. Groynes	16.0	100	15 - 18	92 - 113
3. Dickey's Road	16.0	78	15 - 17	80 - 94
5. Below outfall	-	-	15 - 18	44 - 58
6. Mouth	16.5	50	15 - 18.5	22 - 33
8. Main river (upstream)	18.0	74	17.5 - 24	97 - 102
7. " " (downstream)	16.0	48	16 - 21	33 - 56
(b) North Branch				
1. Baseline	16.0	96	12 - 17.5	85 - 102
2. Ford	16.0	96	13 - 17	41 - 81
3. Junction	16.0	96	13.5 - 19	31 - 45
4. Ohoka	16.0	96	12.5 - 18	96 - 104
5. Cust	-	-	15 - 23.5	60 - 130
6. Kaiapoi River	16.0	82	16 - 20.5	76 - 98
(c) Northbrook Drain				
1.	15	78	14	90
2.	15	47	14.3	79
3.	15	55	14	75
4.	16	63	14	74
5.	15	60	14.2	76
6.	15	68	14.5	80
(d) Cam River				
1.	-	-	13.5	77
2.	-	-	14	92
3.	-	-	14	79

* In 1970-71 oxygen determinations were made on 3 occasions in the North Branch, 4 times in the South Branch and once in the Northbrook Drain and Cam River.

\- = No. sample taken

The 1957 figures quoted were obtained in the following months:

N.Br. - Feb., S.Br. - March, Northbrook Drain - Feb.

APPENDIX 14 Salinities recorded at the lower stations of the North Branch system over a 24hr period, 1-2February 1971.

Station	Salinity (%) 4 (N.Br. mouth)	5 (Ohoka)	6 (Cust)	7 (Kaiapoi R.)
Time				
2p.m.	0.85	0.05	0.10	0.06
6p.m.	0.4	0.06	0.05	0.08
10p.m.	0.05	0.05	0.05	0.05
2a.m.	0.05	0.05	0.05	0.08
6a.m.	0.05	0.09	0.09	0.09
10a.m.	0.17	0.09	0.09	0.10
2p.m.	0.15	0.09	0.08	0.11
MEAN %	0.25	0.07	0.07	0.08
RANGE	0.85-0.05	0.09-0.05	0.07-0.05	0.11-0.05

APPENDIX 15 Northbrook Drain: Water sampling results (Jan 1971). All measurements were made between 10a.m. and 2p.m.

Station	Temp. (oC)	O_2 (mg/L)	O_2 (%Sn)	BOD (5-day)	pH	Conductivity (μmho)	Turbidity (OD 350)
1	14	9.36	90.3	0.29	6.9	96	0.005
2	14.3	8.05	78.6	4.4	6.9	107	0.03
3	14	7.76	75.0	2.8	6.9	102	0.02
4	14	7.70	74.4	2.1	6.9	103	0.01
5	14.2	7.90	76.0	1.9	6.95	101	0.01
6	14.5	8.25	80.5	1.5	7.0	102	0.02

APPENDIX 16 Cam River: Water sampling results (Jan 1971). All measurements were made between 10a.m. and 2p.m.

Station	Temp (oC)	O_2 (mg/L)	O_2 (%Sn)	BOD (5-day)	pH	Conductivity (μmho)	Turbidity (OD 350)
1	13.5	8.05	76.8	0.6	6.6	88	0
2	14	9.55	92.0	2.0	7.0	93	0.02
3	14	8.20	79.0	1.1	7.1	94	0.01

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