A BIOLOGICAL SURVEY OF THE KAIAPOI RIVER FOLLOWING FELLMONGERY EFFLUENT TREATMENT*

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ABSTRACT

Measurements of physico-chemical parameters at five sites on the Kaiapoi River, Canterbury, New Zealand (43°23'S, 172°37'E) during December 1977 and January 1978 gave similar results to those reported for 1975 when a fellmongery-waste treatment plant was first operating satisfactorily. Sampling of benthos has shown a marked increase in species diversity at all stations below the outfall. The benthic community below the fellmongery was dominated by *Lumbriculus variegatus* (Oligochaeta), *Paracalliope fluviatilis* (Amphipoda) and *Potamopyrgus antipodarum* (Mollusca) whereas at the upstream control station two lumbriculid worms (*L.variegatus* and *Stylodrilus heringianus*) and the mayfly *Deleatidium* were most numerous. The "sensitive" nymphs of *Deleatidium* were also common below the discharge, but the tubificid worms, typically associated with polluted streams, were rare or absent. The fauna inhabiting the grass fringe along the river banks was typical of that found in many other North Canterbury streams. The presence of several species of fish (including trout) is indicative of well oxygenated water and the growth of extensive macrophyte beds is probably enhanced by nutrients present in the effluent. These plants form a major habitat for the invertebrate fauna.

INTRODUCTION

The Kaiapoi River (43°23'S, 172°37'E), a major tributary of the Waimakariri River, receives dairy shed waste and effluent discharged by North Canterbury Wool and Fellmongery Limited. Biological and physico-chemical surveys made by Hirsch (1958) and Winterbourn *et al* . (1971) showed that

*This paper is dedicated to the late John Cranko, tragically killed in August 1978, whose engineering skills and concern for the environment have made the Kaiapoi River a better place.

the river was heavily polluted. Since August 1974, fellmongery wastes have been treated prior to discharge (see Toshach 1976, 1977) and physico-chemical studies made by Toshach between January and August 1975 showed a substantial improvement in water quality. Surveys of the macroinvertebrate fauna inhabiting stony substrates on the river bed in November 1974 and November 1975 indicated that species diversity had increased and that some "sensitive" species had recolonised the river bed downstream of the discharge. Since 1975 additional pollution control measures have been undertaken at the factory, principally the installation of a coal filter to further reduce the quantity of particulate material in the effluent.

The results of a further physico-chemical and biological survey of the river are given in this report. The survey was carried out a little over 3 years since the first discharge of treated effluent and it was anticipated that since then a "recovery fauna" should have had time to become established.

METHODS

Sampling was carried out at the stations established by Toshach (1977, Fig. 2) except that station 4 was resited about 200 m downstream (Stations 1 and 1a were above the effluent discharge and stations 2 - 5 below it). Physico-chemical measurements were made between 15 December 1977 and 18 January 1978; biological sampling was done on 15 December 1977. Since the biological surveys carried out in 1970, 1974, 1975 and 1977 were all made in November or December using comparable methods, direct comparisons between them can be made.

PHYSICO-CHEMICAL METHODS

Water samples for chemical analysis were taken from 6 stations on 15 December 1977 and on 5, 10 and 18 January 1978. Not all parameters were measured on each sampling day. On 10 January, samples were collected in the early morning (0630-0700 h) before effluent had started entering the river. All other sampling was done between 1000 h and 1200 h when the treatment plant was operating.

Dissolved oxygen, BOD_5, pH and conductivity were measured with the appropriate meters as described by Toshach (1976, 1977). Conductivity was converted to values at $25^{o}C$ using the table in Golterman (1969). Water temperature 0.1-0.2 m below the surface was measured with a hand-held, mercury thermometer and surface flow was determined at several points across the stream at each station using the float method (Welch 1948). Total particulate matter (organic and inorganic) in the water column was measured by passing 400-1 530 ml stream water through preweighed, 0.45 μm Metricel filters which were then dried and reweighed. Levels of dissolved organic material (DOM) were determined by the wet oxidation method of Maciolek (1962) on 50 ml subsamples of water after particulate matter (more than 0.45 μm) had been removed.

The dry weight of fine particulate organic matter (FPOM) in the upper layer of stream bed was measured in triplicate sediment cores (30-40 mm deep) taken at all stations except 1a on 5 January 1978. Sediments were dried, all animals and plant fragments were removed and material was separated into two fractions by sieving through a 1 mm mesh. Both fractions were weighed and the fine fraction was ashed in a muffle furnace at 550°C for 3 h and reweighed; the loss on ignition was taken as the organic content of the sample.

BIOLOGICAL METHODS

Three benthic samples were collected from stony riffles at each station except 1a using a Surber sampler (area 0.1 m^2, mesh pore size 0.5 mm). Sampling sites at stations 2 and 4 included living macrophytes which were abundant at these stations. Large stones were picked up and wiped and finer sediments were stirred vigorously to a depth of several centimetres. All samples were immediately preserved in formalin. In the laboratory, samples were washed in a 0.5 mm mesh sieve to remove fine sediments and all animals were removed, identified and counted. Subsamples of 25 oligochaetes from each station were mounted and cleared on slides in lactophenol-PVA to enable specific identifications to be made.

Additional non-quantitative collections of fauna including fish were made from the submerged grass fringe at each station using a hand net. Macrophytes and algae were collected for identification and general observations were made on the presence and distribution of plants and fish.

RESULTS AND DISCUSSION

PHYSICAL CONDITIONS

The Kaiapoi River arises from small springs near the north bank of the Waimakariri River about 7 km west of the study area and flows through farmland throughout its length (Bennington 1977). A quinnat salmon (*Oncorhynchus tshawytscha*) hatchery is located at Silverstream in its upper reaches. Riverbed materials are predominantly pebbles (16-64 mm) and medium sand (0.25-0.50 mm), sediments which are characteristic of the lower Waimakariri flood plain (Bennington 1977). Between stations 1 and 5 the river is up to 18 m wide and in riffles where sampling was carried out it was less than 0.6 m deep. A dense, partly submerged fringe of grass was present along the banks and willows (*Salix* sp.) partially overhung the water at Stations 1, 2 and 5. Fresh water which banks up in the lower Kaiapoi River towards high tide affected flow and channel depth at Station 5.

Water temperature, surface current velocity and surface sediment characteristics at five stations (not 1a) are shown in Table 1.

TABLE 1. PHYSICAL PARAMETERS MEASURED AT 5 STATIONS ON THE KAIAPOI RIVER DURING DECEMBER 1977 AND JANUARY 1978.

	Stations				
	1	2	3	4	5
Water temperature (^{o}C)	12-13	13	13	13-13.5	13-13.5
Current velocity (cm/sec)	56-67	51-57	52-77	86-94	43-120
Bed sediment					
(a) % < 1 mm diameter	3.2	9.8	16.8	11.4	5.2
(b) organic content of < 1 mm fraction (%)	2.3	3.2	1.6	1.9	1.6

Water temperatures were similar at all stations on all sampling days (12-13.5^{o}C). Current velocity increased slightly at the downstream stations and was most variable at Station 5. Flow rates were lower than those recorded by Toshach in 1974 and 1975.

The surface layer of bed sediments contained only a small percentage of sand and organic material represented only 1.6-3.2% by weight of the <1 mm sediment fraction. These values are comparable with those obtained at Stations 1 and 2 in 1971 by Bennington (1977) prior to the introduction of effluent treatment at the fellmongery. However, he found that the surface of the river bed at Station 2 consisted of "a mat of wool fibres which trapped organic and silt particles", whereas in 1977 no wool fibres were seen and subjectively the bed could be described as clean.

AQUATIC VEGETATION

No macrophyte beds were present at Station 1 although they occur further upstream and beds of *Elodea canadensis* and *Myriophyllum propinquum* have been found there in other years. Some filamentous algae (*Spirogyra* sp.) was growing on the larger stones.

Large streamers of filamentous algae, mainly *Cladophora* sp. and a moss, *Leptodyctium riparium* covered about half the river bed at Station 2. A grass, *Glyceria* sp. was also present and many exposed stones were coated with a conspicuous, green diatom film; no sewage fungus was seen. Below Station 2 the river gradient falls and thick moss and algal growths covered the entire bed downstream as far as Station 3. Few plants were present at this site which was immediately below a ford. However, thick macrophyte beds dominated by *Potamogeton cheesmanii* and *Nitella* sp., but also including *Elodea* , *Glyceria* , *Myriophyllum* and the alga *Cladophora* covered much of the bed immediately downstream. This same mosaic of species and also *Leptodyctium* covered about three-quarters of the bed at Station 4. *Cladophora* was the dominant plant at Station 5 although some *Leptodyctium* and *Glyceria* were also found.

The distribution and composition of macrophyte beds was not discussed by Toshach (1976) but it appears they were less abundant in the river during the period of his study (S.C. Toshach, pers.comm.). In 1970 much of the bed between the fellmongery and Station 3 was smothered in organic deposits and the only plant noted by Winterbourn *et al* . (1971) was *Potamogeton* at Station 3. The subsequent improvement in condition of the bed in this part of the river has produced suitable habitats for some aquatic plants notably *Leptodyctium* and *Cladophora* ,both of which form streamers attached to the upper surface of stones.

Leptodyctium and algae were abundant also on riffles in the Wainui-o-mata River below the outfall of a sewage treatment plant and Gibbs and Penny (1973) attributed this (along with extensive growths of *Elodea*) to high levels of plant nutrients (nitrogen and phosphorus) present in the effluent. Likewise, nutrients in treated fellmongery effluent could be expected to stimulate plant growth in the Kaiapoi River. However, they cannot be solely responsible for their presence as extensive beds of macrophytes also occur above the outfall and in other North Canterbury rivers.

CHEMICAL CONDITIONS

Results of chemical analyses are shown in Figure 1 and Table 2.

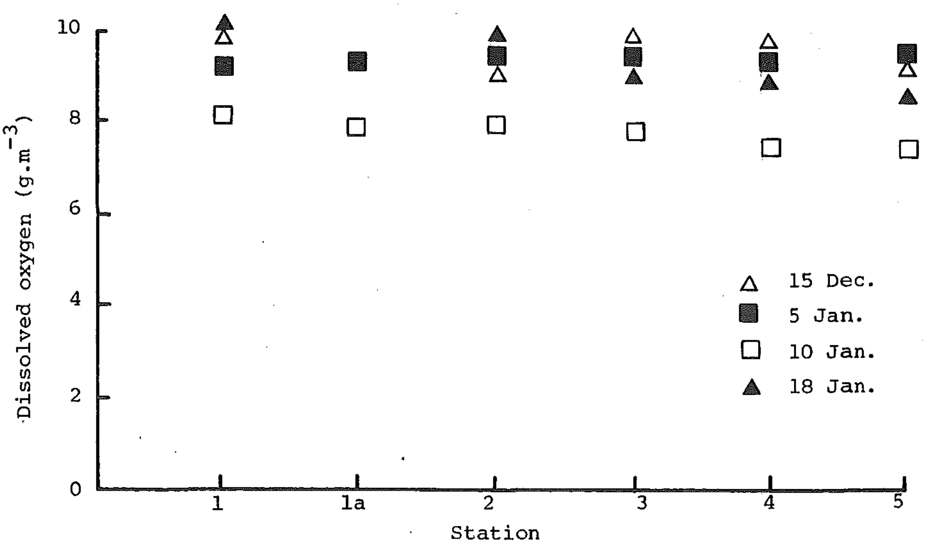

FIG. 1. Dissolved oxygen concentration in the Kaiapoi River on 4 occasions in December 1977 and January 1978.

Dissolved oxygen levels were high (7.3-10.1 g.m^{-3}) at all stations on all four sampling days. Concentration and percentage saturation values were lowest in the early morning (0630-0700 h) series (7.3-8.2 g.m^{-3}; 69-78%) and reflect respiration of the river fauna and flora at night when photosynthesis is curtailed. A slight oxygen sag was observed downstream on 18 January.

TABLE 2. RESULTS OF CHEMICAL ANALYSES MADE ON WATER SAMPLES COLLECTED ON 5 JANUARY 1978 WHEN TREATED EFFLUENT WAS BEING DISCHARGED AND ON 10 JANUARY WHEN IT WAS NOT. NS = NO SAMPLE.

	Stations					
	1	1a	2	3	4	5
BOD_5 (g.m.$^{-3}$)						
5 Jan.	2.5	2.9	4.3	4.3	4.2	3.8
10 Jan.	1.9	NS	6.0	6.0	4.1	5.5
pH						
5 Jan.	7.8	7.7	7.6	7.6	7.6	7.5
10 Jan.	7.5	7.2	7.1	7.1	7.1	7.1
Conductivity (µS)						
5 Jan.	175	173	215	219	231	228
10 Jan.	174	165	160	162	166	161
TPM (g.m^{-3})						
5 Jan.	0.9	0.7	4.7	3.5	1.1	1.7
10 Jan.	0.8	0.1	0.3	0.1	0.8	0.5
DOM (g.m^{-3})*						
5 Jan.	2.2	2.0	5.2	4.6	3.4	3.8
10 Jan.	2.8	2.5	2.2	2.7	2.4	2.7

*DOM values correspond with the COD values given by Toshach (1976) divided by 100. True COD values (American Public Health Association 1965) can be obtained by multiplying DOM figures by 1.45.

An increase in BOD_5, conductivity, DOM and total particulate matter was found at all stations below the fellmongery when treated waste was being released into the river. In contrast, differences between stations were small and showed no consistent increase downstream in the early morning samples. The pH of the river water ranged from 7.1 to 7.8 on both sampling days and was slightly lower below the fellmongery than above it. However, differences between days were greater than those between stations.

Results obtained at Stations 1a and 2 on 5 January 1978 are similar to those obtained by Toshach (1976) at these stations between 1100 h and 1200 h on 20 February and 8 May 1975 when the treatment plant was operating satisfactorily.

THE GRASS FRINGE FAUNA

A large number of invertebrates inhabited the grass fringe along the stream banks at each station. The amphipod, *Paracalliope fluviatilis* and the mollusc, *Potamopyrgus antipodarum* were abundant throughout the river except at Station 1 where the latter was absent. Other common species were the shrimp, *Paratya curvirostris*, the molluscs, *Physa* sp., *Gyraulus corinna* and *Sphaerium novaezelandiae*, and the larvae of the damselfly, *Xanthocnemis zealandica*. These species are all important members of the fringe fauna in three other Canterbury rivers, the Ohoka, South Branch and Saltwater Creek (Carpenter 1976) where *P. fluviatilis* is usually the most abundant species, and indicate that the Kaiapoi River supports a normal, lowland river community.

FISH

Brown trout (*Salmo trutta*), rainbow trout (*S. gairdnerii*), whitebait (*Galaxias maculatus*), bullies (*Gobiomorphus cotidianus*) and flounder (*Rhombosolea retiaria*) were seen between Stations 2 and 5 on various occasions. Eels (*Anguilla* spp.) almost certainly occur and quinnat salmon are known to pass successfully through this section of the river. Apart from the salmonids, all these species were abundant there in 1957 (Hirsch 1958).

THE BENTHIC FAUNA

All stations possessed a rich fauna (Table 4) which showed considerable changes in composition since 1957. Notable is the marked increase in numbers of species taken at all stations below the fellmongery (Table 3). These included one species of mayfly, *Coloburiscus humeralis*, five species of caddisfly, five species of Diptera, a dytiscid beetle, an ostracod and a sphaeriid bivalve, none of which are "typical" inhabitants of polluted waters. In addition, nymphs of the mayfly, *Deleatidium* sp. were common (c. $100/m^2$) at stations 2, 3 and 4 whereas in 1974 and 1975 they were uncommon or absent at these sites. The presence of *Deleatidium* is usually regarded as indicative of high oxygen concentrations and clean water (Gibbs and Penny 1973).

TABLE 3. NUMBERS OF INVERTEBRATE SPECIES TAKEN AT EACH STATION IN NOVEMBER-DECEMBER IN FOUR YEARS. NS = NOT SAMPLED.

Station	1	2	3	4	5
1970	20	4	11	NS	11
1974	23	9	10	7	10
1975	14	13	7	7	9
1977	20	26	26	29	19

Total numbers of invertebrates taken at Stations 2, 3 and 4 were considerably higher than in 1974 and 1975 (except at Station 3, 1974) whereas animal numbers showed little change at Station 1 (Table 5).

TABLE 5. TOTAL NUMBERS OF INVERTEBRATES (NUMBERS PER 0.1 m^2) TAKEN AT EACH STATION IN NOVEMBER -DECEMBER IN FOUR YEARS. NS = NOT SAMPLED.

Station	1	2	3	4	5
1970	167	7090	9320	NS	2066
1974	380	1062	2065	1186	1367
1975	429	643	526	994	559
1977	441	2234	1763	3193	792

This suggests that the lower river is a highly productive waterway, a conclusion supported by the presence of the extensive beds of aquatic plants. The improvement in water quality in terms of increased oxygen content and decreased particulate load brought about by the treatment plant, has improved conditions for many forms of aquatic life, yet it seems likely that the treated effluent is providing a continual supply of nutrients (suggested by the elevated DOM, BOD and conductivity values) which help support high levels of plant growth. Decaying plant detritus trapped on the river bed, in turn provides a source of food for many of the benthic invertebrates.

The invertebrate community at Station 1 consisted predominantly of Ephemeroptera (mainly *Deleatidium*) and Oligochaeta which together made up nearly 80% of the fauna. Both groups were more abundant than in 1975 whereas fewer Trichoptera and Diptera were found. Many of the latter were pupating and emerging at the time of sampling which could, at least in part, account for the reduction in numbers of larvae.

The communities at Stations 2-5 were dominated numerically by oligochaetes, the snail, *Potamopyrgus antipodarum* and an amphipod, *Paracalliope fluviatilis* Chironomid larvae (particularly species of Orthocladiinae) were also common but their relative abundance was considerably lower than in 1974 or 1975.

The presence of large populations of oligochaete worms, especially Tubificidae, on stony stream beds is often taken as a sign of significant organic pollution (Aston 1973). In the Kaiapoi River, oligochaetes were the most abundant macroinvertebrates at Station 2, 3 and 5 and second in abundance at Stations 1 and 4. Species present in subsamples taken from each station are shown in Table 6. No Tubificidae were seen at Stations 1 to 4 where two species of Lumbriculidae, *Lumbriculus variegatus* and *Stylodrilus heringianus* occurred; at Station 5 single specimens belonging to two tubificid species also were found.

TABLE 6. OLIGOCHAETE SPECIES PRESENT IN SUBSAMPLES (N = 25) EXAMINED FROM 5 STATIONS ON THE KAIAPOI RIVER, DECEMBER 1977.

	Stations				
Species	1	2	3	4	5
Lumbriculus variegatus	13	22	19	19	23
Stylodrilius heringianus	12	3	6	6	0
Limnodrilus hoffmeisteri	0	0	0	0	1
Aulodrilus pleuriseti	0	0	0	0	1

According to Brinkhurst (1963) and Ladle (1971) *S. heringianus* is essentially an inhabitant of sands and gravels in stony streams although Cook (1967) and Pickavance (1971b) noted that it can occur equally successfully in a wide range of situations from wave-washed lake shores and rocky, fast-flowing rivers to still, muddy peat pools. It was first recorded in New Zealand by Marshall (1974) who found specimens in clean sands and gravels of the Leeston Drain (Canterbury) where it coexisted with *L. variegatus* . The latter also may occur in a wide range of environments, but its most favoured habitats are quiet reaches of flowing water and ponds with silt, mud and roots in the littoral zone (Pickavance 1971a). The Lumbriculidae are not noted for their abundance in polluted waters and it has been suggested by Brinkhurst (1965) that a correlation may be found between the severity

TABLE 4. MEAN NUMBERS OF INVERTEBRATES (NUMBERS PER 0.1 m^2) IN TRIPLICATE SURBER SAMPLES FROM 5 STATIONS ON THE KAIAPOI RIVER, 15 DECEMBER 1977.

	Stations				
	1	2	3	4	5
PLATYHELMINTHES					
Cura pinguis	2	1.3	44.7	31.7	2
NEMATODA					
Unidentified species	-	< 1	-	< 1	-
OLIGOCHAETA					
Lumbriculidae & Tubificidae	134	934	821	651	576
Eiseniella tetraedra	< 1	6	-	4.7	2.3
EPHEMEROPTERA					
Deleatidium sp.	206	104	101	105	5.3
Coloburiscus humeralis	9	-	-	-	-
TRICHOPTERA					
Aoteapsyche colonica	24.3	2.3	1	11	-
Olinga feredayi	1.3	-	-	1.3	-
Pycnocentria evecta	17.3	23	3.7	4	< 1
Pycnocentrodes aureola	19	5	< 1	7.3	< 1
Hudsonema amabilis	-	< 1	< 1	-	-
Oxyethira albiceps	1	18.3	80	171	14.3
Paroxyethira hendersoni	-	-	< 1	7	-
Hydrobiosis parumbripennis	4	1.7	2.7	9.3	< 1
Psilochorema bidens	1.7	1.3	2	25	2.7
DIPTERA					
Chironomus zealandicus	1	38	21	6.7	7.3
Psectrotanypus sp.	-	3	< 1	< 1	-
Syncricotopus pleuriserialis	3.3	317	48.3	172	40.3
Orthocladiinae Species B	-	14.7	6.3	83	5.7
Maoridiamesa harrisi	5	< 1	< 1	30.7	-
Tanytarsini Species A	-	8.7	1	2.3	< 1
Corynoneura sp.	-	-	-	3.3	-
Austrosimulium sp.	-	-	1.7	-	-
Tanyderidae	< 1	-	-	-	-
Paradixa sp.	-	< 1	-	-	-
Limnophora sp.	-	-	-	-	< 1
COLEOPTERA					
Elmidae	2.3	3.7	3.7	5.3	-
Antiporus sp.	-	-	-	< 1	-
Liodessus plicatus	-	-	< 1	-	-
Staphylinidae	-	-	-	< 1	-
CRUSTACEA					
Paracalliope fluviatilis	7.7	406	194	303	43.3
Herpetocypris pascheri	-	-	4.3	6	-
MOLLUSCA					
Potamopyrgus antipodarum	1	336	364	1362	81.7
Physa sp.	< 1	6.3	55.3	150	6.7
Gyraulus corinna	-	< 1	2	38	1
Sphaerium novaezelandiae	-	< 1	2	4	1.3

of pollution, the abundance of Tubificidae and (negatively) the abundance of Lumbriculidae.

Direct comparisons with oligochaete assemblages present in other years cannot be made, as adequate identifications of worms were not made in other surveys. It is known that *L. variegatus* and Tubificidae were present throughout the river in 1970 (Winterbourn *et al* . 1971) but *S . heringianus* has not been recorded before. It seems likely that it would have been present, at least at Station 1, where it may have been confused with *L. variegatus* or even species of Tubificidae which show similar coiling behaviour (Cook 1967).

To summarise, the large numbers of oligochaetes found in the Kaiapoi River in 1977 were predominantly members of the family Lumbriculidae and not species of Tubificidae which commonly are associated with organically polluted rivers. Therefore, on the basis of its oligochaete fauna the Kaiapoi River shows little unequivocal evidence of pollution.

Similarly, *Lumbriculus* - *Potamopyrgus* - *Paracalliope* dominated communities cannot be considered indicative of organically polluted conditions as such communities are described by Michaelis (1977) and Marshall (1973) in Pupu Springs, north-west Nelson and in spring water at the source of the Avon River near Christchurch. Rather, they appear to be characteristic of clear, flowing, lowland waters supporting abundant submerged vegetation and/or a substrate of sand, silt and gravel or coarse detritus. Where vegetation is absent, *Paracalliope* is rarely found.

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