POLLUTION CONTROL AND WATER QUALITY IN THE UPPER KAIAPOI RIVER

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ABSTRACT

The operation of a pollution control plant on fellmongery discharge into the Upper Kaiapoi River, Canterbury, New Zealand (43°23'S, 172°37'E), resulted in an improvement in water quality based on physico-chemical criteria. Analysis of macroinvertebrates in the stream bed indicated an increase in species diversity following one year of plant operation and sensitive species were found to have recolonised the river bed downstream of the discharge. Diversity indices provided a sensitive measure of changes in the biotic community following improvement in water quality.

INTRODUCTION

Efforts have been made to improve the quality of polluted waters in New Zealand following the 1967 Soil and Water Conservation Act. Minimum standards of water quality were declared and pullution input restricted in an attempt to meet these standards.

The extent of water pollution in the Lower Waimakariri Catchment has been documented by Bennington (1971, 1977), Dalmer (1971), Fowles (1971), Hirsch (1958), Ministry of Works (1956, 1961, 1968) and Winterbourn, Alderton and Hunter (1971). These studies indicated water quality in the Upper Kaiapoi to be worse than the Class D standard set for the river. The major inputs of pollution were dairy-shed wastes and fellmongery discharge from North Canterbury Wool and Fellmongery Ltd. The 1967 Act enabled the North Canterbury Catchment Board to reduce the input of dairy shed waste into the river, control the rate of water abstraction for irrigation, and enforce the installation of a pollution control plant at the fellmongery.

The effectiveness of these pollution control measures on water quality in the Upper Kaiapoi River is the subject of this study. The findings have been reported previously by Toshach (1976).

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STUDY AREA

THE UPPER KAIAPOI RIVER

Figures 1 and 2 show the Lower Waimakariri Catchment and Upper Kaiapoi River respectively. The source of dry weather flow in the Upper Kaiapoi is from the Waimakariri River by seepage through fluviatile gravels under the stopbank. The flow depends on the position of the Waimakariri River channel relative to its stopbank and, over the period 1970-1975, has increased from 0.67 m^3/sec to 3.05 m^3/sec (Hamilton 1972). The Upper Kaiapoi is a breeding ground for brown trout (*Salmo trutta*) and whitebait (*Galaxias maculatus*), and an attempt is being made to establish a quinnat salmon (*Oncorhynchus tshawytscha*) hatchery several kilometres above the fellmongery.

FELLMONGERY AND POLLUTION CONTROL PLANT

Fellmongery operation involves the washing and removal of wool from sheepskins by chemical and mechanical means. Waste water discharge is high and contains chemicals used in the fellmongery operation: sodium sulphide, lime, sodium chloride, sulphuric acid, enzymes, and detergent. Other wastes derived from sheepskins include wool, blood, dirt, lanolin, and fat.

The pollution control plant, which comprises a large settling tank, a rake conveyor to float off wool wastes, and ancillary equipment was operating almost continuously from August 1974. This plant removes an estimated 10.1 tonnes of waste wool and sediment per week from the fellmongery discharge. Equipment to further reduce waste output was being installed at the time of the study.

METHODS

PHYSICO-CHEMICAL METHODS

Water samples were taken from the 6 stations shown in Fig. 2 and described in Table 1. Samples from stations 1 and 1a provided controls for comparison with waters polluted by the fellmongery input. When possible samples were taken at hourly intervals at stations 1a and 2 before and during fellmongery operations on 21.8.75, 11.2.75, 20.2.75, and 8.5.75 to measure the immediate effect of the waste discharge on water quality. The change in water quality downstream from the fellmongery was measured by sampling from all stations on 28.1.75 and 11.2.75 at 0700, 1100, and 1500 hours, while on 16.5.75 samples were taken at 0800, 0900, and 1000 hours excluding station 1a.

Five parameters used to classify class D waters, temperature, pH, dissolved oxygen (D.O.), and suspended solids - were determined. Biochemical oxygen demand (B.O.D.), chemical oxygen demand (C.O.D.), and conductivity were also determined.

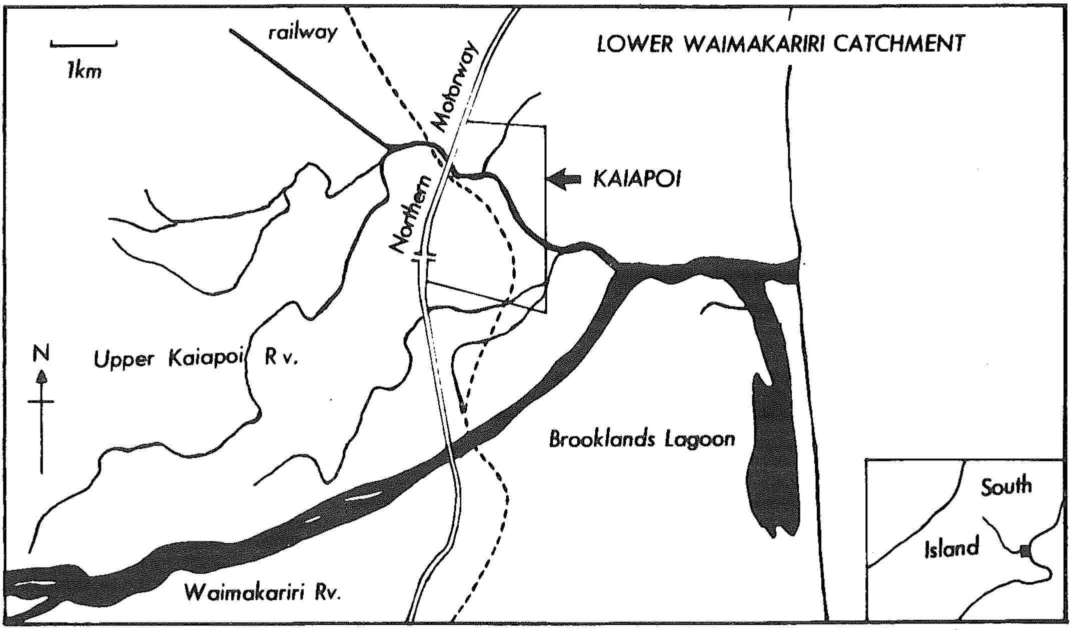

Fig. 1. Lower Waimakariri Catchment.

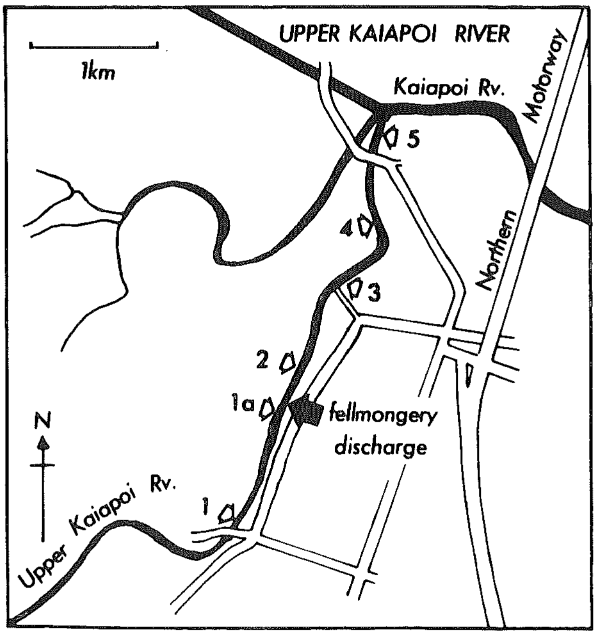

Fig. 2. Upper Kaiapoi River showing sampling stations.

TABLE 1. LOCATION AND PHYSICAL DESCRIPTION OF BIOLOGICAL AND PHYSICO-CHEMICAL SAMPLING STATIONS, UPPER KAIAPOI RIVER 1975. MAP REFERENCES REFER TO NZMS 1, SHEET S76 (KAIAPOI).

Sampling station	Descriptive location	Map reference	Description of substrate	Width (m)	Midstream depth (m)	Current (m/sec) 1974	Current (m/sec) 1975
1*+	10 m below Neeve Road Bridge	995728	Clean shingle, partially interspersed with fine sediment	13	0.25	0.90	0.97
1a	At intake of fellmongery 30 m above discharge		-	-	-	-	-
2*	50 m below fellmongery waste discharge point	001738	Shingle, mostly interspersed with fine sediment	14	0.25	0.89	0.92
3*+	5 m below swing bridge near cowshed	002742	Shingle and sand, little fine sediment	18	0.20	0.86	0.92
4	400 m above confluence of Cust Main Drain and Ohoka Stream	004748	Shingle interspersed with fine sediment and little sand	14	0.35	0.70	0.75
5*+	50 m above confluence of Cust Main Drain and Ohoka Stream	005753	Shingle, partly interspersed with fine sediment	12	0.40	0.83	0.86

* indicates that the station was sampled by Winterbourn *et al.* (1971).

\+ indicates that the station was sampled by Hirsch (1958).

D.O. was measured using the Alsterberg (azide) Winkler method of Golterman (1969) initially and later with a Y.S.I. 54 D.O. Meter. B.O.D. was determined from samples stored in the dark for 5 days at 20°C. Total particulate material was filtered from a 2 l sample onto preweighed 0.45 μm Millipore filters which were then dried at 80°C for 3 days. C.O.D. was determined using the method of Maciolak (1962). pH and conductivity were measured with a Metrohm E512 pH meter and a CPM 2e mains operated radiometer respectively. Current speed was calculated from measurements taken with a Gurley pygmy flow meter.

BIOLOGICAL METHODS

Samples were taken from all stations as shown on Fig. 2 (except 1a), 3 months after the pollution control equipment began operating (24.11.74), and again following one year's operation (19.11.75). The sample stations were stony-bottomed riffle habitat which Winterbourn *et al.* (1971) and Hirsch (1958) have shown exhibit the greatest species diversity in the stream.

Triplicate samples were collected from each station using a Surber sampler of area 0.09 m^2 and mesh pore diameter of 0.5 mm. The macroinvertebrates were removed and identified to the lowest practical taxonomic category.

RESULTS AND DISCUSSION

PHYSICO-CHEMICAL ASSESSMENT

Effects of treatment plant operation on immediate receiving water.

The change in water quality following different levels of waste addition is expressed as the difference between parameter measurements at station 1a (control) and 2 (50 m below input) (Table 2). The results are expressed by difference, rather than in absolute terms, to allow for the seasonal and diurnal variation in the receiving water. The discharge level is grouped into 4 categories ranging from no discharge to discharge of untreated waste.

The results show a clear relationship between the level of treatment and the quality of the Upper Kaiapoi 50 m downstream from the discharge. As treatment of the waste increases the water quality increases. One result, however, is contrary to this trend. The dissolved oxygen level of water containing non-treated waste is less than water containing treated waste. The ponding of treated water may allow the processes which cause increased oxygen demand to be more advanced before discharge.

The marked decline in water quality during periods of no-treatment emphasises the need for responsible factory management. In the event of control plant breakdown discharge should be stopped. Overflow of partially treated waste may be prevented by reducing peak water use through water economy, altering work schedules to minimise peak use and phasing the emptying of washing/treating machines over a longer period.

TABLE 2. THE CHANGE IN WATER QUALITY ACCORDING TO THE LEVEL OF WASTE DISCHARGE*.

Parameter	Level of discharge			
	No discharge	Discharge of treated waste	Discharge of treated waste + partially treated waste	No treatment of discharge
Conductivity μS/cm @ 25°C	0.6±0.5 (5)	31.4±19.2 (20)	93±26.0 (8)	129.5±34.6 (6)
pH	0 (5)	0.54±0.1 (20)	1.47±0.2 (8)	2.2±0.2 (6)
Temperature °C	0 (5)	0 (20)	0 (8)	0 (6)
Dissolved oxygen mg/l	-0.02±0.1 (5)	-0.47±0.1 (20)	-0.96±0.3 (8)	-0.3±0.4 (6)
Biochemical oxygen demand mg/l	0.6±0.3 (4)	3.8±0.6 (13)	4.6±0.5 (6)	4.9±0.1 (6)
Total particulate material mg/l	0.4±0.2 (3)	3.4±1.2 (10)	4.0±1.2 (3)	36.3±4.9 (6)
Chemical oxygen demand mg/l	4.0 (1)	277±56.0 (8)	525±58.4 (3)	664±29.0 (4)

* Results are recorded ± the statistical standard error with the number of observations in parentheses.

Change in water quality with distance downstream from fellmongery.

Samples taken from stations 2-5 show that partial assimilation of fellmongery waste occured between the discharge point and station 5. The level of pollution was greatest at stations 2 and 3 and decreased further downstream (as measured by pH, conductivity, and total particulate material). However, a *steady* decrease in dissolved oxygen concentration occurred downstream of the discharge. The mean decrease between station la and 5 was 1.5 mg/l. Following cessation of waste discharge water quality recovered within half an hour to a level comparable to that at station la.

BIOLOGICAL ANALYSIS

Aquatic life is specifically protected in the Class D minimum quality standard (Soil and Water Conservation Act, 1967): "There shall be no destruction of natural aquatic life by reason of concentration of toxic substance". Clearly the fauna of the Upper Kaiapoi had been partially destroyed as a result of pollution (Hirsch 1958, Winterbourn *et al.* 1971).

Diversity indices and pollution.

Diversity indices can be used to summarise the species composition of a given community and reveal changes in community composition in time and space. The indices may be used to compare natural biotic communities with polluted communities, since changes in the indices often reflect different degrees of pollution (Egloff and Brakel 1973, Wilhm 1970).

A diversity index provides a quantitative measure of the number of species and their relative abundance in a biotic community. The introduction of a limiting factor such as a pollutant, will alter the community composition so that some species are reduced in numbers or excluded. In addition, some species that are tolerant of polluted conditions may increase in numbers (Wilhm 1972).

In this study diversity was measured using Shannon's index (Shannon and Weaver 1949) supplemented with analysis of species richness (Menhinick 1964) and species evenness (Pielou 1967). Results of the diversity calculations made using a computer programme prepared by Mace (1975) are shown in Fig. 3.

(i) The natural community (station 1)

Changes in composition of the natural community have occurred since 1971. Shannon's index showed little change in diversity, while Menhinick's index indicated a decline in species richness with time (Fig. 3). 21 species were recorded in 1971, 23 in 1974, but only 14 in 1975. This decline was not reflected in Shannon's index since species present in low numbers contributed little to the diversity value. It seems likely that the increase in flow during the period affected species richness and this is supported by analysis of relative abundance (see Community structure and relative abundance of taxa).

(ii) The polluted community (stations 2-5)

As expected, diversity in the polluted communities was considerably less than in the natural community (Fig. 3). Within the polluted communities diversity improved following the introduction of pollution control measures. Shannon's index increased from 0.57 to 1.01 between 1971 and 1974, and further increased to 1.33 by November 1975. Generally, the increase in Shannon's index was associated with increases in both species evenness and species richness.

Community structure and the relative abundance of taxa.

Diversity analysis can be usefully supplemented by study of taxa which are sensitive to change in water quality. The distribution and abundance of stream invertebrates is influenced by flow and substrate conditions and changes in these habitat variables must be considered when interpreting the effects of pollution.

The relative abundance of specified taxa at each sampling station is expressed as a percentage of total sample number for 1974 and 1975 (Fig. 4). In addition, the change in abundance of selected species grouped according to their probable sensitivity (Hynes 1963, Goodnight 1973) is given for the same period (Table 3).

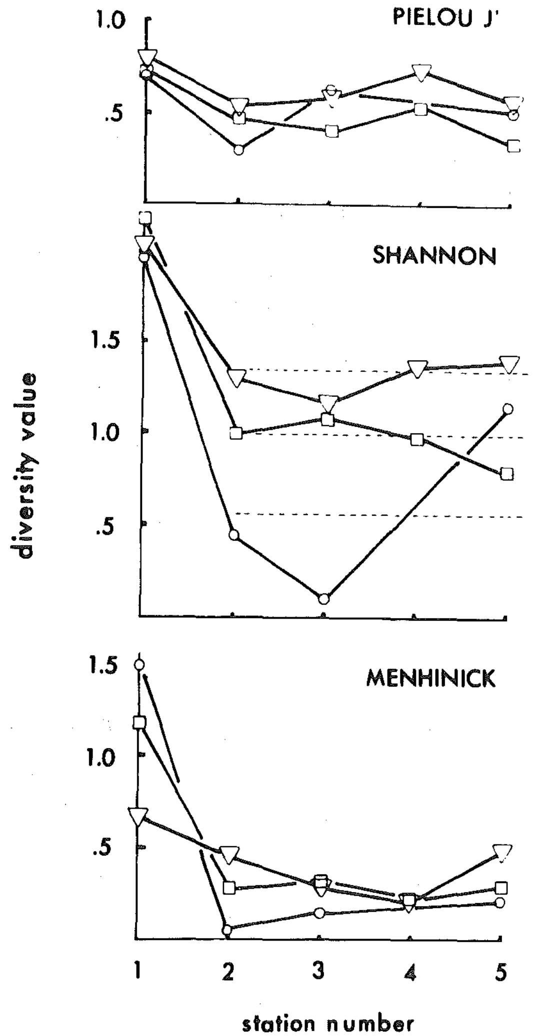

Fig. 3. Diversity values of three indices for the macroinvertebrate fauna of the Upper Kaiapoi River.

○——○ 1970
□——□ 1974
▽——▽ 1975

(i) The natural community (station 1)

Between 1974 and 1975 the relative abundance of Ephemeroptera, Trichoptera and Diptera larvae increased while Oligochaeta and Crustacea decreased. The increase in flow resulted in the removal of most of the fine materials from the substrate and this probably favoured the increase of larvae of the mayfly *Deleatidium* sp. (Ephemeroptera) and the chironomid *Maoridiamesa harrisi* (Diptera) while limiting the available habitat for the Oligochaeta (Brinkhurst and Cook 1974).

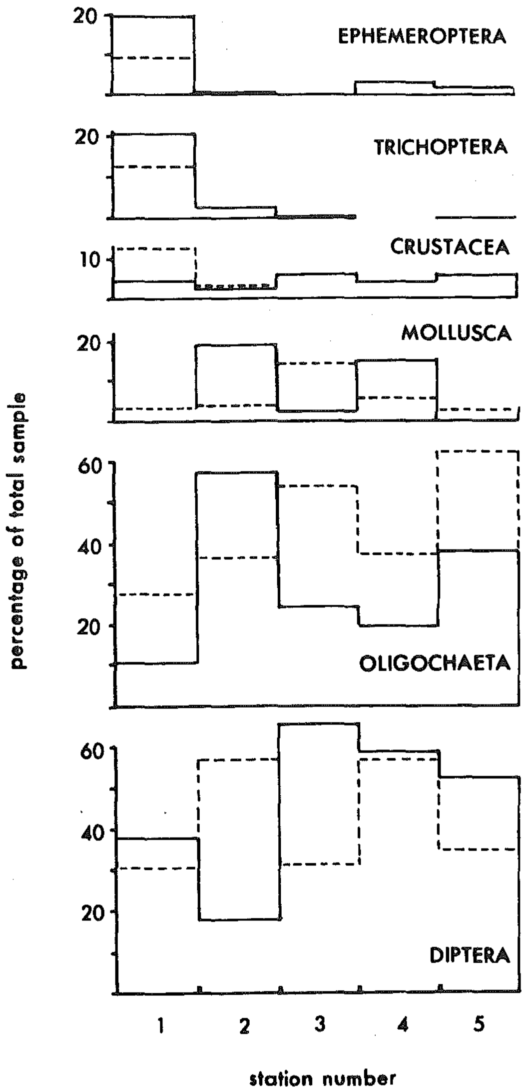

Fig. 4. Relative abundance of macroinvertebrate taxa from the Upper Kaiapoi River.

Sample 1974

1975

The polluted community (stations 2-5).

The numbers of Ephemeroptera and Trichoptera larvae increased between 1974 and 1975. Among these "sensitive" species seven had recolonised the polluted stations by 1975.

TABLE 3. CHANGE IN THE % OF TOTAL SAMPLE OF SELECTED MACROINVERTEBRATES IN THE KAIAPOI RIVER DURING THE PERIOD 24 NOVEMBER 1974 TO 19 NOVEMBER 1975.

Macroinvertebrates	Pollution response	Station number				
		1	2	3	4	5
Deleatidium sp.	sensitive	+10.1	+ 0.3*	- 0.2	+ 2.8*	+ 1.9*
Hydropsyche colonica	"	- 0.5	+ 1.8*	+ 0.5*	-	-
Hydrobiosis parumbripennis	"	+ 0.4	+ 0.4*	- 0.03	-	+ 0.1
Maoridiamesa harrisi	"	+ 4.2	+ 0.8*	- 0.2	-	+ 0.3
Paracalliope fluviatilis	intermediate	- 8.2	+ 1.4	+ 5.3	+ 4.3*	+ 1.5*
Potamopyrgus antipodarum	"	+ 0.9	+14.0	-11.1	+ 9.6	- 0.4
Physa sp.	"	- 1.4	- 0.1	- 0.1	- 0.2	-
Oligochaeta	tolerant	-16.6	+21.7	-29.5	-17.5	-23.3
Chironomus zealandicus	"	- 0.4	+ 0.3	+ 8.3	+ 4.6	+ 6.1
Syncricotopus pleuriserialis	"	+ 5.6	-39.7	+27.6	-3.6	+11.0

* These species not present in 1974.

Paracalliope fluviatilis (Crustacea), an "intermediate" species, was found at stations 4 and 5 in 1974 indicating an improvement in water quality (Scott 1973).

The mollusc *Potamopyrgus antipodarum* tolerates a wide habitat range and is therefore of limited use as an indicator of pollution. *P. antipodarum* favours a stable substrate (Marshall 1974), so the decrease in its relative abundance at station 3 was probably attributable to instability of the sandy substrate from increased flow. At stations 2 and 4, which have relatively stable substrates, *P. antipodarum* increased in relative abundance.

In 1974 the tolerant group (Oligochaeta and Diptera) comprised 86-98% of the total sample at the polluted stations. The decline in abundance in 1975 to 76-91% indicates improved water quality. At stations 3, 4 and 5 Diptera increased in relative abundance between 1974 and 1975 whereas Oligochaeta decreased. The reverse situation occurred at station 2. In 1970 the substrate at station 2 was described by Winterbourn *et al.* (19-1) as "a hard gravel bed coated with mud and soft deposits". By November 1974 there was no evidence of these deposits, the hard gravel bed being clearly visible. The "tolerant" group comprised 99% of the sample at station 2 in 1970, 94% in 1974, and 76% in 1975. The most common dipteran, *Chironomus zealandicus*, decreased from 86% to 19% between 1974 and 1975. This was probably due to the reduction in mud and soft deposits following pollution control.

At stations 3, 4 and 5 the increase in Diptera is attributable primarily to larvae of the chironomid *Syncriotopus pleuriserialis* which live on the upper surfaces of stones and construct permanent tubes (Winterbourn *et al.* 1971). Reduced organic sedimentation and increased current at these stations exposed a greater surface area of stone which favoured *S. pleuriserialis*. The associated reduction of soft organic deposits restricted the burrowing habitat of the Oligochaeta and this explains their reduced relative abundance.

In conclusion, changes in physico-chemical parameters of water in the Upper Kaiapoi River between November 1974 and 1975 are consistent with substantial reduction of pollutant input and dilution by increased flow. The improved water quality is reflected in the recolonisation of sensitive species into previously polluted water and an increase in species diversity.

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