HUBBARD

REGULATED RIVERS RESEARCH AND MANAGEMENT, VOL. 1, 317–329 (1987)

CHANGES IN THE RIFFLE MACROINVERTEBRATE FAUNA OF THE TANJIL RIVER, SOUTHEASTERN AUSTRALIA, DURING CONSTRUCTION OF BLUE ROCK DAM

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ABSTRACT

Macroinvertebrates were sampled from riffles upstream and downstream of the Blue Rock Dam construction site and inundation area in late November/early December 1979 (before construction) and 1982 (late in construction). Changes in the downstream fauna were much less than at some other large dam sites in Australia, probably because of improved erosion control. At the downstream sampling stations the total number of taxa collected was similar in both years, but there was a 30–40 per cent reduction in faunal density; no significant change in density occurred at the upstream station. Multivariate analysis showed that the degree of change in faunal composition between years was similar at upstream and downstream stations. The proportion of fine (<4 mm) inorganic sediment in the streambed increased significantly at downstream stations over the study period, while there was no signficant change upstream. Silt (<250 μm) also increased significantly downstream, but never exceeded 1 per cent of inorganic bed material.

KEY WORDS River ecology Macroinvertebrates Dam construction Erosion control Sedimentation

INTRODUCTION

Studies of rivers in Victoria, Australia, have shown that the construction of large impoundments can result in major ecological changes downstream. At both the Dartmouth Dam on the Mitta Mitta River and the Thomson Dam on the Thomson River, earthworks and forest clearing resulted in downstream increases in suspended and deposited sediments (West *et al.*, 1984; Davey *et al.*, 1987*a*). As a consequence, filamentous algal growth proliferated and the richness, abundance, biomass, and composition of the benthic macroinvertebrate fauna were severely affected (Blyth *et al.*, 1984; Davey *et al.*, 1987b). Elsewhere, changes in invertebrate faunal composition and reductions in diversity or density have been attributed to siltation from various sources including dam construction (Eustis and Hillen, 1954; Coleman, 1978), logging (Tebo, 1955; Lemly, 1982; Culp and Davies, 1983), mining and quarrying (Herbert *et al.*, 1961; Gammon, 1970; Nuttall, 1972; Nuttall and Bielby, 1973; Scullion and Edwards, 1980) and road construction (Rosenberg and Snow, 1975; Barton, 1977- Extence, 1978; Lenat *et al.*, 1981; Cline *et al.*, 1982).

During construction of Blue Rock Dam on the Tanjil River, special erosion control measures were applied following guidelines developed by the Victorian Soil Conservation Authority (Garvin *et al.*, 1979). These measures included grassing of batters, spoil dumps and other disturbed areas, use of vegetation filters as silt traps, and construction of retarding and settlement basins to catch sediment-laden runoff

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0886–9375/87/040317–14$07.00

Received 24 November 1986
Revised 25 March 1987

(Mapson and Ransom, 1985). The present study was undertaken to evaluate the success of these measures in preventing major impacts on the riffle macroinvertebrate fauna of the Tanjil River during the early and middle phases of dam construction. In addition, shifts in macroinvertebrate habitat characteristics, particularly substratum composition, were analysed. Riffles were selected for study for several reasons: their varied and abundant fauna (Marchant *et al.*, 1985) and its likely susceptibility to siltation, their physical similarity upstream and downstream of the dam, their relative ease of quantitative sampling, and the wealth of comparative data from studies of other Victorian dams (Blyth *et al.*, 1984; Davey *et al.*, 1987b). The study is the first of a series on the response of macroinvertebrates in the Tanjil River to dam construction and river regulation.

STUDY AREA

The Eastern and Western Tanjil Rivers rise on the Baw Baw Plateau in eastern Victoria at an altitude of about 1500 m; they flow through steep-sided valleys and join to form the Tanjil River near Hill End (Figure 1). Downstream of this junction the river flows through foothill country for 36 km, past Willow Grove, to Tanjil South. Alluvial flats occur along the final 14 km of the river between Tanjil South and its confluence with the LaTrobe River near Moe, at an altitude of 50 m. The catchment has a total area of 490 km^2, most of which is covered by eucalypt forest, although the foothills and river flats between Willow Grove and the LaTrobe River confluence have been largely cleared for stock grazing. Detailed

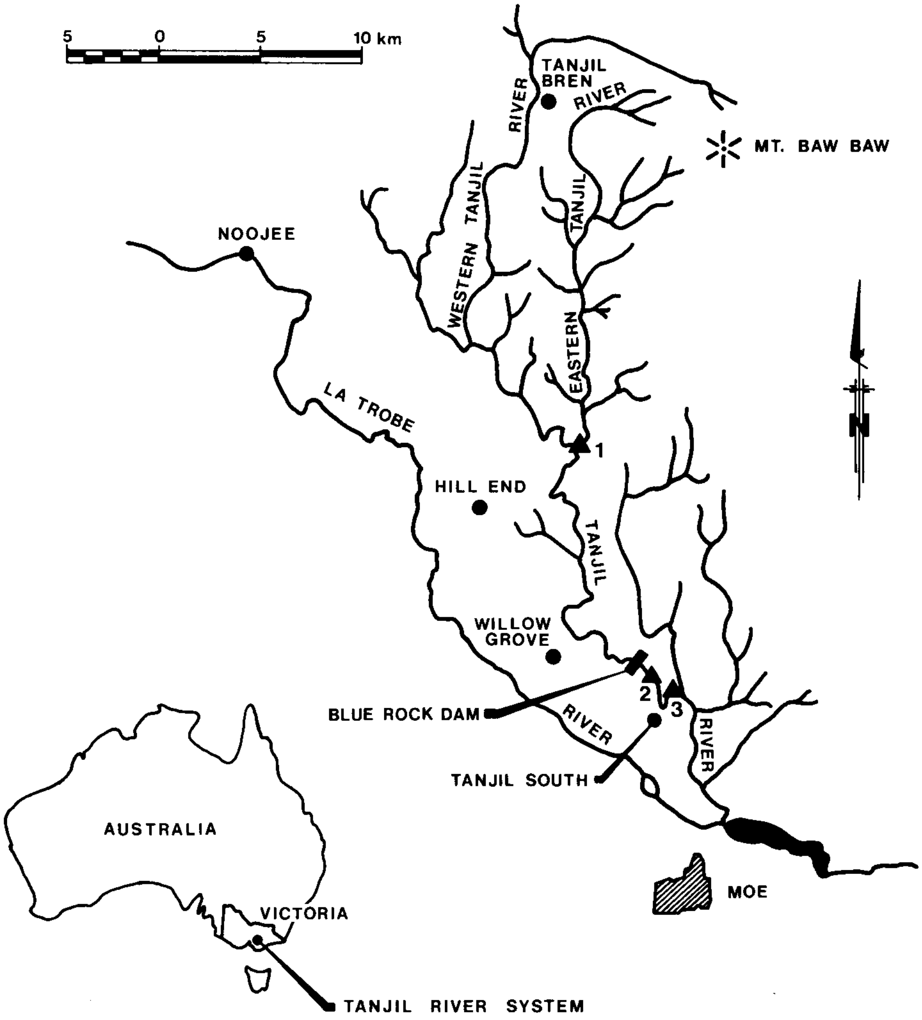

Figure 1. Blue Rock Dam site and sampling stations (1–3) on the Tanjil River

descriptions of the river and its catchment are given by Buckmaster *et al.* (1973), McKinnon and McLennan (1979), Geary (1980), and Wells (1982). Data on the invertebrate fauna of the river are provided by Metzeling *et al.* (1984) and Marchant *et al.* (1985).

Blue Rock Dam is situated near Willow Grove (Figure 1). It has a 75 m high earth and rockfill embankment and a storage capacity of $2 \cdot 0 \times 10^8$ m^3, which exceeds the river's average annual discharge of $1 \cdot 4 \times 10^8$ m^3 and Tanjil South. The dam will regulate flows in the lower Tanjil and LaTrobe Rivers to meet water requirements for brown coal-fired electricity generating stations, irrigation, maintenance of minimum river flows, and other purposes. Initial works at the dam site (clearing and road construction) commenced in late 1979, and stripping of abutments and construction of the diversion tunnel began early in 1980. Diversion of the river through the tunnel took place on 20 May 1981, and the discharge of the river at the Tanjil South gauging station dropped briefly from 1·5 to 0·4 m^3 s^{-1} at this time. Stripping of abutments and construction of the main embankment continued during late 1981 and 1982, and construction of the embankment and excavation of the spillway were completed by March 1983. Work on the spillway and outlet works proceeded during 1983, the diversion tunnel was closed on 16 November 1983, and virtually all site works were finished by late 1984. Clearing of forest areas immediately upstream of the dam site commenced early in 1982 and was completed early the following year. Merchantable timber was extracted from much of the remainder of the inundation area during about the same period.

Sampling stations

Three stations were sampled for this study, one about 32 river km upstream of the dam and 10 km upstream of the inundation area, one about 3 km downstream and one about 6 km downstream (Figure 1). The upstream station (station 1) was located on the Eastern Tanjil River, a short distance upstream of its junction with the Western Tanjil River, at an altitude of 180 m. Here the stream was fast-flowing with an average width of about 10 m and a bed composed primarily of stones and sand. Exposed rock, large boulders, and submerged logs were present in places, with silt deposits occurring at the stream margins. Aquatic plants were limited to algae, mainly *Batrachospermum* spp. and *Nothocladus* spp. (Rhodophyta), and a few mosses. Adjacent land was open forest, and the stream was heavily shaded by the riparian vegetation, dominated by manna gum (*Eucalyptus viminalis*), blanket leaf (*Bedfordia salicina*), hazel pomaderris (*Pomaderris aspera*), and blackwood (*Acacia melanoxylon*). The downstream stations (stations 2 and 3) were situated at Tanjil South at an altitude of 60 m. There the river had a width of 15–20 m and consisted of a pool and riffle sequence. Sampling was confined to the riffle areas, where the composition of the substratum was similar to that at station 1. Aquatic plants were abundant, water ribbon (*Triglochin procera*) and the algae *Chara* sp. (Chlorophyta), *Batrachospermum* spp., and *Nothocladus* spp. being most prominent. Adjacent land was agricultural and the bank vegetation was sparser than at station 1. Manna gum, willows (*Salix* spp.), and tea-tree (*Leptospermum phylicoides*) were the dominant tree species.

MATERIALS AND METHODS

Rectangular sections of riffles 5·2 m wide and 27·5 m long, located centrally within the stream, were defined at each station in relation to local landmarks by surveying techniques. Twelve points within each area, chosen by means of random grid co-ordinates, were sampled in late November or early December of 1979 and 1982 (a different set in each case). Proceeding upstream, a bulk invertebrate and substratum sample was taken at each spot using a cylindrical sampler (modified from Jacobi, 1978). This device consists of an open-ended metal cylinder 500 mm in height and 340 mm in diameter, that can be driven into the substratum to enclose a 0·09 m^2 section of river bed. Water enters the cylinder *via* a 240 × 240 mm inlet port and exits by a similar port which leads into a 200 μm square mesh net and collecting jar. The inlet port is covered by a wire screen of 1 mm square mesh to reduce potential influx of drifting organisms and debris. A movable ring of foam rubber, positioned below a movable metal ring of similar size, encircles the lower part of the cylinder. By standing on the metal ring, the operator presses the foam ring against the substratum during sampling, thus improving the seal between cylinder and river bed.

The sampler was operated by disturbing the enclosed substratum to a depth of about 100 mm and allowing dislodged organisms, debris, and sediment to be washed into the collecting net and jar. Stones and gravel were cleaned with a brush and then removed from the sampler and retained separately. If any immovable rock occurred within the upper 100 mm, its volume was estimated subjectively. To provide information on the abundance of fine sediment and organic matter not retained by the net of the box sampler, subsidiary substratum samples were taken immediately adjacent to the bulk sample. A cylindrical corer (20 mm diameter) and a liquid carbon dioxide freeze sampler (Walkotten, 1976) were used, inserted to about 100 mm; the minimum mass of material thus obtained was 10 g. Measurements of current velocity immediately above the river bed (Ott model 10·002 hydrographic current meter) and water depth were also made at each sampling point.

Material retained in the sampler net was preserved in the field using 5 per cent neutralized formalin. On return to the laboratory, flotation and elutriation with saturated solutions of sucrose or calcium chloride were used to separate each sample into a light, organic fraction and a heavy, inorganic fraction. The light fraction first was sieved over a 1 mm square mesh screen, and the retained material then was sorted with the aid of a stereomicroscope into macroinvertebrates, detritus, and, where present, filamentous algae and water ribbon. Macroinvertebrates were identified and counted while the other components were dried to constant mass at 80 °C, then ignited at 550 °C in a muffle furnace to determine mass loss on ignition. A 20 per cent subsample of the remaining organic material smaller than 1 mm was obtained using an apparatus similar to that described by Södergren (1974), and was examined microscopically for macroinvertebrates only. An estimate of the total number of animals of each identified taxon in the whole bulk sample was then derived. Uniform distribution of material in the subsampler compartments was confirmed for representative samples by chi-square tests for goodness of fit (Sokal and Rohlf, 1969).

The heavy fraction of each bulk sample, consisting almost entirely of inorganic substratum material, was examined by naked eye to check for the presence of animals not removed by the flotation procedure; very few were found. The material was then combined with the stones and gravel removed in the field, oven dried and graded on sieves with meshes ranging from 0·25 mm square to 64 mm square. The following six size classes, partly based on the Wentworth classification, were separated and weighed: cobbles >64 mm; pebbles 64–16 mm; gravel 16–4 mm; coarse sand 4–1 mm; fine sand 1–0·25 mm; and silt <0·25 mm.

Because silt was lost from the bulk samples during collection, it was necessary to estimate the mass of this class, together with organic matter less than 1 mm in size (fine benthic organic matter, FBOM) from analyses of the subsidiary samples. These were oven dried at 80 °C and sieved to yield coarse sand, fine sand, and silt fractions, as defined above. The organic content of the fine sand and silt fractions was determined as mass loss on ashing at 550 °C. No correction was applied for loss of carbonates, but since the Tanjil River is a stream of about neutral pH (Geary, 1980), and contains few molluscs, such losses were not likely to be important. Initial trials, using phosphoric acid treatment to remove carbonates before ashing, did not reveal significant concentrations. Losses of hydration water, measured by rewetting the samples and repeating the drying and ashing procedures, were subtracted from the total losses. The ratios of the masses of sand in corresponding bulk and subsidiary samples, and the sand/silt and sand/FBOM ratios in the subsidiary samples, were then used as a basis for calculating the silt and FBOM content of each bulk sample, prior to losses associated with sampling.

Information on turbidity and suspended solids levels in the river was obtained from a monitoring programme undertaken by the Rural Water Commission of Victoria. For this programme, turbidity measurements were made on water samples taken at Blue Rock Road (upstream of the dam site but in the middle of the inundation area and well downstream of our station 1) and Ashdown Road (downstream of the dam site and between our stations 2 and 3) on most weekdays after mid 1979. Generally both sites were sampled within 30 min, and in many cases, suspended solids concentrations were also determined.

Throughout this paper, statistical significance is assessed by two-tailed Mann-Whitney *U*-tests, and at a probability level of 0·05, unless otherwise stated.

RESULTS

Current, water depth and substratum

At each station, average current speed and water depth were similar in both years (Table I). The amount of benthic coarse detritus (Table I) decreased from 1979 to 1982 at station 3 ($P < 0{\cdot}05$), but elsewhere did not change significantly. Fine benthic organic matter increased at all stations ($P < 0{\cdot}01$), while algae increased at station 1 ($P < 0{\cdot}01$) and were elsewhere unchanged (Table I). *Triglochin procera* was collected only at station 2, where it was equally abundant in both years.

The inorganic substratum was dominated by pebbles and cobbles at all stations (Figure 2). The proportions of silt and coarse sand increased significantly from 1979 to 1982 at stations 2 ($P < 0{\cdot}05$) and 3 ($P < 0{\cdot}01$) but not station 1. Fine sand increased at station 2 ($P < 0{\cdot}05$) but did not change significantly elsewhere.

Numbers of taxa and individuals

Altogether, 230 macroinvertebrate taxa were recorded from the three stations. Most of these were individual species or at least presumed species, although for some taxonomically difficult groups, such as oligochaetes, species differentiation was not attempted. Adults and larvae of beetle species were treated as separate taxa because they could not be associated in many cases. For station 1 the total number of taxa identified was considerably greater in 1982 than in 1979 (Table II) and the mean number of taxa per sample also increased significantly ($P < 0{\cdot}01$). At stations 2 and 3 there was no significant change in the mean number of taxa per sample, and the total number of taxa was similar in both years. The density of individual animals ranged from 481 to 3970 per sample or about 5,000 to 44,000 m^{-2} (Table II). Mean density at station 1 did not change significantly between years, but at station 3 there was a statistically significant decrease of about 30 per cent ($P < 0{\cdot}01$). At station 2 there was a larger decrease (about 40 per cent), but it was not significant ($0{\cdot}10 > P > 0{\cdot}05$). However, combining data for the two downstream stations, the decrease in abundance was highly significant over all ($P < 0{\cdot}001$).

Combining data for the two years, there was no statistically significant Spearman rank correlation between faunal density and the proportion of silt in the substratum at any station ($r_s = 0{\cdot}11$ at station 1, $0{\cdot}16$ at station 2 and $-0{\cdot}28$ at station 3; $P > 0{\cdot}05$ in all cases). The proportion of total fine sediment (silt plus sand) was not significantly correlated with density at station 1 or station 2 ($r_s = 0{\cdot}26$ and $0{\cdot}01$ respectively, $P > 0{\cdot}05$). However, there was a significant negative correlation between these variables at station 3 ($r_s = -0{\cdot}42$, $P < 0{\cdot}05$ for a two-tailed test).

Faunal composition

Two similarity indices were used to assess changes between 1979 and 1982 in the taxonomic composition of the fauna at each station; these were Raabe's Coefficient and Czekanowski's Coefficient (see Hellawell 1978, pp. 170–171 for formulae used). By each measure, the similarity between the 1979 and 1982 collections was about the same at each station (Table III). The two coefficients were also used to compare collections obtained from different stations in each year. Stations 2 and 3 had collections that were most alike (Table III), as would be expected from the closeness of those stations; their similarity was about the same as that between 1979 and 1982 collections from each station.

Of 70 taxa that were judged common (those representing more than 0·1 per cent of all specimens taken), about half changed significantly in abundance at one or more stations (Table IV). There were significant increases in 11 taxa at station 1, six at station 2, and six at station 3. Only three taxa decreased significantly at station 1 compared with ten at station 2, and 13 at station 3. Changes at stations 2 and 3 were generally very similar. Over all the number of significant changes (49) was much greater than expected by chance (10·5 for a significance level of 0·05).

River turbidity and suspended solids

Turbidity and suspended solids data are presented separately for each year from 1979 to 1982 (Table V). In each case, occasional unpaired data (when only one site was sampled on a particular day) have

Table I. Values of various habitat characteristics at each station in 1979 and 1982

Characteristic	Mean (range) at station 1 in: 1979	1982	Mean (range) at station 2 in: 1979	1982	Mean (range) at station 3 in: 1979	1982
Current speed (m s^{-1})	0·49 (0·20–0·80)	0·61 (0·21–1·38)	0·67 (0·23–1·33)	0·74 (0·47–1·12)	0·61 (0·36–0·92)	0·72 (0·61–0·96)
Depth (m)	0·33 (0·23–0·45)	0·32 (0·22–0·42)	0·27 (0·16–0·38)	0·23 (0·10–0·33)	0·35 (0·27–0·46)	0·26 (0·18–0·35)
Coarse (>1 mm) detritus*	4·4 (0·7–9·2)	9·3 (2·0–48·3)	6·3 (0·8–14·4)	8·3 (1·9–16·3)	5·6 (1·3–17·8)	2·1 (0·3–8·0)
Fine (< 1 mm) benthic organic matter*	7·6 (1·1–15·8)	13·2 (8·0–21·0)	4·1 (0·7–7·6)	12·5 (1·8–25·8)	7·6 (3·2–12·0)	13·5 (7·9–19·0)
Algae*	0·02 (0·00–0·08)	0·08 (0·00–0·17)	0·16 (0·01–0·88)	0·14 (0·01–0·37)	0·01 (0·01–0·02)	0·01 (0·00–0·03)
*Triglochin procera**	absent	absent	3·5 (0·0–25·1)	3·2 (0·0–18·4)	absent	absent

*Mass loss on ignition as grams per sample.

Table II. Numbers of invertebrate taxa and individuals collected from the sampling stations

Station	Year	Number of taxa	Taxa per sample		Inividuals per sample	
			Mean	Range	Mean	Range
1	1979	120	54	46–63	1370	778–2500
	1982	144	67	54–80	1357	481–2065
2	1979	132	58	44–75	2598	1087–3970
	1982	120	61	45–71	1592	1129–2412
3	1979	120	56	46–70	2547	1684–3738
	1982	117	53	43–66	1719	1005–2698

Table III. Similarity between 1979 and 1982 collections from each station, and between collections from different stations in each year, measured by two indices

Comparison	Similarity measured by:	
	Raabe's Coefficient	Czekanowski's Coefficient
1979 and 1982 (station 1)	0·65	0·65
1979 and 1982 (station 2)	0·65	0·61
1979 and 1982 (station 3)	0·69	0·66
Stns 1 and 2 (1979)	0·52	0·46
Stns 1 and 2 (1982)	0·55	0·55
Stns 1 and 3 (1979)	0·56	0·50
Stns 1 and 3 (1982)	0·54	0·51
Stns 2 and 3 (1979)	0·63	0·63
Stns 2 and 3 (1982)	0·61	0·61

been excluded. Highest values of both indicators were recorded at the downstream site, and in the later years of construction (1981 and 1982). The relative increase from the upstream to the downstream site also rose over time.

DISCUSSION

The early and middle stages of construction of Blue Rock Dam evidently had little effect on downstream macroinvertebrate populations or their habitat. The number of taxa per sample at the downstream stations (2 and 3) did not alter significantly between 1979 and 1982, and the degree of change in faunal composition was similar upstream and downstream of the dam. As 1982 was the year of highest mean turbidity and suspended solids levels downstream of the dam (Table V) any effect on the fauna should have been greatest at this time. The abundance of aquatic plants at the downstream stations did not change significantly between 1979 and 1982, and fine benthic organic matter increased by a similar amount both upstream and downstream. Although the proportion of silt in the streambed increased at the downstream stations, its mass in 1982 still did not exceed 1 per cent of the mass of inorganic material in the top 100 mm of the substratum (Figure 2). In addition, the proportion of silt did not correlate with faunal density. The relative abundance of sand rose significantly below the dam, and after construction averaged 14 per cent of inorganic bed material compared with 7 per cent before construction. Low river flows during 1982 (about half of the long-term average: Latrobe Valley Water and Sewerage Board stream gauging data) may partly account for the accumulation of fine organic and inorganic material observed during the study. However, it is apparent from the water quality data (Table V) that towards the end of the study period there was an appreciable increase in the concentration of suspended material in

Table IV. Numbers of specimens of common taxa (those representing >0·1 per cent of all specimens collected) taken from each station in each year. Species codes are those used for the LVWSB reference collection of freshwater invertebrates. Boxed numerals indicate statistically significant changes between years at a particular station (Mann-Whitney U-tests, $P < 0{\cdot}05$)

CLASS **Order** Family	Genus and species	No. of specimens Station 1 1979	 1982	 Station 2 1979	 1982	 Station3 1979	 1982
TURBELLARIA							
Tricladida			15	27	55	20	74
NEMATODA.		$\boxed{24}$	$\boxed{63}$	71	49	5	22
OLIGOCHAETA		734	1003	3721	2374	1300	797
GASTROPODA							
Basommatophora							
Ancylidae	*Ferrissia petterdi*	$\boxed{5}$	$\boxed{202}$	5	2		1
ARACHNIDA							
Acarina							
Hydracarina	Sp. 11	17	10	84	105	148	90
	Sp. 23	118	47		20	21	15
INSECTA							
Coleoptera							
Elmidae (larvae)	*Austrolimnius* spp. 6 & 10	3427	2962	2168	2786	4270	4621
	Austrolimnius sp. 9	123	474	450	852	656	1014
	Kingolus sp. 5		3	24	75	27	85
	Notriolus quadriplagiatus	5	58	67	58	56	5
	Simsonia brooksi	29	55	$\boxed{54}$	$\boxed{2}$	$\boxed{26}$	
Elmidae (adults)	*Austrolimnius* sp. 3	585	446	471	133	$\boxed{580}$	$\boxed{187}$
	Austrolimnius sp. 4	350	648		11	7	2
	Austrolimnius sp. 9	15	62	$\boxed{39}$	$\boxed{235}$	$\boxed{26}$	$\boxed{112}$
Helodidae	*Cyphon* sp. A	26	33	90	194	329	430
Psephenidae	*Sclerocyphon* spp.	61	95	71	83	$\boxed{102}$	$\boxed{53}$
Ptilodactylidae	*Byrrocryptus* sp.A	110	162		3		6
Diptera							
Athericidae		45	63	5	8	26	21
Blephariceridae	*Edwardsina polymorpha*	396	61				
Ceratopogonidae	Spp. A & N	38	104	26	8	14	8
Chironomidae	Aphroteniinae sp. 501	310	288	31	10	6	7
	Brillia sp. 12	5	27	78	51	25	43
	Cardiocladius sp. 10	25	6	592	332	26	21
	Cordites sp. 3	220	253	979	1483	$\boxed{377}$	$\boxed{1264}$
	Micropsectra sp. 207	82	334	269	180	82	57
	Orthocladiinae group A*	$\boxed{123}$	$\boxed{349}$	2622	1066	616	401
	Orthocladiinae group B†	$\boxed{16}$	$\boxed{100}$	640	501	174	145
	Paramerina sp. 302	$\boxed{65}$	$\boxed{224}$	84	84	5	
	Pentaneura sp. 306	32	29	$\boxed{8}$	$\boxed{68}$		$\boxed{86}$
	Polypedilum oresitrophus	26	54	36	60	12	39
	Rheotanytarsus sp. 202	$\boxed{481}$	$\boxed{1016}$	$\boxed{2183}$	$\boxed{334}$	$\boxed{317}$	$\boxed{56}$
	Riethia spp. 250 & 251	$\boxed{2023}$	$\boxed{290}$	$\boxed{5748}$	$\boxed{500}$	$\boxed{5855}$	$\boxed{232}$
	Nr *Saetheria* sp. 140	154	19	147	214	122	227
	Tanypodinae spp. 301 & 310	$\boxed{367}$	$\boxed{51}$	576	432	459	356
	Thienemanniella sp. 4	98	162	$\boxed{689}$	$\boxed{265}$	168	108

Table IV. *Continued*

CLASS **Order** Family	Genus and species	No. of specimens Station 1 1979	 Station 1 1982	 Station 2 1979	 Station 2 1982	 Station3 1979	 Station3 1982
Empididae		46	77	303	277	206	292
Simuliidae	*Austrosimulium* spp.	1722	221	580	733	117	128
Tipulidae	Sp. A	157	182	10		56	16
	Sp. C	60	42	19	53	5	27
	Sp. E	2	62	85	357	46	39
	Sp. F	21	26	27	32	18	24
Ephemeroptera							
Baetidae	*Baetis* spp.	269	406	313	485	607	276
Leptophlebiidae	*Atalophlebioides* sp. C	682	1804	2231	1259	8476	6061
	Jappa sp. D	3	88	5	122		
	Kirrara procera	11	28	55	36	39	10
	Nousia sp. A	71	17	303	371	45	63
	Nousia sp. D	385	18	70	123	217	384
Oligoneuriidae	*Coloburiscoides* sp. A	17	67	35	18	14	15
Hemiptera							
Veliidae	*Microvelia* sp. A			2	26	42	153
Megaloptera							
Corydalidae	*Archichauliodes* sp. A	4	6	122	66	91	27
Plecoptera							
Eustheniidae	*Stenoperla australis*	179	193	15	17	46	55
Gripopterygidae	*Illiesoperla australis*	51	39	38	15	9	
	Newmanoperla thoreyi	58	69	103	3	6	
Notonemouridae	*Austrocercella mariannae*	9	169		1		
Trichoptera							
Conoesucidae	*Costora delora*	3		324	60	71	1
	Sp. B	28	31	8	4	72	35
Ecnomidae	Sp. B		6	182	271	401	215
	Sp. E	10	32	77	34	42	21
	Sp. M	123	283	41	6		5
Glossosomatidae	*Agapetus* sp. A	100	313	754	150	721	86
Hydrobiosidae	*Ethochorema* sp. A	38	43	131	67	110	63
Hydropsychidae	*Asmicridea* spp.	111	103	291	209	690	203
	Cheumatopsyche sp. A			20	124	57	341
	Smicrophylax sp. B	12	70	418		84	1
Hydroptilidae	*Orthotrichia ? bishopi*	9	104	31	25	40	
	Oxyethira columba		10	25	128	5	20
Leptoceridae	*Notalina bifaria*	1146	1062	1188	120	1570	303
	Notalina fulva	258	112	9	5	40	
Philopotamidae	*Chimarra* sp. B	6	17	236	158	84	103
Philorheithridae	Sp. B	26	48	485	613	186	368

***Orthocladius/Cricotopus* spp. group 5 and *Nannocladius* sp. 16.

†*Eukiefferiella* spp. 1 and 39 and Orthocladiinae sp. 6.

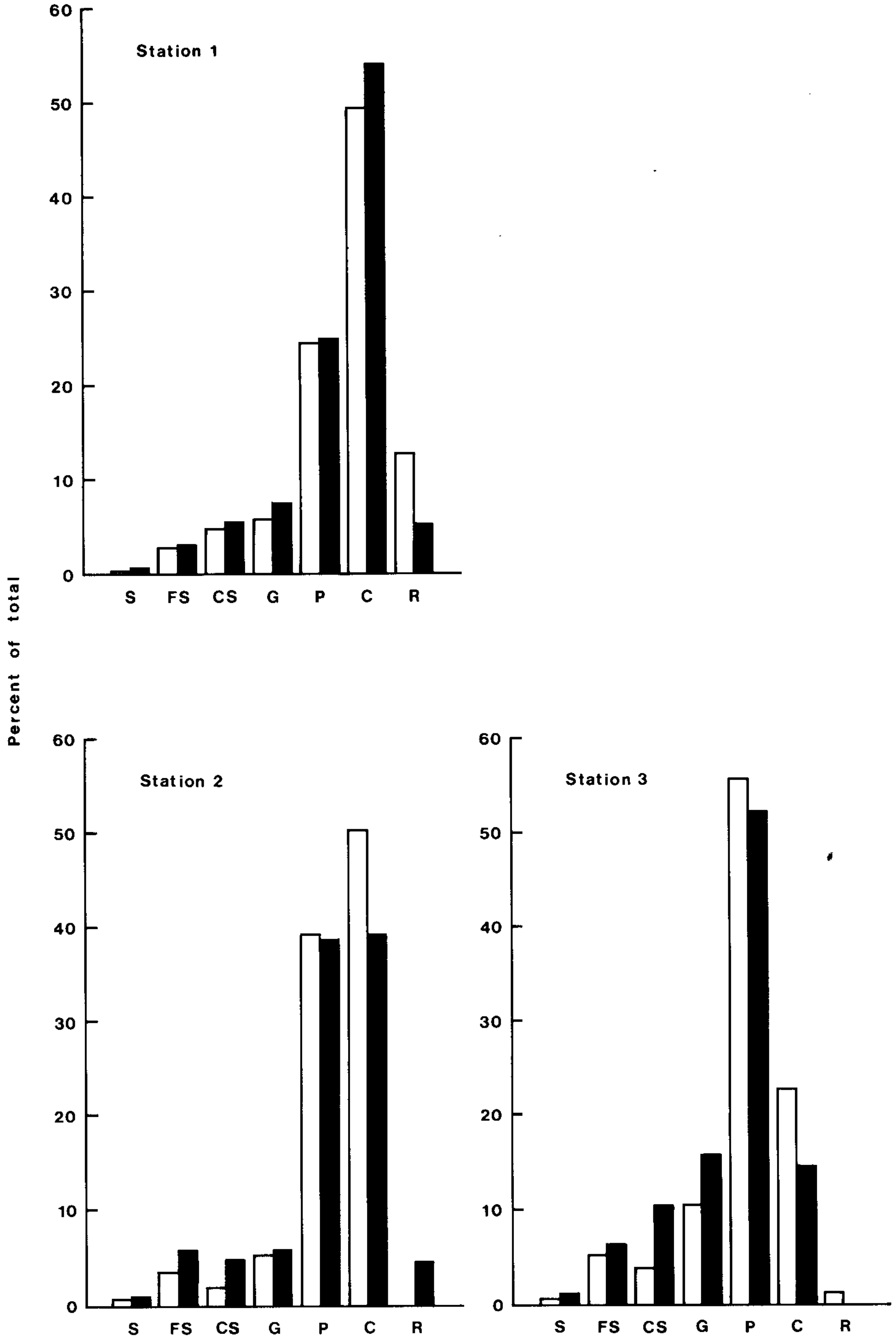

Figure 2. Percentage composition of inorganic substratum material sampled at each station in 1979 (white bars) and 1982 (black bars). S, silt; FS, fine sand; CS, coarse sand; G, gravel; P, pebbles; C, cobbles; R, rock

Table V. Turbidity and suspended solids levels in the Tanjil River upstream (Blue Rock Road) and downstream (Ashdown Road) of the Blue Rock Dam between 1979 and 1982. Sample sizes and increases in mean values between sites are also shown. Data are from the Rural Water Commission of Victoria's Tanjil River Monitoring Programme (excluding unpaired results)

Year	Geometric mean (range) at upstream site	Geometric mean (range) at downstream site	Percentage increase in mean	Samples per site
		Turbidity (NTU)		
1979	3·1 (1–22)	3·9 (1–120)	26	70
1980	3·0 (1–55)	3·8 (1–49)	27	240
1981	4·2 (1–110)	6·5 (1–370)	55	226
1982	4·1 (1–29)	7·1 (1–480)	73	90
		Suspended solids (g m^{-3})		
1979	7·8 (< 1*–66)	7·9 (1–52)	1	27
1980	6·0 (< 1*–400)	7·7 (<1*–320)	28	75
1981	5·5 (1–210)	9·0 (1–1500)	64	99
1982	12·6 (1–160)	28·4 (5–520)	125	47

*Treated as 0·5 in calculation of geometric mean.

the river, particularly downstream of the dam. Some of this suspended matter may have settled at the downstream macroinvertebrate sampling stations. Highest mean suspended solids concentrations occurred in 1982, despite low river flows and rainfall and hence reduced runoff from disturbed areas. Clearing of forest in the inundation area, which took place in that year, may have been primarily responsible rather than works at the dam site. This would account for some suspended solids increase being observed at Blue Rock Road (upstream of the dam but within the inundation area) as well as at Ashdown Road (downstream of the dam).

The absence of large alterations in the Tanjil River fauna is consistent with other studies which have concluded that light sedimentation does not greatly affect benthic macroinvertebrate populations (Ellis, 1936; Hamilton, 1961; Cummins and Lauff, 1969; Rabeni and Minshall, 1977). Generally, major faunal changes follow when there is gross siltation sufficient to smother the streambed or fill gaps between large substratum particles (e.g. Tebo, 1955; Herbert *et al.*, 1961; Gammon, 1970; Nuttall, 1972; Nuttall and Bielby, 1973; Extence, 1978; Lenat *et al.*, 1981; Lemly, 1982). However, there were some shifts in the Tanjil River invertebrate populations which conceivably signify a minor impact. During the study period faunal abundance declined significantly downstream of the dam, although it still remained comparable with the abundance upstream, which was unchanged. A few common species dropped sharply in numbers at both downstream sites, for example the caddisfly *Smicrophylax* sp. (Table IV). Whether these changes were natural or construction-induced is open to conjecture, but it may be noted that there was a negative correlation between abundance of fine sediments (silt plus sand) and faunal density at station 3. In addition, several authors have observed adverse effects of suspended particles on aquatic invertebrates, at concentrations within the range recorded downstream of Blue Rock Dam, even in association with little or no sedimentation. Harrison and Farina (1965) found that snail egg capsules were detrimentally affected at suspended solids concentrations of 190–360 g m^{-3}. Gammon (1970) and White and Gammon (1977) reported that drift of riffle macroinvertebrates was increased by addition of suspended solids at concentrations between 18 and 271 g m^{-3} and that reductions in population density occurred in the absence of visible accumulations of sediment on the substratum. Gray and Ward (1982) found that sediment releases from a reservoir, resulting in downstream concentrations of suspended solids of up to 422 g m^{-3}, produced a drastic decline in chironomid densities despite only slight deposition on the streambed. Interference with feeding and respiratory mechanisms was suggested as the cause.

Any impact on invertebrates in the Tanjil River was clearly substantially less than in the Mitta Mitta River downstream of Dartmouth Dam, where massive sediment deposition led to a persistent shift from a diverse fauna to an impoverished one dominated by a few tolerant, widespread taxa (Blyth *et al.*, 1984). It was also less than in the Thomson River below the Thomson Dam, where there was also considerable sedimentation and a marked depression in the biomass, density, and species richness of the invertebrate fauna (Davey *et al.*, 1987b). Thus erosion control measures at Blue Rock evidently were successful in preventing major ecological impact downstream during the construction phase of the development. Changes in the fauna occurring as a result of the filling and operation of Blue Rock Dam are the subject of studies which will be reported later.

ACKNOWLEDGEMENTS

This work was funded by the State Electricity Commission of Victoria and the Rural Water Commission of Victoria through the Interdepartmental Committee on the Tanjil River (Blue Rock) Dam. We thank Ms. J. Jelbart, Mr. S. McCallum and Ms. M. Siinmaa for help in the field and laboratory, Mr. B. Smith for drawing the figures, and Ms. J. Martin for typing the manuscript. For advice on floral and faunal identification we are grateful to Mr. J. Blyth (various groups), Mr. D. Cartwright (Trichoptera), Mr. J. Dean (Trichoptera), Mr. T. Entwisle (red algae), Ms. A. Glaister (Elmidae), Dr. R. Marchant (various groups), Dr. J. Martin (Chironomidae), Mr. L. Metzeling (various groups), Dr. A. Neboiss (Trichoptera), Ms. R. St. Clair (Leptoceridae), and Dr. P. Suter (Ephemeroptera).

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