Aust. J. Mar. Freshw. Res., 1987, **38**, 289–99

Some Effects of the 1982–83 Drought on Water Quality and Macroinvertebrate Fauna in the Lower LaTrobe River, Victoria

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Abstract

Following severe and prolonged drought, flows in parts of the lower LaTrobe River reached record lows in February 1983. Consequent lack of dilution for wastewater discharges resulted in marked deterioration of water quality, with dissolved oxygen concentration dropping to 2 g m^{-3} and electrical conductivity rising to 115 mS m^{-1}. Despite these changes there was little alteration in the taxonomic richness or composition of the aquatic macroinvertebrate fauna. Faunal richness in the river downstream from Yallourn was low both before and after the drought, but the causative factors remain obscure.

Introduction

The impact of drought conditions on river water quality may be substantial. Typical effects are increases in total dissolved solids and their constituent ions, elevated ammonia and biochemical oxygen demand, and decreases in dissolved oxygen and suspended sediments (Anderson and McCall 1968; Anderson *et al.* 1972; Stefan and Combs 1978; Muchmore and Dziegielewski 1983). Nitrate levels have been observed to both increase and decrease, with a sharp rise often occurring after drought-breaking rainfall (Slack 1977; Walling and Foster 1978; Casey and Clarke 1979; Dickson *et al.* 1983). These changes have been related to natural hydrogeological phenomena, alterations in diffuse waste inputs, reduced dilution of effluent discharges and variations in instream processes.

Biotic responses to extreme drought have included fish mortalities as a result of low oxygen concentrations, high temperatures and other factors (Brochet 1977; Brooker *et al.* 1977). Responses of invertebrates may be diverse, with increases, declines and stability of populations of various species reported (Hynes 1958; Larimore *et al.* 1959; Kamler and Riedel 1960; Moth Iverson *et al.* 1978; Extence 1981; Ladle and Bass 1981; Taylor 1983; Canton *et al.* 1984; Cowx *et al.* 1984; Kownacki 1985). These differences are explained by the multiplicity of environmental changes occurring during drought, some of which are adverse (e.g. drying, lowered water quality) and some beneficial (e.g. accumulation of food resources, reduced scouring by storm flows).

The lower LaTrobe River is subjected to multiple human impacts including water abstraction, accelerated bank and tributary erosion, urban and agricultural runoff and discharges of thermal power station effluents, treated sewage and pulp and paper mill wastes (Bird *et al.* 1979; Anon. 1978, 1982). During the severe drought of 1982–83 many of these impacts intensified and accordingly the Latrobe Valley Water and Sewerage Board (LVWSB) monitored the physicochemical properties of the lower LaTrobe River very frequently in order to provide data for day-to-day management purposes and as a record of river behaviour. The frequency of routine monitoring of invertebrates was also increased. Other, long-term

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monitoring programs of physicochemical parameters undertaken by the LVWSB, the Environment Protection Authority, the State Electricity Commission (SEC) and the Rural Water Commission of Victoria overlapped the drought period. These studies are to be reported elsewhere.

Table 1. Instantaneous minimum flows and extreme water-quality indicator values recorded during each month of the study

Data for an earlier period (July 1979–June 1982 inclusive) are shown for comparison. – No records available

Variable	Month	Value at site: A	B	C	D	E	F
Minimum flow ($m^3\ s^{-1}$)[A]	July 1979–June 1982	1·4	–	1·9	–	–	2·2
	Dec. 1982	1·6	–	1·3	–	–	1·3
	Jan. 1983	1·2	–	1·2	–	–	0·8
	Feb. 1983	0·9	–	0·5	–	–	0·2
	Mar. 1983	1·0	–	0·6	–	–	0·2
	Apr. 1983	1·3	–	2·2	–	–	2·6
Maximum temperature (°C)	July 1979–June 1982[B]	21·5	25·4	23·0	–	24·0	23·5
	Dec. 1982	–	23·1	20·2	21·5	22·0	24·0
	Jan. 1983	–	24·7	21·1	20·1	20·5	21·9
	Feb. 1983	–	26·0	23·4	22·0	22·9	25·0
	Mar. 1983	–	25·8	23·0	23·0	24·0	25·0
	Apr. 1983	–	17·7	14·5	–	16·5	16·6
Minimum dissolved oxygen ($g\ m^{-3}$)	July 1979–June 1982[B]	5·6	6·8	7·2	–	6·8	6·2
	Dec. 1982	–	7·5	7·4	6·6	6·4	6·5
	Jan. 1983	–	7·6	6·9	6·3	6·4	6·7
	Feb. 1983	–	6·5	4·9	5·2	2·0	2·1
	Mar. 1983	–	6·7	6·1	6·1	5·1	3·1
	Apr. 1983	–	9·0	8·8	–	8·3	8·3
Maximum electrical conductivity ($mS\ m^{-1}$)	July 1979–June 1982[B]	15	22	51	–	60	62
	Dec. 1982	–	17	44	42	55	55
	Jan. 1983	–	29	45	82	81	64
	Feb. 1983	–	51	71	115	114	105
	Mar. 1983	–	34	78	93	100	110
	Apr. 1983	–	19	31	–	44	48

[A] Records from LVWSB stream gauging stations.
[B] Data from Anon. (1984).

Hydrometeorological Background

The severity of the 1982–83 drought is illustrated by the fact that there has been no drier 11-month interval recorded for the LaTrobe Valley than that between April 1982 and February 1983. Rainfall in Traralgon for this period was 365 mm compared with the long-term (83–84 year) average of 696 mm (LVWSB data). From October to February inclusive, Traralgon rainfall was only 117 mm in contrast to an average of 303 mm. Flows in the LaTrobe River (Table 1) fell by February 1983 to minima of $0\cdot9\ m^3\ s^{-1}$ at Willow Grove (upstream of major human influence), $0\cdot5\ m^3\ s^{-1}$ at Thom's Bridge (near Morwell), and $0\cdot2\ m^3\ s^{-1}$ at Rosedale, the farthest downstream gauging station on the river. At Willow Grove the minimum was slightly higher than that recorded during the previous most severe drought, in 1967–68 ($0\cdot8\ m^3\ s^{-1}$), but at Rosedale the 1983 minimum was the lowest since records began in 1900. This was probably because of the large amounts of water abstracted from the lower river by agricultural diverters and by the LVWSB to supplement the supply from Moondarra Reservoir on the Tyers River.

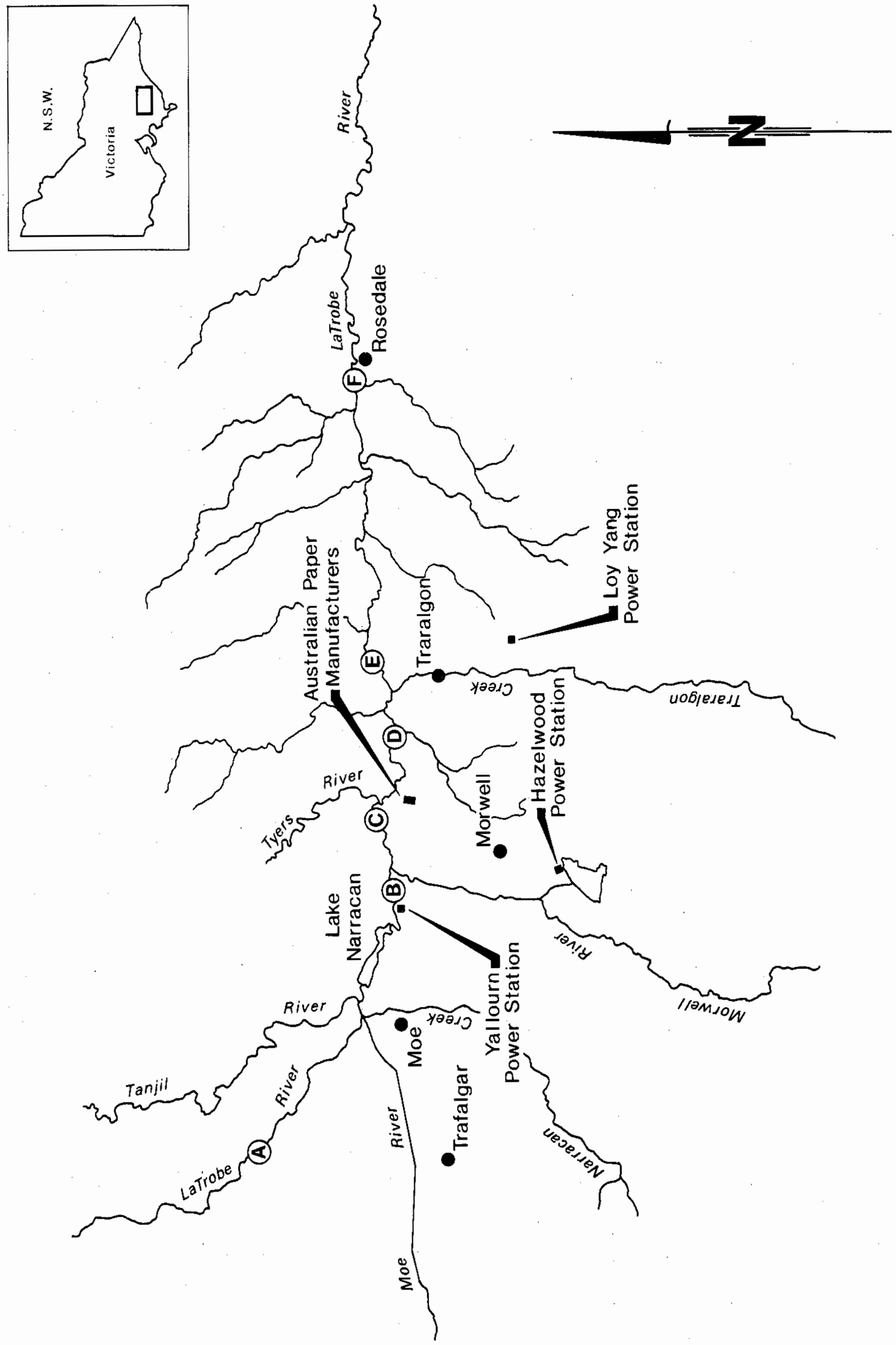

Fig. 1. Map of the central part of the LaTrobe River system showing the locations of the sampling sites (A–F).

The Study Area

Monitored data are reported for six sites (Fig. 1) situated along the lowland section of the river (altitude below 75 m). This reach is almost entirely in agricultural surroundings with sheep and cattle grazing being the principal adjacent land uses. The river is 10–25 m wide and generally no deeper than 2 m, with eroded banks supporting grasses, herbs, willows and some remnants of the original eucalypt-dominated vegetation. The channel substratum consists of clays, silt, sand and gravel, with some logs and other debris.

Site A (at Willow Grove) is upstream of major human influences other than limited agricultural development. Downstream of site A the river receives treated sewage from Moe via the Moe Drain, and is impounded as Lake Narracan ($8 \cdot 4 \times 10^6$ m^3 capacity). Immediately below Narracan Dam, and upstream of site B (L5 weir to Brown Coal Mine Bridge) the river receives thermal effluent from SEC coal-fired power generating stations at Yallourn. The Morwell River, which joins the LaTrobe between site B and site C (Thom's Bridge) carries treated sewage from Morwell and various SEC effluents. During the drought the most important of these were intermittent discharges of saline groundwater from the Morwell open cut coal mine, and Yallourn power station cooling tower purge routed via the Yallourn open-cut fire service basin and flocculation pond. Saline boiler-ash sluicing water from Yallourn was also periodically discharged to the LaTrobe just upstream of the Morwell River junction via the 'Blue Lagoon' outfall.

Site D (at the Traralgon–Tyers Road crossing of the river) is a short distance downstream of the Australian Paper Manufacturers (APM) pulp and paper mill at Maryvale, which during the drought discharged an average of about $0 \cdot 5$ m^3 s^{-1} of wastewater with a total dissolved solids concentration near 1000 g m^{-3}. Site E (at Scarne's Bridge on the Traralgon–Glengarry Road) is downstream of the confluence of Traralgon Creek. At the time of the study the main waste entering this creek was turbid site runoff from the Loy Yang power station construction area. No point source waste discharges and only a few minor tributaries enter the LaTrobe River between site E and site F (at Rosedale).

Materials and Methods

Water quality indicators were assessed for sites B–F from early December 1982 until mid-April 1983. Initially the frequency was weekly, but from late January samples were taken on most weekdays. Nearly all sampling was in early morning (0600–1000 h) to coincide with the expected daily minimum dissolved oxygen concentration. Water temperature was measured on site with a mercury thermometer and samples for dissolved oxygen (DO) and electrical conductivity (EC) determinations were collected in glass-stoppered BOD bottles and polyethylene bottles respectively. On return to the laboratory (within *c.* 1 h) DO was measured with a Yellow Springs model 57 oxygen meter and EC with a Philips model PW 9505 conductivity meter. EC readings were corrected to 20°C.

Invertebrate sampling followed a semiquantitative procedure used by the LVWSB for routine biological surveillance of water quality. This involved collecting nine samples per site per survey: three 'kick' samples from the stream bed, three sweep samples from the river margins (including semi-aquatic vegetation) and three samples from submerged logs. For each sample type, one sample was taken from an area of relatively fast current, one from an area of little current and one from an intermediate location. Each kick or sweep sample was collected along a transect of *c.* 10 m using a 200-μm mesh pond net and the log samples were obtained by washing, scraping or picking material from one large or a few small logs after their removal from the water. Each sample was examined visually in the field for a period of 30 min, as many organisms as possible being removed from associated debris with forceps and pipettes and preserved in 5–10% formalin. In the laboratory the organisms were identified (usually to species), and each taxon awarded an abundance score for each sample according to the approximate number of specimens present as indicated in the following tabulation:

No. of specimens	1–2	3–5	6–10	11–15	16–25	26–40	41–60	61–80	81–100	>100
Score	1	2	3	4	5	6	7	8	9	10

A full series of invertebrate samples was collected at sites A–D and F in April–June 1982 (before the drought), and at all sites in December 1982–January 1983 (during the drought) and April–May 1983 (immediately after the drought). In April 1983 a second series was also taken at site B to demonstrate the repeatability of results obtained by this procedure. The samples from site B were collected near Brown Coal Mine Bridge, 1 km downstream from the L5 weir where most of the site B samples for chemical analysis were obtained.

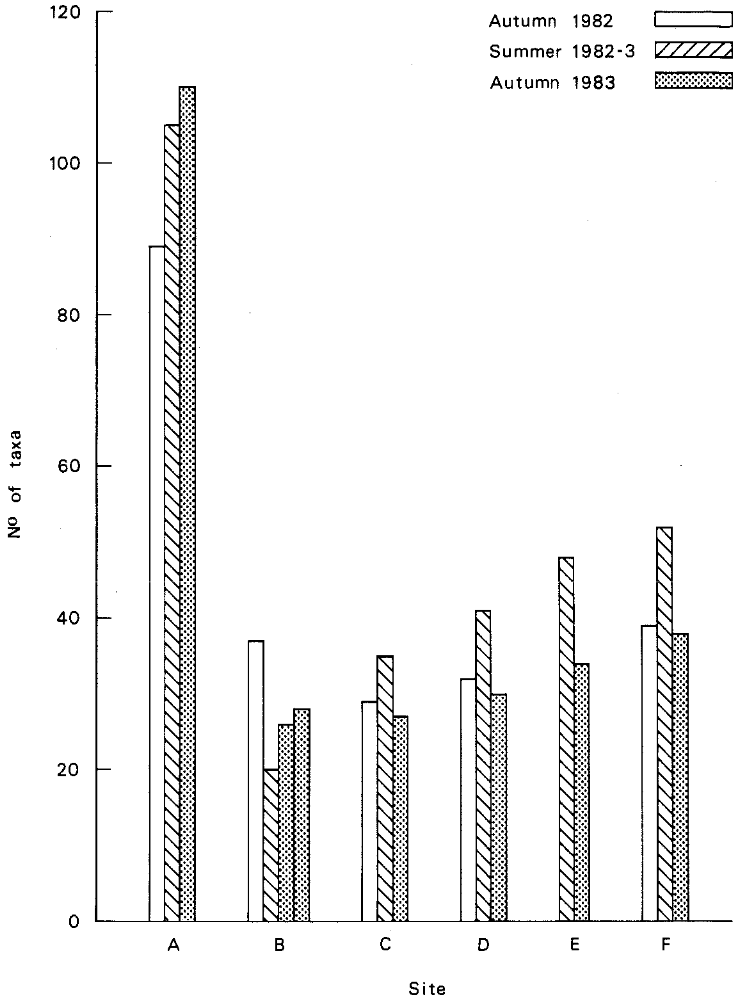

Fig. 2. Numbers of invertebrate taxa collected from each site in autumn 1982 (before the drought), summer 1982–83 (during the drought) and autumn 1983 (after the drought).

Results

Water Quality Indicators

Water quality indicator values often fluctuated rapidly from day to day in response to variations in river flow and wastewater discharges. The highest temperature recorded was 26·0°C at Yallourn (Table 1), not far above the maximum of 25·4°C observed there during a monthly water-quality survey from July 1979 to June 1982 (Anon. 1984). Since the drought period measurements were made in early morning, they may underestimate the true temperature maxima. DO concentrations fell to 2 g m^{-3} at sites E and F (Table 1), well below the minima recorded in 1979–82, but elsewhere remained above about 5 g m^{-3}. EC values ranged up to 115 mS m^{-1} at the more downstream sites, almost twice as high as the maxima for the 1979–82 period.

Invertebrate Fauna

The total numbers of invertebrate taxa recorded per site on each survey are shown in Fig. 2. Site A was much richer than all the downstream sites, of which sites B and C were generally the poorest. There was a steady increase in richness from sites B and C to site F. The low richness of the downstream sites resulted mainly from a poorer representation of Coleoptera, Diptera, Ephemeroptera, Plecoptera and Trichoptera (Table 2). Of the major invertebrate groups, only Hemiptera and Odonata had relatively many taxa at the downstream sites. There was an increase in collectable taxa at most sites in December–January, but the numbers of taxa obtained in autumn pre-drought (1982) and post-drought (1983) were similar; the slight decline apparent downstream of Yallourn (sites B, C, D and F) was not statistically significant (paired *t*-test, $n = 4$, $P > 0 \cdot 1$).

Table 2. List of major invertebrate groups collected at each site
For molluscan and arthropod groups the approximate numbers of species collected are also indicated. +, present; blank space, none collected

Group	Representation at site: A	B	C	D	E	F
Porifera	+				+	
Hydrozoa	+	+	+	+		
Temnocephalidea			+	+		
Turbellaria	+	+	+	+	+	+
Nematoda	+					
Polyzoa				+	+	
Oligochaeta	+	+	+	+	+	+
Hirudinea						+
Gastropoda	2	1	1	1	1	1
Bivalvia	1		1	1	1	2
Arachnida	4					
Cladocera		1		1		
Copepoda		1				
Amphipoda						1
Decapoda	1	1	1	1	1	1
Coleoptera	30	9	8	6	10	12
Diptera (Chironomidae)	31	13	12	15	20	18
Diptera (others)	13	2	1	3	1	5
Ephemeroptera	18	2	2	2	2	3
Hemiptera	3	6	7	7	7	8
Lepidoptera						1
Megaloptera	1					1
Odonata	2	5	3	3	3	5
Plecoptera	12	—	1	1	—	1
Trichoptera	32	8	9	7	9	10

Taxa with a mean abundance score for all samples greater than $0 \cdot 1$ were regarded as common. The distribution of these common taxa is shown in Table 3. Virtually all taxa that were abundant in autumn before the drought were about equally abundant in the same season and at the same sites after the drought. Many common taxa, especially of Ephemeroptera and Trichoptera, were collected only from site A. Others (e.g. *Coxelmis v-fasciata*, *Aulonogyrus strigosus*, *Simulium ornatipes* and some Hemiptera, Odonata and Hydropsychidae) were collected only downstream of Lake Narracan. A few (e.g. *Coxelmis novemnotata*, *Rheotanytarsus* sp., *Austrosimulium furiosum*, *Baetis* spp. and *Leptoperla* spp.) were well represented at site A and the most downstream sites, but scarce in between.

Discussion

The water-quality changes observed in the river mainly reflected variations in the flow volume available to dilute waste inputs. Thus DO was lowest and EC highest from early February to mid-March when river flow was minimal (Table 1). It is uncertain whether the very low DO values at sites E and F at this time were caused by the impact of APM wastes; DOs were much higher at site D, the first site downstream of APM's outfall, but it is possible that travel time to this site was insufficient for DO sag to occur. Anon. (1977) found that under low-flow conditions in 1970–74, DO downstream of APM reached a minimum at site D, with recovery at subsequent sites. However, APM's waste treatment processes have changed considerably since that time, and it is likely that the behaviour of the waste on entering the river has also changed. The marked decline in DO in February–March did not appear to be caused by rising temperatures as maximum temperatures were fairly uniform from December to March (Table 1).

Most studies of the response of stream invertebrates to drought (references cited in Introduction) have been concerned with the effects of cessation of flow or desiccation of the stream bed. In the LaTrobe River some flow was always present and although parts of the stream bed were exposed, drying out was not severe. A few authors (e.g. Seagle *et al.* 1980; Extence 1981; Pratt *et al.* 1981) have observed adverse effects of low flows on stream invertebrates apparently caused by lack of dilution for wastewater discharges or urban runoff. In the LaTrobe River, despite the decline in oxygen levels at the downstream sites, the drought seemed to have little impact on the invertebrate fauna there. There was no significant decrease in faunal richness between the autumns of 1982 and 1983 and most species common before the drought were also common thereafter (Table 3). Only a few (e.g. *Triplectides similis*) were not collected downstream of Yallourn after the drought; Korboot (1963) found that *Triplectides* spp. did not survive oxygen concentrations below about 6 g m^{-3}. The general lack of response of the downstream fauna suggests that even before the drought, membership of the invertebrate assemblage of this part of the river was largely restricted to species tolerant of low dissolved oxygen concentrations.

Our invertebrate survey data may be compared with an earlier, more detailed quantitative study of the benthic fauna of the same section of river undertaken from May 1979 to March 1981 by Marchant *et al.* (1984). Their list of common taxa, dominated by Chironomidae, is very different from our list of common taxa but the discrepancy is not surprising. Marchant *et al.* sampled only the sandy substratum of the river, both within 1 m of the bank and near the centre of the stream. They did not collect from marginal semi-aquatic vegetation or from submerged logs which in our study clearly harboured a different fauna from that of the general river bed. Secondly, our partly subjective sampling and analysis technique may bias in favour of certain taxa, although the similarity of results from the duplicate post-drought surveys at site B (Table 3) suggests that the method at least yields reproducible results. Similar procedures have been shown by Anon. (1983) and Mackey *et al.* (1984) to produce representative and consistent data.

Marchant *et al.* (1984) recorded lowest taxa richness in the 'main channel' of the river between Thom's Bridge and the Traralgon–Glengarry Road (their sites 7–9). Near the bank, sites further upstream (between the Yallourn heated water outfalls and the Morwell River confluence) were also very impoverished. Similarly, our study found the lowest taxonomic richness immediately downstream of Yallourn and at Thom's Bridge with a gradual improvement thereafter. Both studies clearly indicate a faunal recovery at Rosedale, manifested as increased taxonomic richness and the re-appearance of some taxa common upstream of Yallourn.

Marchant *et al.* (1984) were not able to identify a physicochemical cause for the poverty of the fauna at their sites 7–9. They noted that conductivity downstream of the Morwell River junction was relatively high (up to *c.* 60 mS m^{-1}), but considered that a direct salinity impact was unlikely because conductivity was also high at Rosedale where the fauna seemed to be

Table 3. Abundance scores of common taxa at each site in autumn 1982 (before the drought), summer 1982–83 (during the drought) and autumn 1983 (after the drought)

Total abundance scores for each site (sum of scores for nine samples) are represented as follows: *, 1–9; **, 10–18; ***, >18. Species codes are those of the LVWSB reference collection of freshwater invertebrates

CLASS / **Order** / Family	Genus and species	Autumn 1982 abundance at site:					Summer 1982–83 abundance at site:						Autumn 1983 abundance at site:						
		A	B	C	D	F	A	B	C	D	E	F	A	B1	B2	C	D	E	F
HYDROZOA																			
Hydroida																			
Hydridae			*				*	*					*	**	*				
TURBELLARIA																			
Tricladida		*		*		*	*				*	*	*	*	*		*	*	
OLIGOCHAETA		***	*	*	**	*	**	*	**	***	*	*	***	**	**	**	**	*	*
GASTROPODA																			
Bassomatophora																			
Planorbidae	Physastra gibbosa	*		*	*	**			*		**	*	*	*	**	**	*	**	
CRUSTACEA																			
Decapoda																			
Atyidae	Paratya australiensis	*	***	***	***	**	*	***	**	*	**	**	*	**	**	**	*	*	*
INSECTA																			
Coleoptera																			
Elmidae	Coxelmis novemnotata			*	*	*	*		*	*	*	*	*			*	*	*	*
	Coxelmis v-fasciata					*					*	*						*	*
	Notriolus allynensis	*	*				*						*	*	*				
	Notriolus maculatus	*	*	*	**	**		*	*	**	**	*		*	*	*	**	*	**
	Notriolus quadriplagiatus	**	*		*	*	**		*	*			**					*	
	Notriolus victoriae	*	*	*	*	***	**	*	*	*	*	**	**	*	*	*	*	**	*
	Simsonia tasmanica	*	*		*	*	*			*			*		*	*		*	*
Gyrinidae	Aulonogyrus strigosus		*	*	*	*		*	*	**	*	*		*		*	*	*	*
Diptera																			
Chironomidae	Cryptochironomus griseidorsum		*			*			*	*	*	*	*						*
	Eukiefferiella sp.1	*				*	*			*			*						
	Micropsectra sp.207	*					*			*	*		*			*		*	*
	Nannocladius sp.16		*				*	*	**	*	*	*	*	*	*	*	*	*	*
	Orthocladius/Cricotopus spp.	*	**	*	*	*	*	**	***	*	*	*	***	*	**	*	**	**	*
	Polypedilum griseiguttatum	*	*	*		*	*		*	*	*		*						*
	Polypedilum oresitrophus	**			*		*				*	*	*				*		
	Rheotanytarsus sp.202	*	*	*	**	**	**			**	**	**	***			*	**	**	**
	Riethia sp.250	*	*	*	*		*						*						
	cf. Smittia sp.6	*				*			*	**	*	*							

Simuliidae	Austrosimulium furiosum	*			*	**	*						**						*
	Simulium ornatipes					**													*
Ephemeroptera																			
Baetidae	Baetis spp.	***	*	**	**	***	**		*	*	**	**	**			*	*	**	***
Caenidae	Tasmanocoenis tonnoiri	*		*	*		*		*	**	*	**	*				*		*
Leptophlebiidae	Atalophlebia sp.B	*					*						*						
	Atalophlebia sp.C	**					**						**						
	Nousia sp.A	***					**						*						
	Nousia sp.D	*					**						*						
Oligoneuriidae	Coloburiscoides sp.A	**					**						*						
Hemiptera																			
Corixidae	Agraptocorixa eurynome		*		**											*	*	*	
	Micronecta batilla	*	*	***	***	*	**		*	**	***	***	***		*	*	***	***	**
Notonectidae	Anisops spp.		*		*			*		*		*		*	*	*	*	*	*
Odonata																			
Aeshnidae	Austroaeschna spp.		*	*		*	*	*	*	*	*	*	*	*				*	*
Coenagrionidae	Ischnura heterosticta		*	*		*								*	*	*	*	*	
Plecoptera																			
Gripopterygidae	Leptoperla spp.	*		*		*				*		*	*				*		*
Trichoptera																			
Ecnomidae	Ecnomus pansus		***	*	**	*		***	**	**	*	*		***	**	**	**	*	***
Hydrobiosidae	Ethochorema sp.A	*					**						*						
Hydropsychidae	Asmicridea edwardsi	**	*	*	**	*	**	**	***	***	**	**	**	*	*	*	**	*	*
	Cheumatopsyche sp.A						*		*				**			*			*
	Cheumatopsyche sp.D		**	***	***	***		***	***	***	*	**		*	*	**	*	**	***
	Cheumatopsyche sp.G		*	*	***	*		*	**	**	*	*		*	*	*	**	**	**
Leptoceridae	Notalina bifaria	*					***						*						
	Triplectides similis	*		*	*	*	*		*				*						
Philorheithridae	Philorheithrid sp.A	*					*						**						

less affected. They suggested that increased conductivity might simply be an indicator of generally lower water quality, with an unknown factor being responsible for reduced species richness and abundance. Our results demonstrate the conductivity tolerance of the invertebrates of the lower river; this indicator rose markedly during the 1982–83 drought without a concomitant decline in faunal richness. The role of other water-quality factors in controlling the invertebrate biota of the river needs to be assessed by further studies.

Acknowledgments

We are grateful to the following Latrobe Valley Water and Sewerage Board staff for assistance in the field and water sample analysis: Ms S. Booth, Ms J. Gilmour, Ms D. Hunter, Ms P. Hutton, Ms L. Kelly, Ms B. Maglen and Ms M. Siinmaa. Mr B. Smith is thanked for preparing the figures.

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Manuscript received 31 July 1985, revised 27 August 1986, accepted 22 September 1986