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RECOVERY OF AQUATIC MACROINVERTEBRATE ASSEMBLAGES DOWNSTREAM OF THE CANNING DAM, WESTERN AUSTRALIA

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ABSTRACT

Macroinvertebrate assemblages downstream from the Canning Dam, on the Canning River, Western Australia, were sampled to assess the impact of long-term impoundment and the role of a major tributary in community recovery.

Kick samples and associated physical measurements were taken from riffle zones in three reaches in March and July 1989. The lower reach was located immediately downstream of the confluence with Stinton Creek, the first major tributary below the dam, with the middle and upper reaches positioned between the tributary and the dam.

Reduced concentrations of dissolved oxygen in the upper and middle reaches in March, compared to the lower reach were attributed to significantly higher levels of organics, high summer water temperatures, and a proposed increase in microbial activity. The build-up of organics was probably related to reduced flushing, as a result of impoundment. Stinton Creek increased the discharge of the Canning River below the confluence, particularly in winter, which presumably prevented the build-up of organics in the lower reach.

Significant differences in the aquatic macroinvertebrate fauna between reaches were detected. A total of 68 taxa was recorded from the lower reach, 88 per cent of which were also present in the middle and upper reaches. However, the middle and upper reaches contained a greater number of taxa (112 and 90 respectively), approximately 50 per cent of which were not recorded from the lower reach. The additional taxa were more typical of lowland rivers or lentic (standing water) systems, suggesting that physical conditions in the middle and upper reaches were more like a lowland river than an upland stream.

More collectors and shredders occurred in the upper and middle reaches, associated with the accumulation of particulate organic matter. Ordination and classification procedures based on macroinvertebrate assemblages clearly separated samples from the upper and middle reaches from the lower reach. There was also a distinct seasonal separation.

These observations support a hypothesis that while the reduced flow below Canning Dam had an impact on the macroinvertebrate fauna, confluence with a major tributary (Stinton Creek) allowed recovery of the macroinvertebrate community, through the tributary acting as a source of increased discharge. The implications for the management of impounded rivers in southwestern Australia are discussed.

KEY WORDS Impoundment Macroinvertebrate assemblages Western Australia

INTRODUCTION

Community structure of benthic invertebrates at a site in a stream is the result of the interplay of numerous factors including flow, substratum, temperature, water chemistry, aquatic and riparian vegetation, food, and biotic interactions (Armitage, 1984). Impoundment and regulation of stream flow directly or indirectly affect these factors and associated processes and thereby influence macroinvertebrate community structure (Petts, 1980). The ecological effects of river regulation on assemblages of aquatic macroinvertebrates have received wide attention in the literature (Ward and Stanford, 1979a; Lillehammer and Saltveit, 1984; Craig and Kemper, 1987; Petts and Wood, 1988). In Australia, this literature has grown considerably since the late 1970s (for review see Walker, 1985). However, the majority of research has been based in the east of the

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continent (Walker, 1979, 1980; Blyth, 1980; Marchant *et al.*, 1984; Doeg *et al.*, 1987), and there is little information on the effects of flow regulation on the aquatic fauna of streams of Western Australia (Storey and Edward, 1989; Storey *et al.*, 1990).

A recent study on the Canning River identified a site downstream of the Canning Dam at which macroinvertebrate community structure had changed from that expected in a similar location on an unimpounded river to a community structure more associated with a lowland river (Storey *et al.*, 1990). However, recovery of the fauna was detected further downstream from the dam, below the confluence with Stinton Creek, the first major tributary entering the river. It was proposed that the initial change was a reflection of reduced flow due to impoundment, with the subsequent recovery in the fauna a response to decreased regulation as a result of inputs from Stinton Creek.

As yet, little is known of the flow requirements of aquatic macroinvertebrates of streams of southwestern Australia. The aim of this study was to assess the effects of impoundment on selected physical variables and the aquatic macroinvertebrate fauna of the Canning River and to investigate the role of Stinton Creek in changing these variables and in the recovery of the fauna.

METHODS

Study area

The Canning Dam is one of the larger impoundments in southwestern Australia. Completed in 1940, it has a catchment area of 804 km^2 and a capacity of 93·4 million m^3. The dam impounds all flow without compensation releases. As a result the Canning River downstream of the dam exhibits a substantially changed flow regime. The mean annual discharge at the dam site for the 27 years prior to construction (1908–1934) was 52·2 million m^3, with a maximum instantaneous flow of 38·9 cumecs and a mean maximum instantaneous flow of 20·4 cumecs (Anon., 1984). Post-impoundment figures from the Araluen pumpback station, located on the Canning River immediately above the confluence with Stinton Creek, give a mean annual discharge over the gauging weir of 1·4 million m^3, a maximum instantaneous flow of 7·8 cumecs and a mean maximum instantaneous flow of 2·6 cumecs for a 13 year period (1977–1989).

Three reaches, each approximately one kilometre in length, were sampled downstream of the dam. The lower reach was located below the confluence with Stinton Creek. The middle and upper reaches were located above the confluence, with the latter close to the dam (Figure 1). The lower and middle reaches were selected on the basis of having the same gradient, while the upper reach had the lowest gradient within the five kilometre length of river between the dam and Stinton Creek.

Sampling strategy

To allow for seasonality in the macroinvertebrate fauna of streams of the region (Bunn *et al.*, 1986; Bunn, 1988; Storey *et al.*, 1990), samples were taken from each reach in March (summer/autumn) and July (winter/spring) 1989. Sampling was by the kick technique (Furse *et al.*, 1981; Mackey *et al.*, 1984; Storey *et al.*, 1991) using a standard FBA pond net, with 0·25 mm mesh aperture. Sampling procedure consisted of placing the net on the stream bed and disturbing the substratum immediately upstream, by vigorous kicking, for a total sampling time of three minutes. At each site the operator moved in a zig-zag fashion up the stream bed for 30 m and sampling was restricted to riffle zones. Sediment, organic matter, and macroinvertebrates were dislodged and swept into the net by the current. Seven samples were taken from separate riffle zones in the lower and middle reaches in March and July 1989. Due to the dominance of pool habitat in the upper reach only four samples could be taken from this reach in March and six samples in July.

Physical variables

Stream depth, width, and water velocity were measured at the downstream, mid-point, and upstream end of each site. One measure each of water temperature and dissolved oxygen (DO, expressed as per cent saturation) were taken at the upstream end of each site. Substratum heterogeneity and mean particle size (MPS) were estimated for each site using a visual technique (Wright *et al.*, 1984); the substratum was first given a score of heterogeneity based on the number of recognizable substrate types (*viz.* clay, silt, sand, gravel,

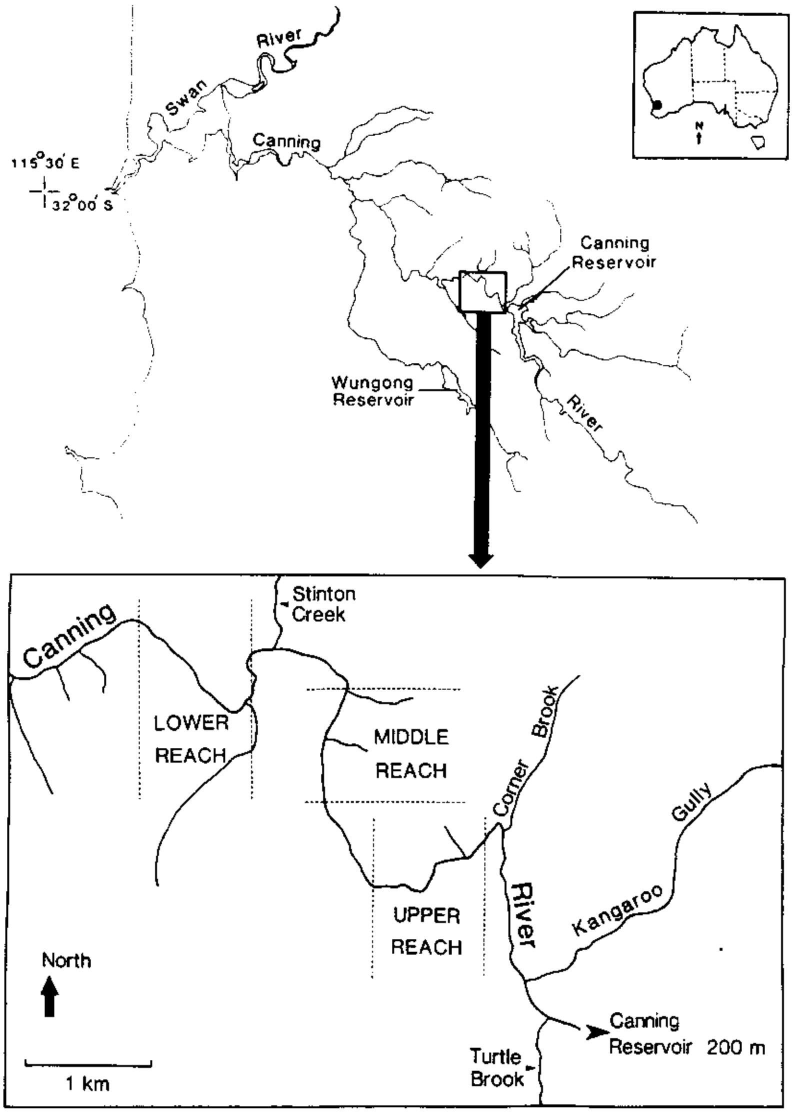

Figure 1. The Canning River study area, with location of the three sampling reaches

pebbles, cobbles, boulders, bedrock, and macrophyte) and then the mean particle size was calculated as the mean phi value weighted by the percentage composition of the substratum (clay = phi 9·5, silt = phi 6·5, sand = phi 2·0, gravel = phi −2·0, pebbles = phi −4·5, cobbles = phi −6·5, and boulders = phi −9·0). Particulate organic matter (POM) retained by the net was removed from each sample in the laboratory by flotation and dried at 50°C to constant weight.

Two-way analysis of variance (ANOVA) was used to test for significant between-reach and -season differences in physical variables, using sites as replicates within reaches. Prior to analysis the homoscedasticity of sample variances was examined by Cochran's C and Bartlett-Box tests. Transformations applied to achieve homoscedasticity of sample variances are indicated in the results. Tukey's studentized range test (HSD), which controls for Type I experimentwise error rate (Day and Quinn, 1989) was used to locate between-season and -reach differences for variables that showed significant variation in ANOVAs.

Macroinvertebrate fauna

Macroinvertebrates were sorted from the organic fraction of each sample to provide qualitative data on species composition. Specimens were identified to the lowest possible taxon, using previously collected and curated voucher specimens held in the Zoology Department, The University of Western Australia. Species richness (total number of macroinvertebrate taxa) was recorded for each kick sample and compared between reaches and seasons using sites as replicates within reaches (ANOVA). Taxa were then assigned to functional feeding groups (*sensu* Hawkins and Sedell, 1981: collectors, scrapers, shredders, filter-feeders, and predators, with pupae assigned as 'others'). This was based on past work on the macroinvertebrate fauna of forested streams in Western Australia (Bunn, 1985, 1986) and by reference to the literature (Cummins, 1973; Merritt and Cummins, 1978). Between-reach and -season differences in the number of taxa in each feeding group were tested (ANOVA). Finally, macroinvertebrate assemblages for each sample were ordinated using detrended correspondence analysis (DECORANA; Hill, 1979a) and classified using two-way indicator species analysis (TWINSPAN; Hill, 1979b), using presence/absence data. Relationships between ordination scores (axes 1 to 4) and physical variables recorded at each site were examined using Spearman rank correlation. Bonferroni corrections (*sensu* Sachs, 1984) were applied to reduce the chance of Type I errors. This involved dividing the significance levels of 0·05 and 0·01 by the number of tests (9) to give adjusted levels of $p < 0.005$ and $p < 0.001$.

RESULTS

Physical variables

Mean values (± 1 S.E.) for each physical variable are presented in Table I and between-reach and -season differences summarized in Table II. Stream depth varied between reaches and seasons. All reaches were shallower in March than July. The lower reach was deeper than the middle reach, however neither differed significantly from the upper reach. Stream width did not differ between reaches; however, all reaches were wider in July than March. Similarly, there was no difference in water temperature between reaches, but temperatures were higher in March than July. Levels of POM did not vary between reaches on a seasonal basis, however both the upper and middle reaches had higher accumulations of POM than the lower reach. Substrate heterogeneity and mean particle size showed no differences between reaches or seasons. Dissolved oxygen demonstrated reach and season differences, with a significant interaction. Dissolved oxygen levels were lower in March than July. Range tests were then performed on each season separately to interpret the significant interaction. Higher percentage saturation was recorded from the lower than the middle and upper reaches in March, but no between-reach differences were recorded in July. Velocity similarly demonstrated a reach and season difference, with a significant interaction. Velocities were lower in March than July. In

Table I. Mean values (± 1 S.E.) for physical variables by reach and season. Units of measurement are given in parentheses

	Lower		Middle		Upper	
	March	July	March	July	March	July
Depth (cm)	15·4 (1·53)	36·0 (3·44)	12·0 (0·69)	25·9 (2·21)	16·0 (0·91)	25·8 (2·29)
Width (m)	2·27 (0·39)	3·43 (0·30)	1·75 (0·17)	3·31 (0·39)	1·48 (0·62)	3·07 (0·36)
Temp (C)	19·5 (0·85)	13·1 (0·12)	19·8 (0·29)	12·3 (0·03)	19·3 (0·30)	12·3 (0·07)
P.O.M. (g dry wt)	35·1 (4·09)	31·1 (5·26)	208·5 (68·05)	105·7 (10·63)	120·7 (18·30)	166·9 (44·69)
Hetero (#)	6·0 (0·31)	6·1 (0·14)	6·0 (0·31)	6·3 (0·18)	6·8 (0·48)	6·7 (0·21)
M.P.S. (Phi)	−1·50 (0·13)	−2·39 (0·86)	−1·34 (0·23)	−1·24 (0·17)	−1·68 (0·31)	−1·63 (0·18)
D.O. (% sat)	98·0 (2·84)	90·9 (2·19)	63·9 (4·98)	89·3 (1·41)	62·7 (5·13)	88·5 (0·95)
Velocity ($\mathrm{cm\ s^{-1}}$)	16·4 (2·97)	57·4 (6·78)	6·4 (1·00)	24·6 (2·83)	12·0 (1·47)	22·2 (3·13)

Table II. F-ratios and associated levels of significance for two-way analysis of variance on physical variables by reach and season ($p < 0.001$*; $p < 0.01$†; $p < 0.05$‡; not significant, n.s.). Tukey's studentized range tests (HSD) indicate between-reach and season differences. Sites not underlined by a common line are significantly different ($p < 0.05$)

ANOVA	Season	Reach	Season by Reach
Depth (sqrt)	91·11*	5·99†	2·60n.s.
Width	25·74*	1·33n.s.	0·28n.s.
Temp	388·99*	0·69n.s.	0·93n.s.
POM (log)	0·60n.s.	27·75*	0·68n.s.
Hetero	0·71n.s.	2·77n.s.	0·22n.s.
MPS (log)	0·55n.s.	1·99n.s.	0·11n.s.
DO (arcsin)	22·54*	25·39*	23·17*
Velocity (sqrt)	71·96*	20·60*	5·05‡

Tukey's	
Depth	1.) March < July 2.) Lower Upper Middle
Width	1.) March < July
Temp	1.) March > July
POM	1.) Lower Middle Upper
DO	1.) March < July 2.) March: Lower Middle Upper
Velocity	1.) March < July 2.) March: Lower Upper Middle 3.) July: Lower Middle Upper

March, velocities were higher in the lower reach than the middle reach, however neither differed significantly from the upper reach, and in July the lower reach was higher than the middle and the upper reaches.

Macroinvertebrate fauna

A total of 132 taxa were taken, with 68, 112, and 90 taxa recorded from the lower, middle, and upper reaches respectively. There was no seasonal difference in species richness (ANOVA, $p > 0.05$), however between-reach differences were significant (ANOVA, df 1,2, $F = 24.22$, $p < 0.001$), with the middle reach demonstrating a higher species richness than the upper reach, which was higher than the lower reach (Tukey's, $p < 0.05$).

Eight taxa had distributions restricted to the lower reach, comprising 11·8 per cent of the fauna, with 25 (22·3 per cent) and 11 taxa (12·2 per cent) restricted to the middle and upper reaches, respectively (Table III). The middle and upper reaches together contained 125 taxa, 62 of which (49·6 per cent) did not occur in the lower reach. Analysis of the composition of functional feeding groups in each reach demonstrated significant reach and season differences in collectors, shredders, predators and others, and a between-reach difference in scrapers (Table IV). Filterers showed no difference between reaches or season. Collectors, predators, and others were more abundant in March than July, with shredders exhibiting the opposite distribution. The upper and middle reaches supported more collectors and shredders than the lower reach and scrapers and predators were more prevalent in the middle than the lower or upper reaches.

Ordination and classification of all samples collected in March and July ($n = 38$) are illustrated in Figures 2 and 3. Axis 1 of the ordination demonstrated a separation of the lower reach from the middle and upper, with a high degree of overlap between the latter reaches. This pattern was consistent for both seasons. On

Table III. Taxa restricted to each reach, giving the number of samples (in parentheses) in which each was recorded from the lower ($n = 14$), middle ($n = 14$), and upper ($n = 10$) reaches

LOWER REACH

Richardsonianidae sp.1 (1)
Ostracoda sp.1 (8)
Syncarida sp. (1)
Cherax tenuimanus (Smith) (Parastacidae) (4)
Neboissophlebia occidentalis Dean (Leptophlebiidae) (1)
Cricotopus ?albitibia (Walker) (Chironomidae) (8)
Limoniinae sp.C (Tipulidae) (1)
Liodessus inornatus (Sharp) (Dytiscidae) (1)

MIDDLE REACH

Glacidorbis sp.B (Glacidorbidae) (1)
Ostracoda sp.3 (1)
Bibulmena kadjina Dean (Leptophlebiidae) (3)
Nyungara bunni Dean (Leptophlebiidae) (1)
Leptophlebiidae sp.E (8)
Cloeon sp.1 (Baetidae) (1)
Hemicordulia tau Selys (Corduliidae) (2)
Veliidae sp.2 (1)
Simuliidae GKW1 (1)
Orthocladiinae sp.V44 (Chironomidae) (1)
Orthocladiinae sp.V61 (Chironomidae) (1)
Ceratopogonidae sp.E (1)
Ceratopogonidae sp.K (4)
Ceratopogonidae sp.M (2)
Limoniinae sp.A (Tipulidae) (3)
Thaumaleidae sp.A (1)
Culicidae sp. (2)
Diptera sp. (1)
Triplectides sp.B (Leptoceridae) (1)
Triplectides australis Navas (Leptoceridae) (1)
Platynectes sp.A (Dytiscidae) (3)
Platynectes decempunctatus (Fabricius) (Dytiscidae) (3)
Liodessus sp.A (Dytiscidae) (1)
Hydrophilidae sp.I (1)
Hydrophilinae sp.A (Hydrophilidae) (1)

UPPER REACH

Hurleya sp. (Paramelitidae) (1)
Hemigomphus armiger (Tillyard) (Gomphidae) (1)
Argiolestes minimus Tillyard (Megapodagriidae) (1)
Orthocladiinae sp.V63 (Chironomidae) (1)
Orthocladiinae sp.VSC1 (Chironomidae) (1)
Stenochironomus sp.V17 complex (Chironomidae) (5)
Stenochironomus sp.V69 complex (Chironomidae) (1)
Ceratopogonidae sp.C (3)
Muscidae sp.1 (1)
Notalina sp.C (Leptoceridae) (4)
Acritoptila globosa Wells (Hydroptilidae) (4)

Table IV. F-ratios and associated levels of significance for two-way analysis of variance on composition of functional feeding groups by reach and season ($p < 0·001$*; $p < 0·01$†; $p < 0·05$‡; not significant, n.s.). Tukey's studentized range tests (HSD) indicate between-reach and -season differences. Sites not underlined by a common line are significantly different ($p < 0·05$)

ANOVA	Season	Reach	Season by Reach
Collectors	9·06*	16·40*	0·53n.s.
Shredders	90·90*	16·26*	1·59n.s.
Filterers	1·41n.s.	0·66n.s.	0·37n.s.
Scrapers (log)	0·92n.s.	6·93†	0·07n.s.
Predators	6·99‡	27·73*	1·74n.s.
Others	13·30*	3·39‡	0·13n.s.

Tukey's	
Collectors	1.) March > July 2.) Lower Middle Upper
Shredders	1.) March < July 2.) Lower Middle Upper
Scrapers	1.) Lower Upper Middle
Predators	1.) March > July 2.) Lower Upper Middle
Others	1.) March > July

axis 2, samples taken in March separated from those collected in July. Axes 1 and 2 accounted for the majority of variation based on the first four axes, explaining 41·8 per cent and 33·0 per cent respectively.

Spearman rank correlation coefficients between each physical variable and sample scores on axes 1 to 4 of the DECORANA ordination are presented in Table V. Significant correlations with axis 1 scores demonstrated gradients of increasing water velocity and per cent saturation of DO, and decreasing levels of POM from the upper and middle reaches to the lower. Distance of each reach from the dam was also significantly correlated with axis 1 scores. Significant correlations with axis 2 scores related to the separation of samples

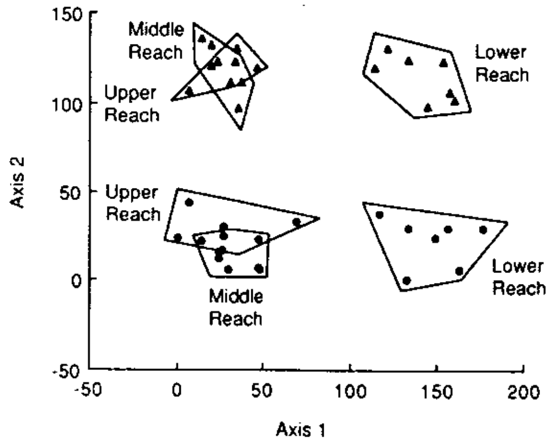

Figure 2. Ordination by DECORANA (Axes 1 and 2) of individual kick samples ($n = 38$) taken in March (▲) and July (●) 1989. Polygons enclose all samples from each reach in each season

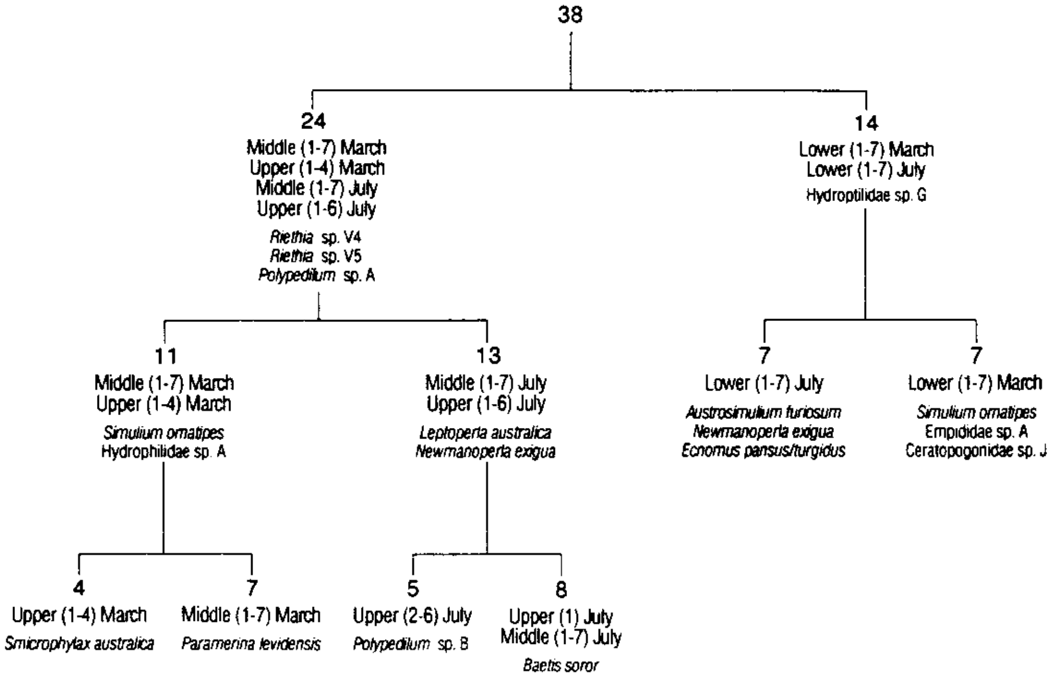

Figure 3. Classification by TWINSPAN of individual kick samples ($n = 38$) taken from each reach (Lower, Middle, and Upper) in March and July 1989. Indicator taxa and the number of samples in each group are presented for each division, sample numbers are given in parentheses

Table V. Spearman rank correlation coefficients between sample scores on DECORANA axes 1 to 4 for the 3 reach by 2 season dataset and physical variables ($p < 0{\cdot}005^*$; $p < 0{\cdot}001\dagger$) ($n = 38$ except where indicated)

Variable	Axis 1	Axis 2	Axis 3	Axis 4
Distance	0·738†	0·004	−0·267	0·084
Depth	0·134	−0·736†	0·046	−0·105
Width	0·224	−0·597†	−0·113	−0·113
Temp ($n = 36$)	0·188	0·724†	0·144	−0·048
Vel	0·458*	−0·646†	0·003	−0·287
POM	−0·774†	−0·041	0·147	0·046
DO ($n = 36$)	0·650†	−0·286	−0·069	0·324
Hetero	−0·112	−0·034	0·266	0·117
MPS	−0·143	−0·056	−0·131	0·250

on a seasonal basis; sites in March were significantly shallower and narrower with lower water velocities and higher temperatures than in July.

Classification by TWINSPAN separated the lower reach from the middle and upper reaches in both seasons (Figure 3). The Trichoptera Hydroptilidae sp.G was an indicator for sites in the lower reach, with the Chironomidae *Riethia* sp.V4, *Riethia* sp.V5, and *Polypedilum* sp.A indicator taxa for the middle and upper reaches. Level two of the classification separated March samples from those taken in July for the lower, middle, and upper reaches. Further division of samples from the lower reach was not biologically meaningful and this side of the classification was terminated at level two. Level three of the classification separated the majority of samples from the upper reach from the middle reach in both seasons. Indicator taxa for each division are presented in Figure 3.

DISCUSSION

Impoundment of the Canning River has resulted in a substantially changed flow regime downstream from the dam. Mean annual discharge in the Canning River at Araluen, immediately above the confluence with Stinton Creek is currently 2·6 per cent of preimpoundment levels, with the size of spates (maximum instantaneous flow) reduced by 80 per cent. These reductions compare with average reductions of 50 per cent in median flows and 30 per cent in mean annual floods for a range of impounded river systems in the United Kingdom (Higgs and Petts, 1988). However, inputs from Stinton Creek increased the mean annual discharge of the Canning River downstream of the confluence by approximately 260 per cent, to 3·5 million m^3 (Anon, 1984), which our data suggest was sufficient to provide a return to physical conditions expected in this section of the river. Several tributaries enter the Canning River between the dam and Stinton Creek, but are either diverted to the Reservoir (Kangaroo Gully) or are relatively small with intermittent flows (Turtle Creek and Corner Brook). Inputs from these tributaries did not appear to be sufficient to allow recovery of the system.

The present study detected significant differences in physical variables between reaches. Higher levels of POM in the upper and middle reaches were probably due to lower discharge and reduced flushing by spates. Water velocities were much higher in the lower reach, particularly in winter. DO levels in the lower reach were always near saturation but were at approximately 60 per cent saturation in the middle and upper reaches in March. These reduced DO levels were probably the result of high microbial activity in the accumulated organics, combined with reduced water velocities which prevented the water from remixing and becoming saturated. Microbial activity should be greatest in summer and autumn, when water temperatures are highest, thus accounting for the reduced DO levels in March. The combination of higher water velocities and colder temperatures prevented DO from dropping below saturation in all reaches in winter.

Recent studies in the northern hemisphere (Townsend *et al.*, 1983; Wright *et al.*, 1984; Ormerod and Edwards, 1987), eastern states of Australia (Marchant *et al.*, 1985; Doeg, 1987; Doeg *et al.*, 1987) and Western Australia (Bunn *et al.*, 1986; Storey *et al.*, 1990) have established close associations between the composition of macroinvertebrate assemblages and physical conditions at a site on a river. In the United Kingdom such associations have facilitated the predictive modelling of the response of macroinvertebrate communities to river regulation (Armitage *et al.*, 1987).

Differences in the fauna in this study were associated with differences in physical conditions between the reaches. The majority of taxa taken from the lower reach (90 per cent) occurred in the middle and upper reaches but approximately 50 per cent of the total fauna was restricted in distribution to the upper and middle reaches.

Of the taxa restricted to the middle and upper reaches, the mosquito Culicidae sp., the chydorid and daphniid cladocerans, the mayfly Leptophlebiidae sp.E and the chironomids *Chironomus* aff. *alternans* Walker, *Anatopynia dalyupensis* Freeman, and *Procladius paludicola* (Skuse) are generally either planktonic or inhabit bottom sediments and are associated with lowland rivers and lentic waters (Bunn, personal communication; Edward, 1986; Storey and Edward, 1989). The extensive pools, with slow-flowing water and accumulations of POM, that predominate in the middle and upper reaches are more like conditions in a lowland river than those expected in a mid-order stream, as normally occurs on the Darling Scarp.

Analysis of the composition of functional feeding groups revealed significant differences in some groups between reaches and seasons. The more frequent occurrence of collectors and shredders in the upper and middle reaches is probably related to the accumulation of POM in these areas. Collectors were more common in March than July, a trend previously reported by Bunn (1986), who related it to the settlement of fine particulate organic matter under low flows. Conversely, shredders were more common in July than March, which was probably related to summer leaf fall material becoming available after a suitable period of conditioning (Bunn, 1986). The previously reported increase in filterers in winter, due to the suspension of particulate organic matter by increased flows (Bunn, 1986) was not observed in this study. It is hypothesized that the extensive pools and low velocities in the upper and middle reaches in summer supported a second suite of filterers, masking any seasonal difference.

The middle and upper reaches on the Canning River exhibited physical conditions and a macroinvertebrate fauna more typical of sites located on a lowland river. Similar observations were made by Armitage (1987) for regulated sites in the United Kingdom. He proposed that releases from reservoirs were insufficient to mobilize fine sediment that coated the coarse substratum in the majority of sites, settlement of which favoured the development of large populations of Oligochaeta, Chironomidae, and Mollusca feeding on deposited material. The diversity and abundance of macroinvertebrates at most sites were not reduced by the deposition, but Armitage (1987) noted that the increase in fine sediment, which filled interstitial spaces, was likely to increase the proportion of deposit feeders at the expense of grazers. Armitage (1987) and Ward and Stanford (1979b) found that most major taxa, with a few exceptions, were relatively more abundant downstream of reservoirs than at nearby reference sites. Qualitative sampling in the present study prevented the detection of changes in the abundance of taxa in the Canning River, however species richness was higher in the two reaches below the dam than the recovery reach, downstream of Stinton Creek.

Tributaries are acknowledged as having a major bioenergetic influence on river systems (Vannote *et al.*, 1980) and have been shown to modify physical and functional attributes of rivers (Bruns *et al.*, 1984). Tributaries may achieve this through introducing spates to rivers since spates are considered important reset mechanisms in stream ecosystems (Fisher *et al.*, 1982; Resh *et al.*, 1988). For instance Cline and Ward (1984) noted hydrological and biological recovery downstream of the construction site of a subalpine reservoir. This was attributed to the relatively steep channel gradient and the ameliorative action of tributaries. The observed recovery in macroinvertebrate assemblages downstream of Stinton Creek supports the hypothesis that inputs from this tributary are ameliorative by increasing discharge, intensity of spates, dissolved oxygen concentrations, and sediment/organic matter carrying capacity of the Canning River.

CONCLUSIONS

Although the Canning River was not sampled prior to construction of the dam, results from this study suggest that impoundment has altered the physical condition and the macroinvertebrate fauna immediately below the dam. However, inputs from Stinton Creek increase discharge and spates in the Canning River and macroinvertebrate assemblages recover to that expected from an unimpounded river on the Darling Scarp (Storey *et al.*, 1990).

Additional studies are needed to assess the general applicability of the findings of this study, that natural recovery in both the physical conditions and fauna of impounded rivers will occur if inputs from tributaries downstream of a dam are sufficient. The location of the recovery will depend on the point of entry of an adequate tributary, above which the river will remain impacted.

Where natural recovery is not possible through lack of suitable tributaries then compensation releases may induce recovery. Comprehensive research is needed to estimate the minimum levels of water releases required for recovery and the magnitude and frequency of releases to simulate spates. The relatively small discharge from Stinton Creek suggests that compensation releases required for recovery of the fauna of impounded rivers in southwestern Australia would be small.

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