Research Report 5

Macroinvertebrates of the Mallee Tract

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Final Report to MDBC

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Report Linkages

This individual Research Report forms a component of the larger report:

McCarthy, B., Gawne, B., Meredith, S., Roberts, J. and Williams, D. (2004). Effects of Weirs in the Mallee Tract of the River Murray. Murray-Darling Freshwater Research Centre, Mildura. Report to the Murray-Darling Basin Commission, Canberra.

Introduction

Macroinvertebrates are defined as invertebrates above 500 µm in size. The River Murray supports a diverse assemblage of macroinvertebrates with over 400 taxa being identified (Bennison *et al*., 1989). Macroinvertebrate communities of the Murray-Darling system vary at the macrohabitat (river section) scale (Bennison *et al*., 1989), the mesohabitat (river channel, backwater) scale (Sheldon and Walker, 1998) and the microhabitat (vegetation, woody debris, sediment) scale (Sheldon and Walker 1998; Boulton and Lloyd, 1991). Freshwater ecosystems containing a high degree of habitat complexity also tend to contain greater macroinvertebrate richness (e.g. O'Connor, 1991).

Macroinvertebrates fulfil an important ecological role through their position in freshwater food webs. Macroinvertebrates consume living and dead organic material, transform nutrients, and represent a major food source for fish and birds. The importance of macroinvertebrates in riverine food webs means that changes in the macroinvertebrate community have the potential to affect other components of the ecosystem and key ecological processes. Understanding the effects of our management on the system is improved by understanding the effects of management on the macroinvertebrate community. Developing an adequate understanding is complicated by the absence of pre-regulation information on the ecology of river systems and the myriad of interacting anthropogenic-driven changes that may impact macroinvertebrate communities.

Weirs represent a major anthropogenic change to the riverine environment and in the River Murray have transformed sections of river into a series of stable weir pools. The weir pools have increased river depth, stabilised water levels and reduced flow velocities relative to the free-flowing condition (Research Report 1; Walker and Thoms, 1993). These changes appear to have had a significant effect on macroinvertebrate communities; weir pools have been implicated in the local extinction of snails (Sheldon and Walker, 1997), a change in the abundance of the river mussel (Sheldon and Walker, 1989) and the decline of Murray Crayfish (Geddes, 1990). These changes may be a consequence of changes in hydraulic conditions, deteriorations in water quality at certain times of the year, or changes to the biofilm and macrophyte communities.

Although the effects of weirs on some macroinvertebrate taxa are known, there is little information available on the effects of weirs on the macroinvertebrate community.
An examination of the weir pools and free-flowing sections of river within the Mallee Tract provides insight into potential changes in the macroinvertebrate communities as a result of the construction of weirs. In this study the macroinvertebrate communities were examined at five sites across two macrohabitats (weir pool and free-flowing reaches) at a single mesohabitat (main river channel) and a single microhabitat (large woody debris). This research focus allowed the spatial and temporal patterns in macroinvertebrate communities to be examined from October 2001 – April 2003.

Objectives

The broad objective of this study is to target macroinvertebrates from a specific habitat to address questions relating to changes in macroinvertebrate abundance and community composition as a result of environmental change: in this case, the effects of weirs on the macroinvertebrates of the Mallee Tract.

The specific objectives of the study are:

1. To determine whether macroinvertebrate communities differ between the weir pool and free-flowing sections of the Mallee Tract of the River Murray.

2. To examine other spatial and temporal trends in the distribution of macroinvertebrate communities.

Methods

Experimental Design

Details of the three weir pool (WP) and two free-flowing (FF) reaches along the Mallee Tract of the River Murray (Thoms *et al*., 2000) are provided in the Project Report.

Macroinvertebrates were examined at two free-flowing (FF) and three weir pool (WP) sites, including Boundary Bend (FF), Euston (WP), Iraak (FF), Mildura (WP) and Wentworth (WP) (see Project Report for site details). Quantitative sampling of the macroinvertebrate communities was achieved by suspending River Red Gum (*Eucalyptus camaldulensis*) blocks (300 x 170 x 30 mm: Surface area 0.13 m^2) ca. 0.5 m beneath the surface for 6-9 weeks to allow extensive biofilm establishment and macroinvertebrate colonisation. Samplers were deployed 0.5-1.0 km upstream of the Euston weir and 2-3 km upstream of the Mildura and Wentworth weirs. Samplers were deployed over a 0.5 km reach of the free-flowing sites at Iraak and Boundary Bend. Snag substrates were used because of their suitability for quantitative sampling of macroinvertebrate communities of lowland rivers (Humphries *et al*., 1998). Six substrates were deployed at each of the five sites and were tied to available emergent River Red Gum snags in a position so as to remain in contact with large woody debris beneath the water surface (but elevated from the bottom of the river). A 250 µm sweep net was used to enclose the River Red Gum substrates upon collection, and macroinvertebrates (and biofilm) were scrubbed from each block with a nailbrush and the substrate redeployed. Samples were preserved in 70% ethanol. Three samples from each site-time were randomly selected and macroinvertebrates from a 25% sub-sample were identified at MDFRC, Albury to family level where possible, following the keys listed in Hawking (2000). Samples from seven field trips spanning October 2001-April 2003 were analysed.

Statistical Analysis

Multivariate analysis of the macroinvertebrate community data was conducted with PC-Ord (MjM Software, v4.27). The community data set contained many zeros and was heavily right skewed, so was fourth root transformed to reduce the influence of abundant taxa. Outliers were identified with the Sorensen (Bray-Curtis) distance measure as being >2 standard deviations from the mean resulting in the identification and deletion of four site-times. The Sorensen (Bray-Curtis) distance measure was adopted in the ordination and classification analyses because it is robust and particularly suited to community data sets (both abundance and presence/absence) (Faith *et al*., 1987). For classifications, the Flexible Beta Group Linkage Method (set at –0.1 due to its ability to recover known groups) was used (Belbin *et al*., 1992). For ordinations, non-metric multi-dimensional scaling (NMDS) was used, and the output with the minimum number of axes was selected for an acceptable stress level (<20%). Multi-response permutation procedure was used to statistically test whether defined groups contained significantly different species compositions.

Univariate analyses were conducted with SYSTAT v9 (SPSS Inc.) following square root transformation to shift the data closer to normal and to meet the assumptions of the test.

Results

A total of 81,852 individual macroinvertebrates from 34 taxa were collected from artificial River Red Gum substrates placed at two free-flowing and three weir pool sites in the Mallee Tract of the River Murray from October 2001 – April 2003. The five most abundant taxa accounted for 96.7% of the total abundance, with members of the Chironomidae (70.3%) and Oligochaeta (16.1%) groups dominating the macroinvertebrate abundance in space and time (Table 1). A full list of the 34 taxa is provided in Appendix 1.

Table 1. Five most abundant macroinvertebrate taxa

Taxa	Abundance (% of total)	No. samples where present (of 105)
Chironomidae	57,564 (70.3%)	105 (100%)
Oligochaeta	13,140 (16.1%)	98 (93.3%)
Ecnomidae	4,064 (4.97%)	53 (50.5%)
Hydroptilidae	2,932 (3.58%)	74 (70.5%)
Atyidae (Paratya)	1,406 (1.72%)	74 (70.5%)

Temporal Patterns

Multivariate classification of macroinvertebrate abundance across time (sites pooled) revealed a seasonal change in macroinvertebrate communities; the January and April samples from the warmer months were well separated from the October and August samples (August samples collected in 2002 only) (Figure 1). The close grouping of the macroinvertebrate communities from a particular time in consecutive years suggests that seasonal factors are playing an important role in structuring the macroinvertebrate communities. The communities from April were most similar, with the single August sample being most different from all other samples.

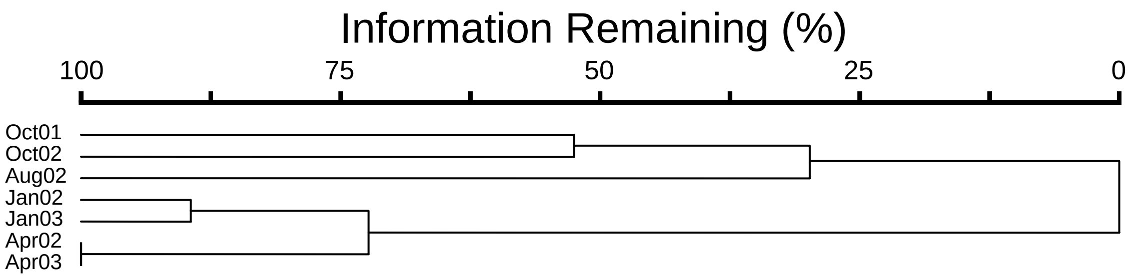

Figure 1. Dendogram of the macroinvertebrate communities from the 7 sampling times from October 2001 – April 2003.

Spatial Patterns

The weir pool sites had a greater macroinvertebrate abundance and taxa richness than the free-flowing sites (Figure 2).

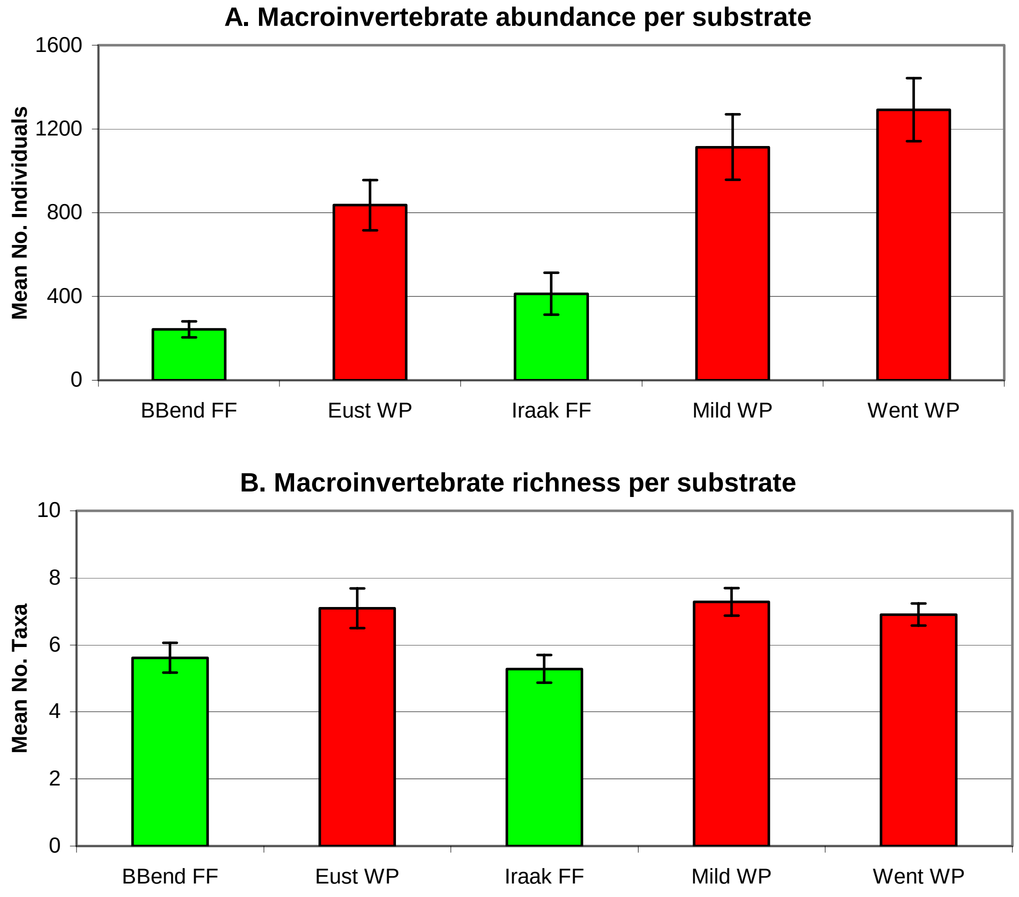

Figure 2. Mean macroinvertebrate (A) abundance and (B) richness per River Red Gum substrate at the two free-flowing (FF, green) and three weir pool (WP, red) sites for the October 2001-April 2003 sampling period. Error bars = ±1 S.E.

Repeated measures ANOVAs revealed that macroinvertebrate abundances at weir pool and free-flowing sites were significantly different to one another (*P*=0.016) but did not differ significantly over time (*P*=0.153) (Table 2). Macroinvertebrate richness also differed significantly between weir pool and free-flowing sites (*P*=0.002) and over time (*P*=0.012) (Table 2). Macroinvertebrate richness was greatest in the warmer months (mean richness exceeded 6 taxa per sample in January and April samples) and lowest in the August and October samples (mean richness less than six taxa).

Table 2. Repeated measures ANOVA: WP v FF

Source		Macroinvertebrate Abundance			Macroinvertebrate Richness		
BETWEEN	df	MS	F	P	MS	F	P
Type (WP v FF)	1	1933.255	24.770	0.016	0.951	100.401	0.002
Error	3	78.048			0.009		
WITHIN							
Time	6	91.011	1.815	0.153	0.311	3.815	0.012
Time*Type	6	62.473	1.246	0.330	0.074	0.904	0.514
Error	18	50.156			0.082		

Multivariate classification of the macroinvertebrate communities was conducted at two different scales (increasing complexity) to determine underlying patterns. The first analysis examined the macroinvertebrate communities across the five sites with times pooled (5 site x 34 taxa matrix). The classification revealed a clear separation of the two free-flowing sites from the three weir pool sites, with the macroinvertebrate communities at the Euston and Wentworth weir pools being most similar (Figure 3).

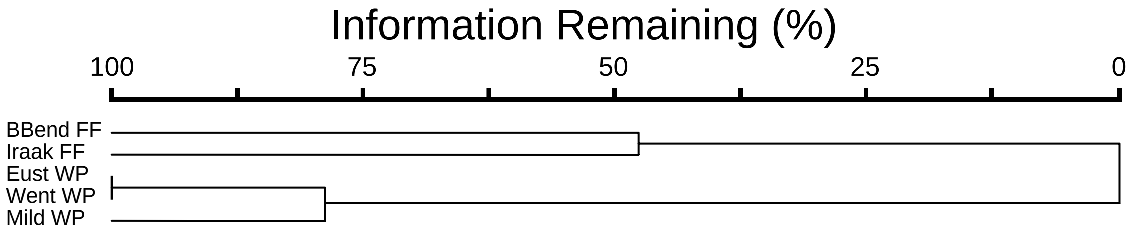

Figure 3. Dendogram of the macroinvertebrate communities (abundance) at the five River Murray sites.

To examine whether the abundance of macroinvertebrates was dictating the spatial patterns, the data set was converted to presence/absence and a classification again performed on the original 5 sites x 34 taxa matrix. The classification remained almost unchanged, demonstrating that the groupings are primarily due to differences in taxa (rather than abundance) of the respective macroinvertebrate communities (Figure 4).

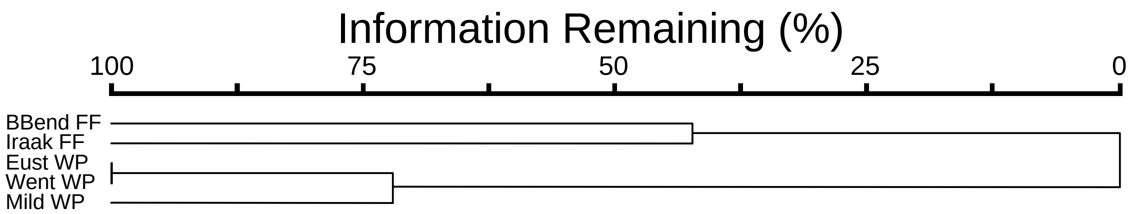

Figure 4. Dendogram of the macroinvertebrate communities (presence/absence) at the five River Murray sites.

The multivariate analyses so far have provided information relating to the (1) temporal only and (2) spatial only patterns of the macroinvertebrate communities. This has allowed general patterns to emerge but invariably results in the loss of some of the more detailed information. Based on the temporal results above that highlighted a separation of the warmer January and April site-times from the cooler August and October site-times, the data set was separated into two groups. Sampling in January and April occurred when water temperatures were above 20^{o}C, whilst the August and October sampling occurred when temperatures remained below 20^{o}C. The Summer-Autumn period comprised 29 taxa from 59 site-times and the Winter-Spring period 23 taxa from 42 site-times. A total of four site-times were identified as outliers and deleted from the ordinations (outlier sensitive). These deleted samples were all from free-flowing sites and contained very low abundances of macroinvertebrates (and when included in the ordination were positioned furthest from the weir pool sites). The resulting ordinations reveal a strong division between the weir pool and free-flowing sites (Figure 5), particularly in the warmer months. Multi-response permutation procedures revealed that the weir pool and free-flowing sites were significantly different to each other during the Summer-Autumn (P<0.001) and Winter-Spring (P<0.001) periods.

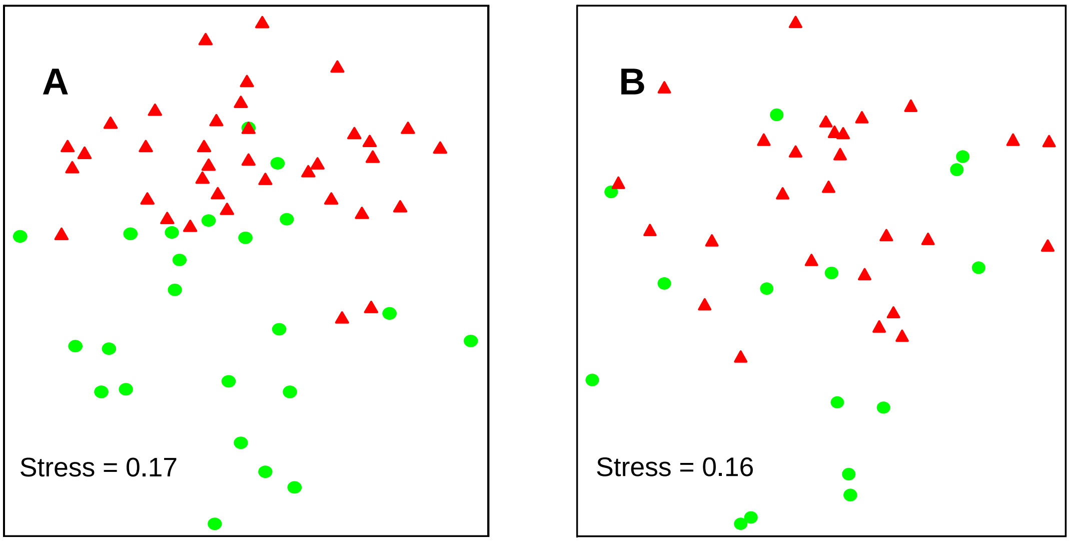

Figure 5. NMDS ordination of macroinvertebrate communities from all site-times in (A) Summer-Autumn and (B) Winter-Spring for weir pool sites (red triangles) and free-flowing sites (green circles).

Dominant Taxa

Dominant taxa in the weir pools included Oligochaeta, Acarina, Ostracoda, Nematoda, Chironomidae (present also at free-flowing sites in lower abundance), Ceratopogonidae, Ecnomidae, Palaemonidae and Atyidae. Those most represented in the free-flowing sites (albeit in low abundance) include Empididae and Simulidae, whilst Caenidae was present at a similar abundance at weir pool and free-flowing sites.

Indicator species were obtained by generating an Indicator Species Analysis in PC-Ord, with the grouping matrix being a 4-group matrix of FF and WP at two different times (warmer and cooler months as defined above). The three most significant taxa were selected (Chironomidae, Oligochaeta and Ecnomidae) and these were also the three most dominant taxa across all sites. Each of these taxa indicated a strong seasonal pattern of abundance, particularly at the weir pool sites (Figure 6). The chironomids and ecnomid caddisflies were most abundant in the warmer months and Oligochaeta was most abundant at the August (winter) sampling time.

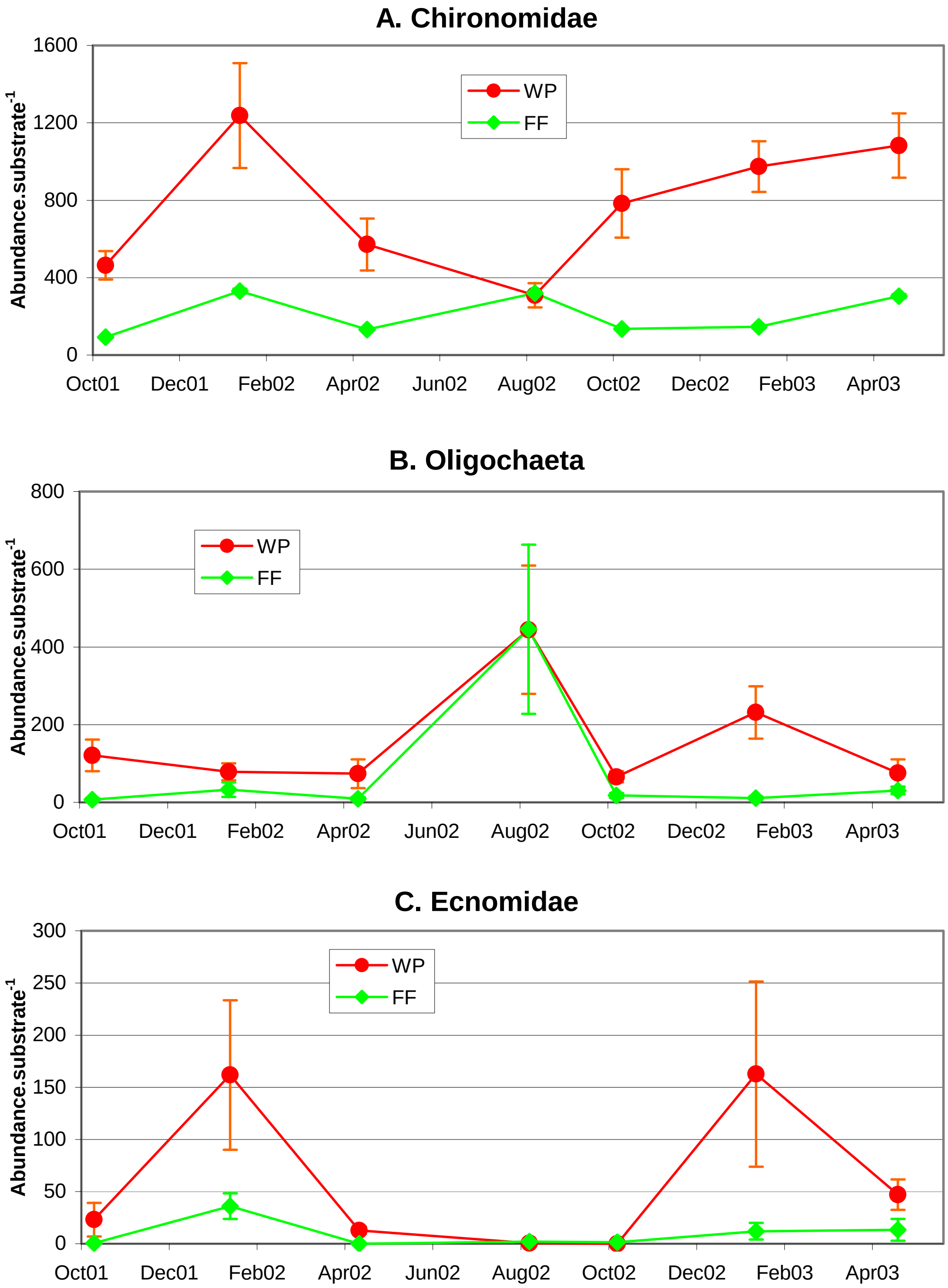

Figure 6. Mean abundance per substrate of the three most dominant taxa (and indicator species) (A) Chironomidae, (B) Oligochaeta and (C) Ecnomidae at the weir pool (WP) and free-flowing (FF) sites over time. Error bars = ±1 S.E.

Discussion

Macroinvertebrate communities were distinctly different between the free-flowing and weir pool sections of the Mallee Tract of the River Murray. This finding has important implications because it demonstrates in a comparative way that weirs and their weir pools have altered the biotic community. The different hydraulic conditions between the weir pools and the free-flowing areas likely play an important role in explaining the distinct macroinvertebrate communities (Nelson and Lieberman, 2002; Stanley *et al*., 2002). Free-flowing areas have a relatively high flow velocity compared to weir pools (Research Report 1) due to their lower cross-sectional areas compared to the weir pools (where the river is deeper and wider as a result of the elevated water levels created by the weir), and this would likely influence the types of macroinvertebrates able to persist. The low flow velocity in weir pools has led to them being characterised as being more akin to lentic systems than rivers (e.g. Walker, 1985), and snag-dwelling macroinvertebrates appear to thrive (in abundance and taxa) in this modified riverine environment. Indeed, the pattern of flow velocity along the river (highest in the free-flowing areas followed consecutively by the Euston WP, Mildura WP and Wentworth WP due to sequential extraction for irrigation) appears to match well the abundance gradient depicted in Figure 6.

The second main hydraulic difference between the weir pool and free-flowing environments is the amount of water level change each site receives. Water levels in the weir pools generally remained within a few cm throughout the study period (due to the manipulation of boards by the lockmasters), whereas those of the free-flowing regions rose and fell within a 2 m range despite the drought conditions. Given that the blocks are maintained at a constant height (but not depth) in the river (and always submerged), changes in depth may have initiated changes in the macroinvertebrate communities. As a result, the macroinvertebrate assemblages in the free-flowing regions may be predicted to be more diverse than those of the weir pools. However, there was limited evidence for this (Figure 5A with four outlier free-flowing sites deleted).

The different snag macroinvertebrate communities in the weir pool and free-flowing reaches are consistent with a study revealing distinctly different benthic macroinvertebrates at pool and free-flowing sites of the Baraboo River, Wisconsin (USA) prior to the removal of a low-head dam (Stanley *et al*., 2002). Following the removal of the dam, changes in the hydraulic conditions mobilised sediments from the former pool and the benthic macroinvertebrate community shifted closer to resemble those at the free-flowing sites. In the River Esko in Norway, too, there was an increase in benthic macroinvertebrate biomass in weir pool sediments following the construction of a low level weir; this increase was attributed to the trapping of organic material within the weir pool (Fjellheim and Raddum, 1996). In the River Murray it is also probable that the benthic macroinvertebrates of the weir pool and free-flowing sites (not examined in this study) would differ given the different sediment characteristics (Research Report 2), and this remains an area for future research.

The different macroinvertebrate communities at the weir pool and free-flowing sites need not be considered negative impacts necessarily. Macroinvertebrates were approximately 3½ times more abundant in weir pools than free-flowing areas, and this may have important implications for secondary production and food webs. Macroinvertebrates are an important trophic level in the food web, and greater abundances would increase the transformation of biofilm (algae, bacteria and fungi) and other food resources into more complex animal tissue, which is in turn consumed by predators such as fish and birds. These high macroinvertebrate densities also match the greater biofilm biomass in weir pools compared to free-flowing regions (Research Report 4). The algal-dominated biofilms in the weir pool sites (Research Report 4) may be providing a greater food resource and habitat for the snag macroinvertebrate communities than at the free-flowing sites.

The greater *abundance* of macroinvertebrates on the snags of the weir pools may not necessarily translate to a greater *biomass* of macroinvertebrates in a given section of river. This is because the weir pools appear to contain less large woody debris than the free-flowing regions and therefore a reduced overall biomass of snag macroinvertebrates. Whilst the amount of large woody debris has not been quantified as part of this study, observations indicated a greater abundance of emergent large woody debris at free-flowing sites. Snags from the weir pools may be submerged as a result of the elevated water levels, although past desnagging of the weir pool regions has occurred.

An important consideration when interpreting the findings of this study is whether particular macroinvertebrates are present in free-flowing regions but have been lost from the weir pools. Five taxa were identified to be specific to free-flowing regions, including the springtail Collembola and the insect families Simulidae, Muscidae, Hydraenidae and Hydrophilidae. However, each taxon was rare with only a single individual being collected with the exception of Simulidae (5 individuals from 3 samples). Simulids are passive filter feeders and consequently rely on relatively high flow velocities in order to persist; their low abundance overall (including at free-flowing sites) could potentially reflect the generally low flow conditions due to the drought. The results suggest therefore (with the possible exception of Simulidae) that the taxa identified only at the free-flowing sites have not necessarily been "lost" from the river due to regulation, but rather that their absence from the weir pool sites is more likely attributable to them being naturally low in abundance (or present at these sites in habitats other than large woody debris).

Conversely, the weir pool environment appears to favour several taxa that were absent from the free-flowing regions. Individuals from two damselfly families (Coenagrionidae and Protoneuridae) and the dragonfly family Libellulidae (and an unidentified damselfly) were only present in the weir pools, along with the freshwater shrimp Caridina, the water slater Cirolanidae, the stick caddis Leptoceridae and the riffle beetle Elmidae. All of these were present in very low numbers (present in a maximum of 3 samples), making it difficult to state with confidence that these species are typical of the weir pool environment and not the free-flowing one. The one taxon that was relatively abundant in the weir pools and absent from the free-flowing sites was the hydra polyp of the family Hydridae. This active filter-feeder was present in a total of 8 samples from the Euston and Mildura weir pools at two sampling times, suggesting that the low flow velocities in the weir pool environment have favoured this taxon.

Macroinvertebrate communities appear to undergo seasonal change such that communities were similar at similar times of the year. This result has implications for sampling design because it demonstrates that different communities are present at different times and may indicate optimum times to sample. However, sampling throughout this study occurred during a prolonged drought. Changes in the macroinvertebrate community during high flow events are likely and given that the hydraulic conditions within the weir pool and free-flowing reaches would become more similar during these events, macroinvertebrate communities may also become more similar between sites at these times.

The three most significant indicator species for habitat and season were Chironomidae, Oligochaeta and Ecnomidae (based on a 4-group classification of WP and FF in warmer and colder periods of the year). These taxa contributed over 96% of the total abundance and were distributed widely, and would be particularly important taxa to follow over time - particularly in the event of structured change such as a weir manipulation. Oligochaeta and chironomids are generally collector gatherers, and are likely in higher abundance due to the greater biofilm resources within the weir pool (Research Report 4). The ecnomids are predatory and may be feeding upon the chironomids given that they are each most abundant in the warmer months.

The use of artificially-placed River Red Gum substrates has demonstrated itself to be a useful technique for examining macroinvertebrate communities as shown previously by Humphries *et al*. (1998). The rough-sawn blocks used in this study contain a more homogenous surface than natural snags but were successful in quantifying the macroinvertebrate community over time and between sites. It should be noted that these substrates were not deployed to sample the entire macroinvertebrate community for a section of river, or even an entire snag, but rather provide a standard technique to enable comparisons in space and time. Despite these restrictions, the macroinvertebrate communities sampled correspond well with others collected in lowland rivers of Australia using a variety of sampling techniques. The dominance of chironomids and oligochaetes, for example, was consistent with other studies on lowland rivers (Humphries *et al*., 1998; Sheldon and Walker, 1998; Bennison *et al*., 1989; Hawking *et al*., 2003).

To determine the overall effects of weir pools on invertebrate communities would require an examination of other habitats, including littoral habitats and the riverbed. The littoral margins of weir pool reaches contain a much greater abundance of macrophytes (Research Report 6), which potentially support a high abundance and diversity of micro- and macroinvertebrates. However, it is probable that the riverbed within the weir pools supports a homogenous and potentially depauperate invertebrate fauna due to the accumulation of organic matter and fine sediments (Research Report 2) and the generation of anoxic conditions within the sediments (Popp and Hoagland, 1995). Alternatively, the accumulation of organic material in weir pools may at times support high abundances of some benthic macroinvertebrate taxa (Fjellheim and Raddum, 1996). Study of benthic macroinvertebrates at weir pool and free-flowing sites remains an area of future research.

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Appendix 1. Macroinvertebrate taxa and abundance per site.

						Total Abundance				
Group	**Class**	**Order**	**Family**	**Genus**	**Common name**	**BBend(FF)**	**Eust(WP)**	**Iraak (FF)**	**Mild(WP)**	**Went(WP)**
Oligochaeta	Oligochaeta				Segmented worms	500	3360	2824	2504	3952
Mite	Arachnida	Acarina			Freshwater mite	16	84	4	16	32
Collembola	Collembola				Springtails	2	0	0	0	0
Ostracoda	Ostracoda				Seed shrimp	120	336	12	180	44
Clavidae (*Cordylophora*)	Hydrozoa		Clavidae	Cordylophera	Colonial polyp	0	0	36	156	100
Temnocephalida					Temnocephalans	16	36	48	0	4
Nematoda					Round worms	4	8	4	4	16
Hydridae	Hydrozoa		Hydridae		Solitary polyps	0	8	0	84	36
Chironomidae	Insecta	Diptera	Chironomidae		Non biting midges	3796	12604	4960	17060	19144
Empididae	Insecta	Diptera	Empididae			12	8	8	0	8
Simulidae	Insecta	Diptera	Simulidae		Black flies	0	0	20	0	0
Muscidae	Insecta	Diptera	Muscidae		Muscids	0	0	4	0	0
Ceratopogonidae (*Ceratopogoninae*)	Insecta	Diptera	Ceratopogonidae/Ceratopogoninae		Biting midges	8	108	16	104	32
Diptera pupa (indet)	Insecta	Diptera				0	12	0	0	8
Corixidae (*Micronecta*)	Insecta	Hemiptera	Corixidae	Micronecta	Waterboatmen (True Bugs)	6	12	0	8	48
Ecnomidae	Insecta	Trichoptera	Ecnomidae		Caseless caddisflies	156	256	236	2036	1380
Hydroptilidae	Insecta	Trichoptera	Hydroptilidae		Microcaddis	124	216	236	540	1816
Trichoptera (pupa)	Insecta	Trichoptera			Caddisflies	0	0	8	0	0
Leptoceridae	Insecta	Trichoptera	Leptoceridae		Stick Caddis	0	0	0	0	4
Caenidae	Insecta	Ephemoptera	Caenidae		Mayflies	76	176	172	156	52
Leptophlebiidae	Insecta	Ephemoptera	Leptophlebiidae		Leptoflebs/Mayflies	4	0	0	4	0
Baetidae	Insecta	Ephemeroptera	Baetidae		Baetids (Mayflies)	12	20	4	12	0
Coenagrionidae	Insecta	Odonata/Zygoptera	Coenagrionidae		Damselflies	0	0	0	0	4
Protoneuridae	Insecta	Odonata/Zygoptera	Protoneuridae		Damselflies	0	0	0	16	0
Libellulidae (*Orthetrum*)	Insecta	Odonata/Epiproctophora	Libellulidae		Dragonflies	0	4	0	4	0
Zygoptera (indet)	Insecta	Odonata/Zygoptera			Damselflies	0	8	0	4	4
Hydraenidae	Insecta	Coleoptera	Hydraenidae		Beetles	4	0	0	0	0
Hydrophilidae	Insecta	Coleoptera	Hydrophilidae		Water scavenger beetles	0	0	4	0	0
Elmidae	Insecta	Coleoptera	Elmidae		Riffle Beetle	0	0	0	8	0
Plecoptera (indet)	Insecta	Plecoptera			Stoneflies	0	0	4	0	0
Palaemonidae (*Macrobrachium*)	Crustacea	Decapoda	Palaemonidae	Macrobrachium	Freshwater prawns	14	44	4	8	60
Atyidae (*Paratya*)	Crustacea	Decapoda	Atyidae	Paratya australiensis	Freshwater shrimp	230	248	68	484	376
Atyidae (*Caridina*)	Crustacea	Decapoda	Atyidae	Caridina	Freshwater shrimp	0	8	0	0	4
Cirolanidae	Crustacea	Isopoda/Flabellifera			Water slaters	0	0	0	0	12
					Total	5100	17556	8672	23388	27136