AQUATIC INVERTEBRATE COMMUNITIES IN AVON AND DALE RIVER POOLS

Report to

Species and Communities Branch, Department of Environment and Conservation

by

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INTRODUCTION

The Avon River

The Avon River arises near the town of Wickepin, about 25 km upstream of where it receives overflow from Lake Yealering. Further downstream, near Brookton, it is joined by the vast inland Yilgarn palaeodrainage system via the Salt River and the Yenyening (or Beverley) Lakes. These lakes are naturally saline but have increased in salinity and hydroperiod since clearing (Water and Rivers Commission 2002). Water is retained in the lakes by a man-made structure at the Qualandary Crossing, which reduces flows and salt load into the Avon (Water and Rivers Commission 2002). Several other major tributaries flow in to the Avon including the low salinity Dale River. The Dale would have been fresh prior to European settlement and retains fairly low salinity because it largely flows off the eastern slopes of the Darling Range (Department of Environment 2006). This helps to reduce salinities in the Avon downstream of the confluence of these rivers. At Northam, the Avon receives the saline Mortlock Rivers (north, east and south branches) and below Toodyay it is joins the low salinity Toodyay Brook. The Avon River is severely affected by siltation, salinisation and nutrient enrichment, but these have been dealt with in other publications so are not discussed in detail here (e.g. Department of Water 2007; Kendrick 1976; Water and Rivers Commission River Recovery Plans).

The Avon River and its larger tributaries have numerous deep pools. Originally there were 26 major pools on the Avon Rivers plus numerous smaller ones separated from each other by long shallow braided channels (Department of Water 2007). The Dale River also has 25 named pools (Department of Environment 2006) and small pools occur on tributaries such as Toodyay Brook and the Mortlock Rivers. Many of the Avon pools have now filled with sediment, largely as a result of engineering works in the late 1950s to early 1970s (the 'River Training Scheme'). This scheme was designed to prevent flooding by straightening the river and removing braided sections to allow more rapid movement of water. About half of the pools have partly or completely filled with sediments (Davies and Ecoscape 1997) but some of these have been dredged in recent years in an attempt to restore their depth. Some Dale River pools are also silting up as a result of catchment erosion. In the pre-European river the Avon catchment's pools would have had ecological significance as drought refuges for aquatic invertebrates, fish, amphibians and waterbirds, plus as a water source for terrestrial vertebrates, including humans. To a large extent, the pools continue to fulfil this role, although the increase in salinity and sedimentation will have reduced the value of the pools for many taxa. The remaining pools and braided sections of the Avon and tributaries are listed as a Priority Ecological Community by DEC.

Objective

The purpose of this report is to summarise new and published evidence to allow an assessment of whether Avon River pool invertebrate communities represent a threatened ecological community (TEC). A TEC is defined by the Department of Environment and Conservation as "A naturally occurring biological assemblage that occurs in a particular type of habitat" that "is found to fit into one of the following categories; "presumed totally destroyed", "critically endangered", "endangered" or "vulnerable", as defined in DEC (2007).

This report expands upon a preliminary report, based on the first sampling round in late summer 2007, by Pennifold (2007).

River Pools sampled

Four river pools were sampled for this project (Table 1, Figs 1 and 2). The following information is largely from Department of Environment (2006), Department of Water (2007) and Water and Rivers Commission and Avon Waterways Committee (2002).

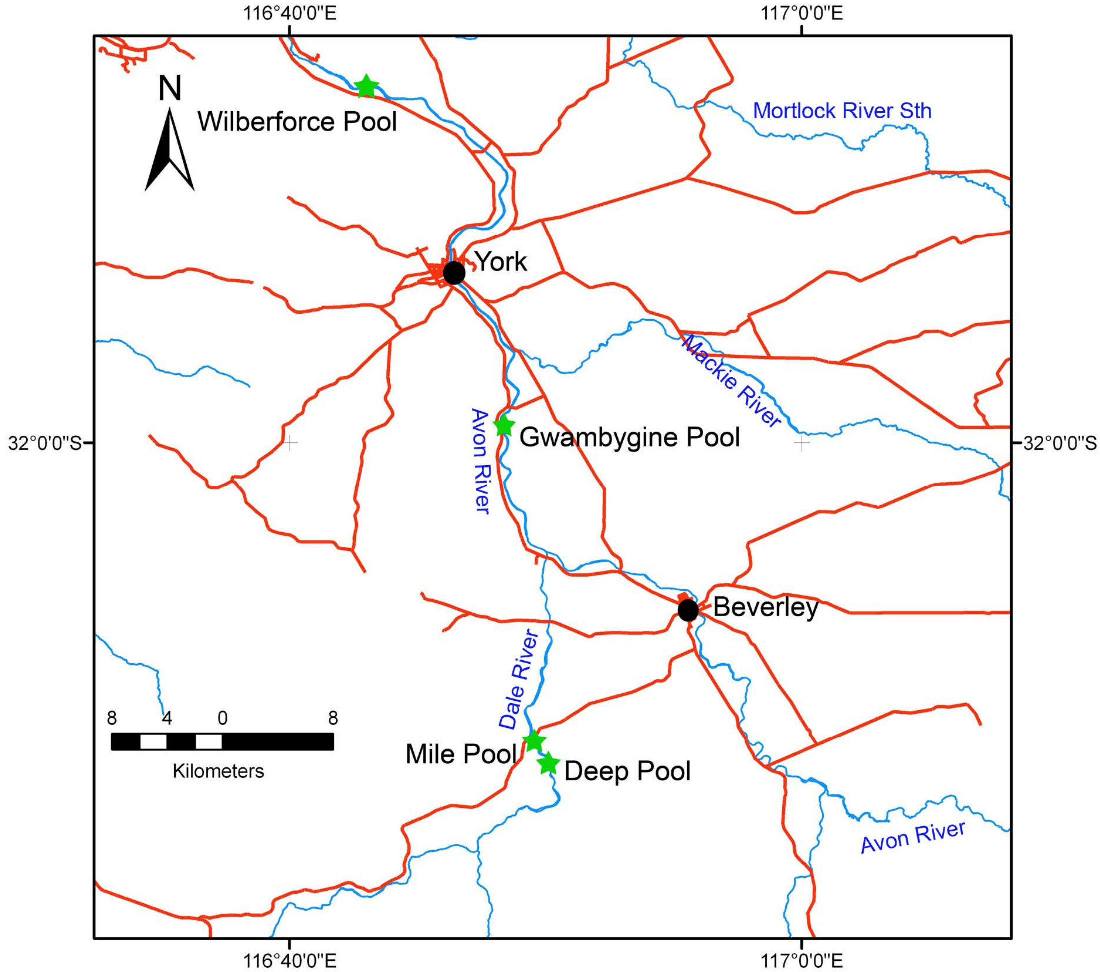

Figure 1. Map showing locations of the four pools.

Wilberforce Pool on the Avon River

Wilberforce Pool is located downstream of the Wilberforce Road Bridge, approximately 14 km south-east of Northam. The pool is about 800 metres long but has reduced in length since 1960 when it was measured at 980 metres. It had an average depth greater than three metres in 1996 (Davies *et al.* 1996). The bed of this pool is mostly clay and sedimentation has been minimal because the upstream Church Pool has retained most of the mobilised coarse sediment. The pool has a narrow band of riparian vegetation but it is grazed and in poor condition with little understorey.

Gwambygine Pool on the Avon River

Gwambygine Pool is located 13 km south of York. It is about 1 km long and up to four metres deep, making it the deepest pool upstream of York. Sediments are mostly silt/clay except at the upstream extent where a sand slug is present. Sediment has been excavated from the pool on two occasions (May 1996 and May 1999). The pool is set within cleared farmland and has only a very narrow riparian zone.

Deep Pool on the Dale River

Deep pool is only 350 metres long and is located 16 km upstream of the Dale-Avon confluence between two braided channel sections. This reach of the river has a very narrow band of riparian vegetation and was allocated an overall condition score of 'moderate' by Department of Environment (2006).

Mile Pool on the Dale River

Mile Pool is located approximately 14 km upstream of the Avon-Dale confluence, between the Westdale Road bridge at its downstream extent and a braided channel section. It is about 400 metres long and maintained by fresh groundwater. The environmental assessment of the Department of Environment (2006) allocated an overall condition score of 'poor' to this section of the river.

Wilberforce Pool on the Avon River

Gwambygine Pool on the Avon River

Deep Pool on the Dale River

Mile Pool on the Dale River

Figure 2. Photographs of the four pools sampled for this project.

The Avon fauna

There have been several studies of aquatic invertebrates of the lower Avon Catchment – here defined as the Avon and tributaries upstream of Jimperding Brook but excluding the large inland zone of ancient drainage above Yenyening Lakes.

Kendrick (1976) documented changes that had (or were likely to have had) occurred in the mollusc fauna since European settlement. He noted presence of thiarid and hyriid molluscs in mid-19th century accounts and 20th century records of five other molluscs. He suggested that the hyriids (*Westralunio carteri*) had become very rare in the Avon by 1976. This still seems to be the case, although they were collected at two sites on the Avon River by Halse *et al.* (2001) and in Gwambygine Pool by River Conservation Society (1999). The thiarid appears to have disappeared from the main channel of the Avon River before 1950, but remains in smaller tributaries flowing off the Darling Range and was collected from Duck Pool on the Mortlock River by Halse *et al.* (2001). Smith (1996) found most of the species discussed by Kendrick except for *Westralunio* and *Ferrissia*. Kendrick suggested that *Ferrissia peterdi* (ancylid gastropods) would have occurred in the Avon River prior to salinisation, based on their widespread distribution elsewhere in the south-west. This limpet-like snail is rare in water with salinity above 1 g/L (DEC unpublished data), but was recorded in Christopher Brook (a freshwater tributary of Dale River, 0.72 g/L) by Pinder *et al.* (2004).

Tresslyn Smith's 1996 honours project involved sampling aquatic invertebrates and water chemistry at 19 sites along the Avon River and a few tributaries, each sampled once in spring. Seven pools (Bland, Scarp, Cobbler, Glen Avon, Northam, Public Utility and Tipperary pools) were included in that study, but only the first five of these were sampled for invertebrates using methods comparable with those used in the current study (Tipperary Pool was sampled by grab sampling only). One hundred aquatic invertebrate taxa (mostly identified to species level) were collected, with site richness ranging from 6 to 18 species. Conductivity was the strongest predictor of richness. Smith (1996) compared her data with data from the Canning River (ARL 1986) and provided a list of 24 invertebrates that she suggested might have been lost from the Avon, with the proviso that differences other than salinity between the two river systems may explain the absence of those species from the Avon. The latter is an important point because the Canning River study collected invertebrates only from riffles, so many of these species would never have occurred in deep Avon River pools, even if they once occurred in the shallow inter-pool channels of the Avon. Smith particularly noted the absence or rarity of stoneflies, annelids and water mites: three groups that are particularly salt-sensitive, although stoneflies, which inhabit flowing water, would not be expected in the river pools.

Four sites in the lower Avon Catchment were each sampled once during the Biological Survey of the South-west Agricultural Zone by Pinder *et al.* (2004), but none of these sites were extant river pools. The sites were Dale River at Luptons Road (well upstream of Deep Pool), Christopher Brook, Jimperding Brook and Toodyay Brook at Dewars Pool (now entirely filled with sediment). A total of 118 species were collected from these sites, including 8 protozoans and rotifers (groups which have not been identified in any of the other projects). Between 52 and 63 species were collected per site, with highest richness in the freshwater Christopher Brook. The high richness in these sites is partly due to sampling zooplankton with a fine mesh net and partly to the generally low salinity of the sampled sites.

River Conservation Society (1999) sampled Gwambygine Pool for aquatic invertebrates over an 18 month period between January 1996 and June 1997. A total of 56 macroinvertebrate species were collected, with highest richness in spring 1996. Some of the species collected were not collected from any of the sites sampled by Smith (1996), including *Gyraulus* snails, *Eylais* water mites, the beetle *Megaporous howitti,* hemipteran *Anisops thienemanni* and dragonflies *Pantala flavescens* and *Orthetrum caledonicum*. Diversity of annelids and water mites were low, although unidentified leeches, which are very rare in the Avon River and particularly salt-sensitive, were recorded.

Nineteen sites in the lower Avon River catchment were included in the Monitoring of River Health Initiative (MRHI) and/or the associated First National Assessment of River Health (FNARH) (Halse *et al*. 2001; Kay *et al*. 2001). Identifications were to family level only except that Sutcliffe (2003) later identified the stoneflies, caddisflies and odonates to species level. This project aimed to develop models to predict the richness of invertebrate families that would be expected at a site assuming that it was undisturbed. The Avon catchment was allocated to condition band "B" meaning that it was significantly impaired, rather than severely or extremely impaired (bands C and D). However, it was difficult to find undisturbed reference sites on which to build the predictive models. This meant that the models probably under predicted 'reference' (unimpaired) richness, so the catchment scored higher than it perhaps deserved (Halse *et al*. 2001). Halse *et al.* (2001) also pointed out that there is no pre-salinisation data on aquatic invertebrates for the Wheatbelt region and that it may be that the fauna has always predominantly consisted of salt tolerant species. Fifty seven families of macroinvertebrates were collected from the Avon catchment during the MRHI/FNARH projects. None of the sites sampled were deep pools, although sites AVO11 and AVO13 were in the channel just upstream of Gwambygine Pool and just downstream Wilberforce Pool respectively.

Sutcliffe (2003) also accumulated all known records of Odonata, Trichoptera and Plecoptera from south-western Australia, including the Avon catchment. Twenty eight species from these groups have been recorded from the Avon.

METHODS

All field work was undertaken by staff from DEC, including Sheila Hamilton-Brown, Monica Hunter, Megan Green, Sonja Creese, Mia Podesta, Mick Davis, Margaret Wheeler, Lance Mudgway, Wendy Chow, Matt Forbes, with assistance from the River Conservation Society, in particular Cicely Howe and other volunteers (including Nick Thake, Marie-Alice Small).

Sampling was undertaken in summer because this was when the pools were most likely to be acting as refuges from drying conditions in the non-pool channels.

Staff of the Species and Communities Branch of DEC selected the four pools. All of these except Deep Pool have been sampled on four occasions in late spring or summer between February 2007 and December 2008. Deep Pool was only sampled three times because access was not possible in November 2007. Invertebrates were collected by sweeping a 250 µm mesh net through the littoral water column, disturbed sediments and aquatic and draped riparian plants. Each sample consisted of 60 sweeps. Coarse organic matter was discarded after washing and the remaining sample preserved in 100% ethanol. All identifications are to species level where possible, using names compatible with previous DEC projects.

Table 1. Name and locations of pools sampled.

	River	Latitude	Longitude
Wilberforce Pool	Avon	31.770	116.711
Gwambygine Pool	Avon	31.985	116.804
Mile Pool	Dale	32.192	116.824
Deep Pool	Dale	32.210	116.837

Sorting and identification of invertebrates was carried out by DEC staff (mostly) or by Bennelongia environmental consultants (for the December 2008 samples).

Conductivity, pH, oxygen, oxygen reduction potential (ORP), water temperature and turbidity were all measured in the field. Nutrient and chlorophyll concentrations were measured in the laboratory by the Marine and Freshwater Laboratory at Murdoch University.

Multivariate analyses were performed using Primer 6.1.1.1 and Permanova + 1.01 (Primer-E Ltd 2008). Primer's Bray-Curtis index was used as a measure of similarity between invertebrate samples. Nematodes were excluded from the multivariate analysis as there was probably more than one species involved. The ordination was a non-metric multidimensional scaling using 50 restarts and a minimum marginal stress value of 0.01. The hierarchical agglomerative cluster analysis used 'group averaging' to position new samples in the dendrogram. Permanova analysis of a nested model (fixed factors: pools within river) was performed with 999 permutations. A distance-based linear model (in Primer, using adjusted r^2 as an indicator of model performance) was used to estimate the degree to which salinity was correlated with community composition.

The Estimate S software of Colwell (2004) was used to estimate the likely total species richness in the pools using the data in Appendix 1. The Chao 2 and ICE estimators were used.

RESULTS

Water chemistry

Water chemistry data are provided in Table 2. All pools were brackish to saline, with Deep Pool in Feb 2007 having lowest salinity (5.4 g/L) and Wilberforce Pool in Feb 2007 having the highest salinity (18 g/L). Deep Pool and Mile Pool on the Dale River generally had lower salinities than Wilberforce and Gwambygine on the Avon. Salinity in the pools varies substantially over a hydrological cycle. For example RCS (1999) recorded conductivities in Gwambygine Pool between 5.8 and 38 mS/cm during a 21 month period in 1996/97. Smith (1996) recorded salinities in summer that were 20 to 100% higher than those recorded in the previous spring.

All pools were circum-neutral to moderately alkaline. Water in the pools was generally well oxygenated and turbidity was low, other than in Wilberforce Pool in March 2008. The concentrations of nitrogen, phosphorus and chlorophyll indicate mild nutrient enrichment.

Invertebrate diversity

A total of eighty eight species of aquatic invertebrate was collected from the four pools, with an average of 26 per sample (Appendix 1). Across the whole study period the pools varied in total species richness from 46 in Wilberforce Pool to 62 in Gwambygine Pool (southern site). The single sampling event at the northern site of Gwambygine Pool only added an additional 2 species to that pool. The total number of species collected increased between the third and fourth sampling round (Figure 3), but only by eight species (about 9%). This graph suggests that richness across the pools is unlikely to exceed 110 species using current sampling methods. Species richness increased between the third and fourth samples for all three of the individual pools sampled on four occasions, though more so in Wilberforce Pool (Figure 4). The Chao2 and ICE richness estimators from the Estimate S software suggested a total species pool for these four sites of 111 and 108 respectively and the Chao2 estimator reached an asymptote so the estimated total richness would not be expected to rise further with additional sampling.

Table 2. Water chemistry data.

		Electrical conductivity (mS/cm)	pH	Temp (C°)	Dissolved O² (mg/L)	Dissolved O² (%)	Oxygen reduction potential (mV)	Calculated total dissolved solids (g/L)	Measured total dissolved solids (g/L)	Turbidity (NTU)
Deep	**13/02/2007**	11.5	6.9	24.1				7.7		
Pool	**1/03/2008**	12.45	8.51	23.8	7.8	96	77	8.3	8.4	0
	23/12/2008	10.79	7.95	25.44	8.23	106.1	144	7.2	6.9	1.8
Mile	**13/02/2007**	11.7	8.1	29				7.8		
Pool	**13/11/2007**	11.65	7.74	28.54	6.86			7.8		
	1/03/2008	11.79	7.66	24.85	7.86	98.5	102	7.8	7.5	0.3
	23/12/2008	10.09	7.99	22.61	8.46	104	156	6.7	6.4	3.9
Gwambygine	**13/02/2007**	18.8	7.5	25.2				12.5		
Pool South	**13/11/2007**	13.72	8.29	30.96	7.07			9.1		
	1/03/2008	17	8.62	27.04	9.9	134.5	56	11.3	10.9	9
	23/12/2008	14.5	8.57	28.91	10.28	146.9	126	9.65	9.3	0
Wilberforce	**13/02/2007**	27.1	7.8	29.8				18.0		
Pool	**13/11/2007**	17.8	8.41	25	6.4			11.8		
	1/03/2008	23	8.26	29.09	5.82	75.1	26	15.3	14.7	127
	23/12/2008	21.6	8.59	28.66	8.67	124.4	126	14.38	13.8	3.1

		Ammonia (µg/L)	Orthophosphate (µg/L)	Nitrite/Nitrate (µg/L)	Total nitrogen (µg/L)	Total phosphorus (µg/L)	Chlorophyll + phaeophytin (µg/L))
Deep Pool	**13/02/2007**	74	15	1100	2500	62	23.4
Mile Pool	**13/02/2007**	74	13	1700	2900	92	14.6
Gwambygine Pool	**13/02/2007**	76	13	1600	2900	54	11.8
Wilberforce Pool	**13/02/2007**	9	11	270	1400	68	34.6

Richness was generally higher in the Dale River pools (Mile and Deep) than in Wilberforce Pool on the Avon, although the two highest richness values were recorded at Gwambygine Pool. That Wilberforce Pool had the lowest richness may reflect the higher salinity recorded in this pool on two occasions (Table 2). Overall, however, there was not an obvious relationship between salinity and richness (Figure 5), probably because the range of salinities was relatively narrow. Richness salinity relationships are generally stronger across broader salinity ranges (Pinder *et al*. 2005).

Twenty nine species (a third of those collected) were recorded only from one pool during the four sampling rounds. However, all except two of these were collected on only one occasion, so their occurrence in only one pool may simply indicate rarity rather than restriction to a single pool. The exceptions are the ostracod *Diacypris spinosa* and the beetle *Paracymus pygmaeus* each of which occurred twice in Gwambygine Pool. Conversely, 17 species (one fifth of those collected) were collected from all four pools. Fifty two species occurred only in pools in the Avon River or only in the pools on the Dale River. Within the Avon and Dale Rivers 48% and 75% of the species present in each river occurred in both of the sampled pools during the project.

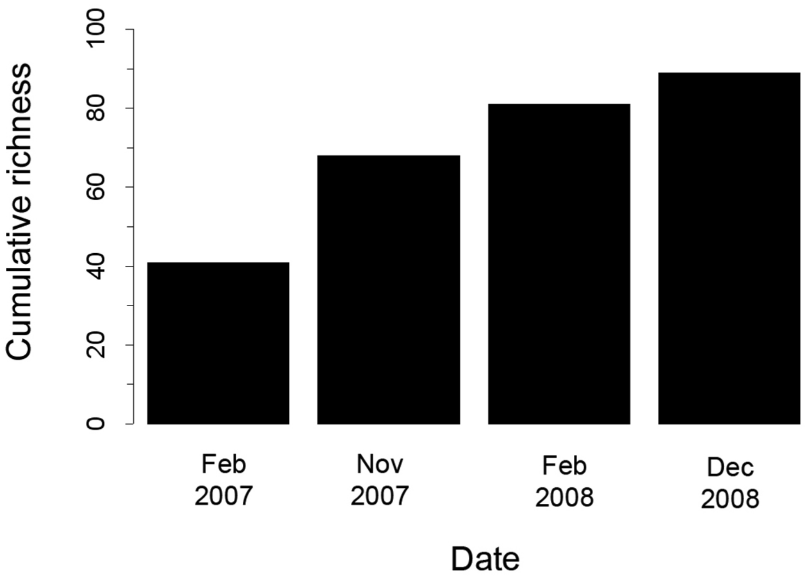

Figure 3. Cumulative species richness across all pools.

Community composition

An n-MDS ordination (Figure 6) showed that there was little tendency for samples to group together by pool, although there was a clear separation by river (Avon versus Dale). The nested permanova analysis also indicated that differences in community composition between the Avon and Dale rivers were significant ($p < 0.01$) but there was no difference between pools within rivers ($p = 0.76$). A cluster analyses (Figure 7) also illustrates the greater similarity of invertebrate communities within a river than between rivers. There were five main cluster groups and all but one of these were composed of samples from just one of the rivers. A distance-based linear model indicated that salinity (as calculated TDS) explained about 16% of variation in community composition ($p<0.01$). In Figure 6 the salinity gradient is clearly aligned with the separation of Dale and Avon pool communities.

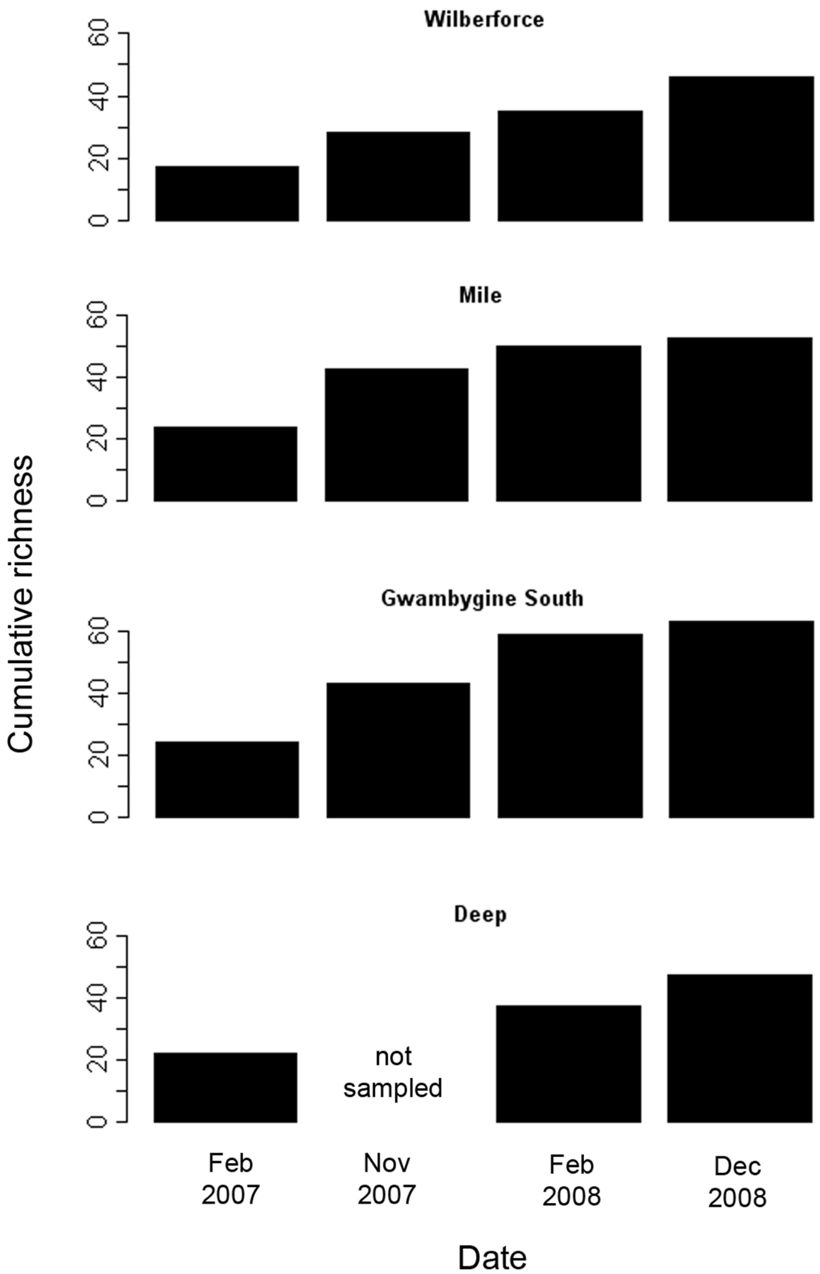

Figure 4. Cumulative species richness in each of the pools sampled on three of four occasions.

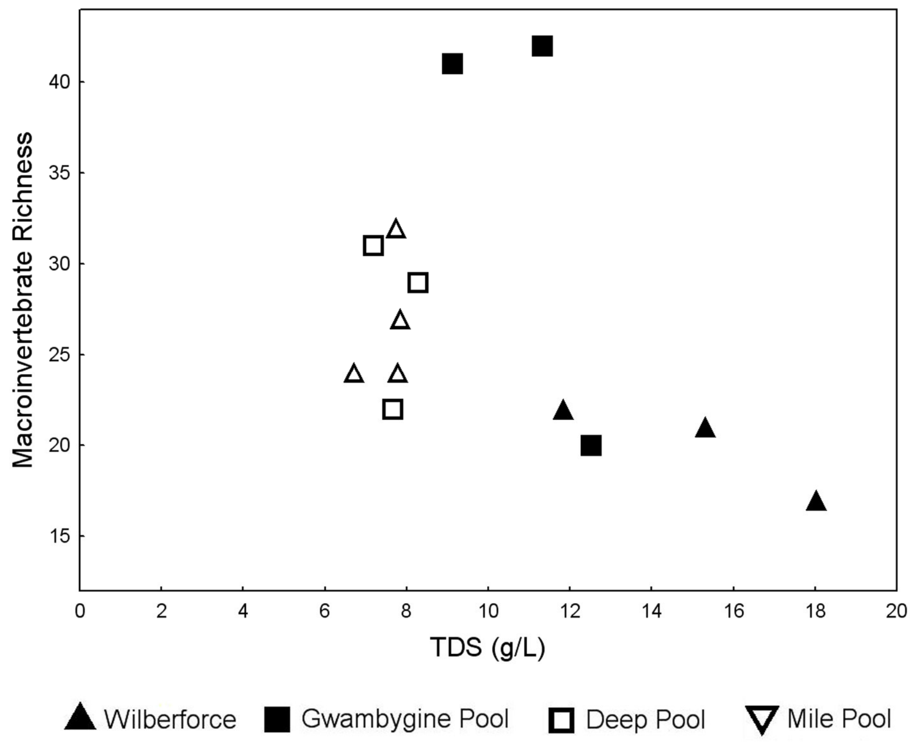

Figure 5. Species richness in samples versus total dissolved solids.

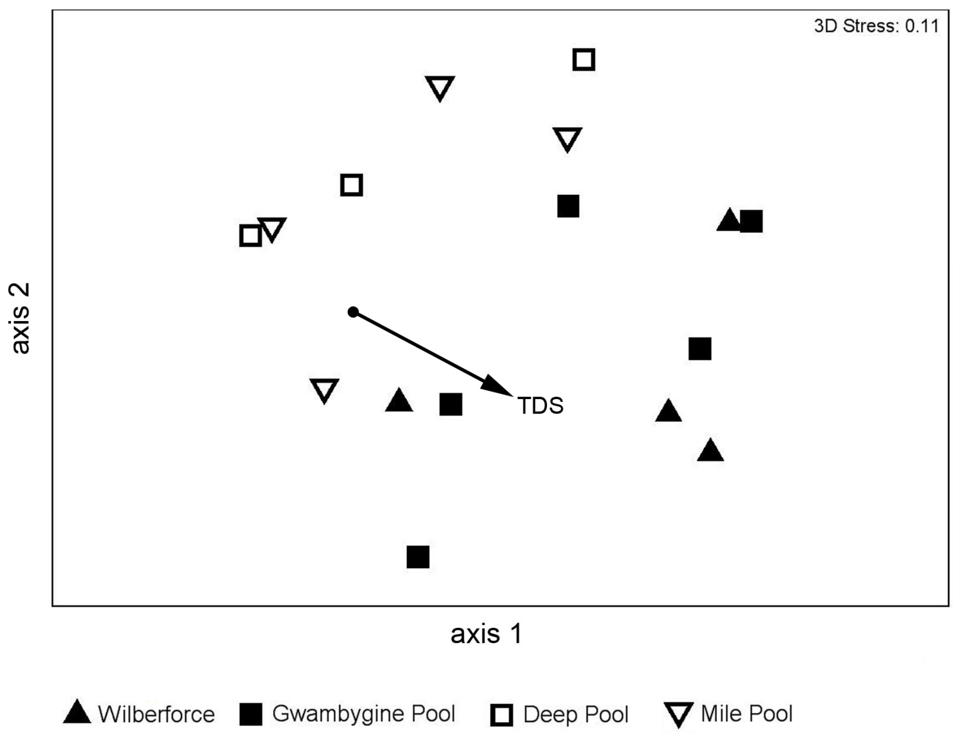

Figure 6. Axes 1 versus 2 of a 3 dimensional n-MDS ordination.

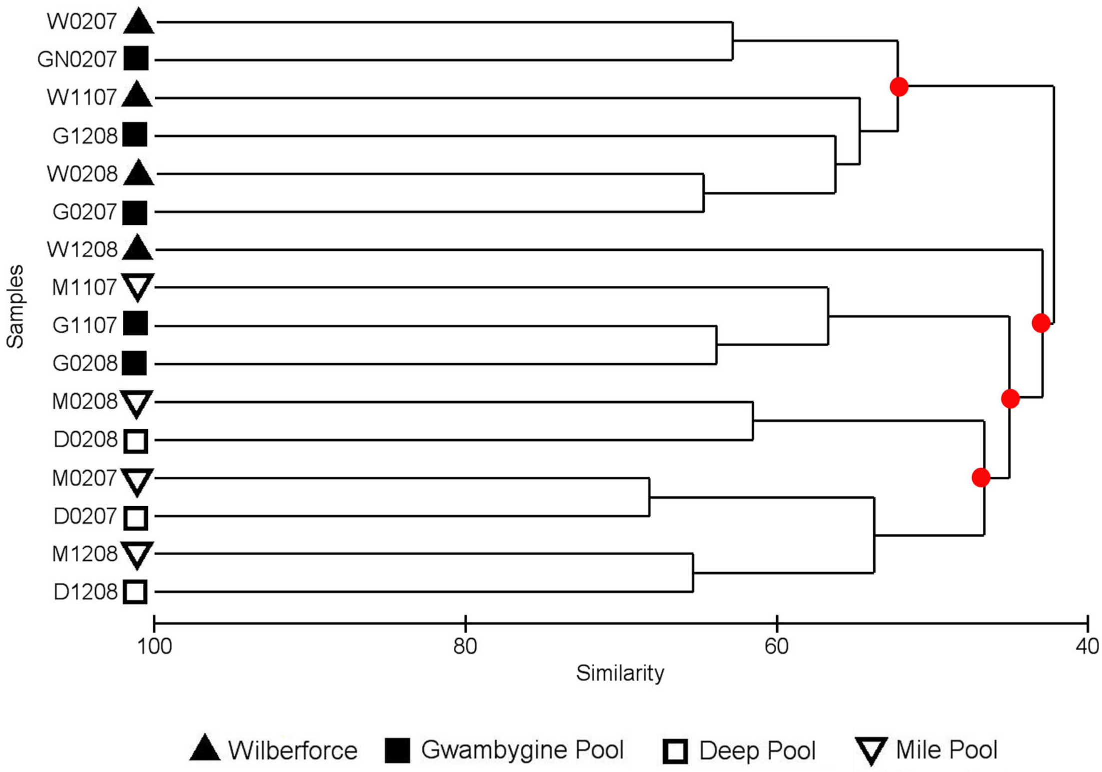

Figure 7. Cluster analysis of invertebrate communities. Sample labels are combined month and year.

DISCUSSION

Diversity and distribution.

Several other studies of the Avon and its tributaries (see Introduction and below) have recorded about half of the species collected during this project, but also many additional species (listed in Appendix 2). In total, 177 species have been collected, including 108 species from the remaining deep pools (those species in Appendix 1 and those indicated with an asterisk in Appendix 2). This is about what was estimated as a total fauna for the pools from Fig. 3 and by the species richness algorithms.

Smith (1996) collected 100 species from 19 locations. Thirty six of these species were collected from the five Avon pools that she sampled (see Introduction), with 22 to 25 species per pool. Only eight of these species were not collected during the present project (but note that some informally identified taxa could not be compared). These eight species are the hydrobiid snail *Potamopyrgus* sp., enchytraeid oligochaetes, *Simulium ornatipes* (black flies), tipulid dipterans (crane-fly larvae), *Stilobezzia* sp. (a genus of biting midges), the ostracod *Cyprinotus edwardi* and the water fleas *Daphnia pusilla* and *Daphnia thomsoni*. The presence of black flies, which require rapidly flowing water, in Cobbler Pool suggests that the sample included flowing sections rather than just the main pool water body, or that these animals had been disturbed and had drifted into the pool.

Several extra species were collected from Gwambygine Pool by River Conservation Society (1999). These were the bivalve *Westralunio carteri*, chydorid water fleas, the gilgie

(*Cherax quinquecarinatus*), leeches, the snails *Gyraulus* sp. and *Coxiella striatula*, hydrachnid and eylaid water mites, *Paroster* and *Antiporus* beetles, at least one additional gyrinid beetle (two species were recorded), *Agraptocorixa parvipunctata* backswimmers and the dragonfly *Pantala flavescens*. The RCS (1999) identification of the beetle *Berosus amoenus* is probably wrong since it is a far northern Australian species and another beetle, the gyrinid "*Macrogyrus reichei*?", needs verification since it is otherwise a south-eastern Australian species.

Almost all of the 108 river pool species are common and widespread in south-western or southern Australia. The dragonfly *Pantala flavescens* was listed as rare but widespread in south-western Australia by Sutcliffe (2003), but it is common in northern Australia, including occurrence in mildly saline wetlands such as Fortescue Marsh in the Pilbara. Four other invertebrates are uncommon in the south-west but common, or at least widely distributed, elsewhere: these are water mites of the genus *Hydrodroma*, beetles *Berosus dallasi* and *Helochares tatei* and the chironomid *Polypedilum leei*. *Hydrodroma* water mites were recorded only from three reservoirs during the Biological Survey of the South-west Agricultural Zone by Pinder *et al.* (2004), but were very common in the Pilbara (DEC, unpublished data) and also occurred in the Carnarvon Basin (Halse *et al.* 2000). The genus has been recorded further south-west (e.g. in the Lake Muir wetlands by A. Storey, UWA, unpublished data). *Berosus dallasi* is more common in northern than in southern Australia, but there are other records from the south-west, including records from the south-coast (one of which was verified by Chris Watts from the South Australian Museum). Likewise, *H. tatei* occurs across northern Australia but was recorded from the far northern Wheatbelt by Pinder *et al.* (2004) and Quinlan *et al.* (2009). *Polypedilum leei* is also primarily a northern Australian species but was recorded from the Murchison River by Pinder *et al*. (2004) and in a freshwater lake near Bolgart in the northern Wheatbelt (DEC unpublished data). Of these four species, *P. leei* was recorded only once in the Avon pools whereas the other three were recorded on more than one occasion, suggesting that they are resident or regular species rather than occasional vagrants.

Differences between pools and other habitats in the Avon

River ecology theory suggests that deep river pools will have invertebrate faunas that are different to those inhabiting shallower reaches of the channel (e.g. Poff and Ward 1990; Poff 1997) and a great many studies provide supporting data (e.g. Brussock and Brown 1991; Scullion et al. 1982). Prior to physical modification of the channel and salinisation of the river this would undoubtedly have been the case in the lower Avon River. Salinisation has probably led to some homogenisation of the fauna since some of the many of the salt-tolerant species were probably the same in different habitats.

Eighty nine species have been collected from habitats other than river pools on the Avon River and tributaries by Halse *et al*. (2001), Pinder *et al.* (2004), Smith (1996) and Sutcliffe (2003). These include some zooplankton species (rotifers, copepods and cladocerans) which most likely do occur in pools, but these would not have been well surveyed by the techniques used (particularly the coarse mesh nets). Some of the species not recorded in pools are usually associated with shallow flowing water, or at least with smaller creeks, so would not be expected to occur in pools. These include blackflies (Simulidae), hydropsychid caddisflies, gripopteridgid stoneflies, *Agrionoptera* dragonflies and thaumaleid dipterans. Others are particularly salt-sensitive, including dugesiid flatworms, *Alona* cladocerans, isopods, haliplid beetles, baetid mayflies, some of the oligochaetes (e.g. *Pristina jenkinae*), the snail *Ferrisia peterdi* and hydroptilid caddisflies (*Hellyethira* and *Oxyethira*). These species occurred only in the lowest salinity sites and, together with the leeches, may have been more widespread in the Avon, including river pools, when it was fresher. Even some species that are tolerant of mild salinity may have become much less common in pools since salinisation.

Conversely, about half of the 108 species recorded in river pools have not yet been collected in other habitats of the lower Avon catchment. This is likely to be at least partly a sampling artefact because the pools have now been sampled more intensively than other habitats. Furthermore, most of the species currently known only from the pools (within the lower Avon) are very widespread species and certainly not restricted to river pools across their wider ranges. Nonetheless, in the lower Avon, species such as *Westralunio carteri*, backswimmers (*Anisops* spp.), pyralid lepidopterans, the odonates *Hemicordulia tau* and *Pantala flavescens*, the caddisfly *Notalina spira* and *Berosus* beetles, may be more common in the more lentic reaches of the river (such as river pools).

Apart from the likelihood that some species have a preference for the deep pools within the system, the pools are likely to act as summer drought refuges for a variety of invertebrates that can recolonise the broader river as flow returns in winter. This most likely applies to many of the adult hemipterans and beetles and dragonfly nymphs but also annelids and water mites that lack drought resistant life-stages.

There is no comparable data for superficially similar saline pools in other large rivers such as the Hotham, Arthur and Blackwood rivers. However, it is very likely that similar pool communities can be found in some of these rivers.

The fauna in relation to salinity

The majority of species recorded in the pools are halotolerant freshwater species. That is, they are species that are most frequently recorded in freshwater but will tolerate some salinity. These vary greatly in their salt-tolerance, from the mayfly *Tasmanocoenis tillyardi* and snail *Gyraulus* sp., which rarely occur above 5 g/L to the beetle *Necterosoma penicillatus* which is regularly recorded at salinities above 50 g/L. For this component of the fauna, any further rise in salinity in the Avon pools would reduce richness or at least alter composition. It is important to note that the critical salinity for the persistence of a species is not the salinity recorded on any one day but the maximum salinity encountered during the most salt-sensitive life-stage (usually juveniles). Some additional species tolerant of the salinities recorded in Table 2 may have been prevented from persisting in the pools by higher salinities at other times of the year. For example, RCS (1999) recorded minimum and maximum salinities of about 5.6 and 38 mS/cm in Gwambygine Pool in 1996/97. The presence of the leech in Gwambygine Pool is significant, as they tend to be particularly salt-sensitive and are intolerant of drying. These have probably disappeared from most of the Avon. The only other published record from the Avon is from the freshwater Christopher Brook (Pinder *et al.* 2004).

A small number of species are halophilic – meaning that they prefer saline conditions, rarely occurring in freshwater. The latter include the cladocerans *Daphnia thompsoni* and *Daphnia pusilla*, ostracods *Cyprinotus edwardi*, *Diacypris spinosa*, *Leptocythere lacustris* and *Mytilocypris mytiloides*, *Coxiella* snail(s), the copepods *Halicyclops* sp. 1 and *Cletocamptus dietersi* and possibly the enchytraeid oligochaetes.

A third group of species are those that normally inhabit estuarine or near coastal saline waters but will extend up rivers where salinity allows. These are the oligochaete *Paranais litoralis*, the copepods *Sulcanus conflictus* and *Onychocamptus bengalensis*, the shrimp *Palaemonetes australis* and the bivalve *Fluviolanatus subtorta*. *Paranais litoralis* is a cosmopolitan species that also occurs in Towerrining Lake in the upper Arthur River, Lake Wheatfield near Esperance and some more inland wetlands. It also occurs in near-shore marine waters. *Sulcanus conflictus* occurs in estuaries around south-western Australia but has been recorded in the Hotham River, Lake Towerrining and Eadine Spring (near Clackline). *Onychocamptus bengalensis* is a very widespread copepod that also occurs in Lake Towerrining, Lake Wheatfield and various south-west rivers and coastal salt lakes. *Palaemonetes* is a euryhaline species, commonly occurring in freshwater or brackish to mildy saline rivers and wetlands, but primarily those along the coast rather than inland. This assemblage, other than *F. subtorta*, is also quite common in the naturally saline rivers along the south-coast (see Pinder *et al*. 2004).

Kendrick (1976) provided ample evidence that much of the Avon River was fresh most of the time prior to European settlement, probably with occasional brackish to saline periods in some parts of the channel. The latter might have occurred as a result of occasional flows from naturally saline eastern tributaries (especially overflow from the Yenyening Lakes) or evapoconcentration in dry years, but some of this would have been ameliorated (spatially and temporally) by consistently fresh flows from western tributaries. Such pulses of raised salinity may have periodically eliminated some species from some sections of the river, but it is uncertain whether this would have been sufficient to have entirely eliminated salt-sensitive invertebrates from the main river channels. Evidence from wetlands in the south-west is that salt-sensitive species readily colonise salinised wetlands that become fresh to brackish when they are full (e.g. Cale 2008). It is certain that salinity in the Avon and its tributaries has increased significantly throughout the hydrological cycle. It is also well-known that salinity is a very strong determinant of richness and composition of invertebrate communities, especially within the relatively low range of salinities present in the Avon (mostly <20 g/L). Salinity alone was sufficient to account for most of the differences in community composition between the Dale and Avon Rivers in this project and Smith (1996) found that salinity was a strong correlate of richness and abundance of invertebrates. Richness of freshwater invertebrates in Wheatbelt wetlands was found to decrease rapidly as salinity increases above and 3 to 4 g/L and by 12 g/L richness would be expected to be reduced by about 30% compared to freshwater wetlands (Pinder *et al.* 2005).

There is a suite of species that, within the lower Avon catchment, are currently restricted to the freshest reaches, primarily smaller tributaries flowing off the eastern slopes of the Darling Range. These include the following taxa that may once have been common in Avon pools but which are now absent or rare in such habitats:

Flatworms

Mollusca

- *Ferrissia peterdi*
- *Plotiopsis australis*
- *Westralunio carteri* (possibly more common than believed due to difficulties of collecting with a sweep net)

Annelida

- Leeches
- *Pristina jenkinae* and probably numerous other oligochaetes
- *Aeolosoma* (Aphanoneura)

Crustacea

- *Cherax quinquecarinatus*
- *Paramphisopus palustris* (Isopoda)
- Probably numerous cladocerans, including *Alona*
- Possibly *Perthia* amphipods but no known records from the lower Avon?

Water mites (probably a variety of species)

Insects

Baetid mayflies

Hydroptilid caddisflies (including *Oxyethira* and *Hellyethira*)

Haliplus (beetles)

Hebrus axillaris (Hebridae)

Cricotopus and *Harrisius* chironomids (and probably other species)

Some odonates (e.g. *Austrothemis nigrescens*, *Zyxomma elgneri*)

Smith (1996) listed a number of species (mostly insects) that are unknown from the Avon but which occurred in a study of the freshwater Canning River by ARL (1986). A few of these (the snail *Ferrissia peterdi*, stoneflies, the damselfly *Argiolestes pusillus*, and trichopteran *Hellyethira*) have since been found in the Avon catchment but not in the pools. However, the Canning River study focussed on riffle habitat rather than pools, so many of the species listed by Smith (1996) would be restricted to rapidly flowing water and would therefore never have occurred in pools. For example, the caddisflies *Condocerus aptus* and *Hydrobiosella michaelseni* are species that typically occur in rapidly flowing streams (Sutcliffe 2003).

There may have been other species that were restricted to pool habitats that have now entirely disappeared from the Avon, but there is no evidence for this because there is virtually no pre-salinisation data. Conversely, given that salinity has increased in the Avon catchment, it is very likely that some of the salt-tolerant and halophilic species that are now common in pools have either colonised since salinisation or have at least become more common. It is difficult to speculate on which species this would apply to, but the halophilic species would be the most likely candidates.

Threats to the Avon pool invertebrate fauna

The species listed in Appendix 1 and the additional river pool species collected from Avon pools by other authors are mostly common and widely distributed in at least south-western Australia. Their broader conservation is in no way dependant upon presence of pools in the Avon catchment. They are also all tolerant of mild salinity, although in the Avon pools many are close to their recorded upper salinity limit. Some species are undoubtedly rare in the Avon because of the present salinity and any further persistent increase in salinity would see additional species also disappear from the pools, especially in the Dale River. Sedimentation of the river pools may also be a threat to some species, especially if this leads to summer drying or declining water quality. The extent to which the present community is threatened depends on whether salinity is likely to increase further and whether sedimentation can be managed. Salinity does not appear to be increasing in the Avon and Dale Rivers. Salinities recorded at Gwambygine Pool by RCS (1999) in summer 1996 and 1997 were about the same as those listed in Table 2. Also, Smith (1996) recorded conductivities similar to (in October 1995) or greater than (in February 1996) those recorded in the Avon River during the present project. Data presented in Department of Environment (2006) suggests that salinities are stable in the Dale River. Also, Pinder *et al.* (2004) recorded salinity in the Dale River of 7.65 g/L in spring 1997, which is about the same as recorded in 2007 and 2008 in summer.

At present, salinisation does not pose a significant threat to the extant community. Sedimentation is an ongoing threat that will require continued in-stream and catchment management. Nutrient enrichment is also a problem in the river, but at present levels is probably not a serious threat to the remaining fauna. Acidification of the inland catchment as a result of agricultural drainage schemes may be problem for the Avon River if it affects the Yenyening Lakes or the other eastern tributaries such as Mortlock River. The Salt River, which eventually drains into Yenyening Lakes, is already acidic 60km downstream of the input of significant drainage works (G. Janicke, UWA, pers. comm.). On balance, however, given the tolerant nature of the component species, the Avon pool invertebrate communities are not particularly under threat, although populations of some individual species may be threatened by continuing sedimentation.

Conclusions

- After more than a century of degradation the Avon River still supports diverse aquatic invertebrate communities. However, the present day pool communities are almost certainly very different from those inhabiting the river in pre-European times. Pool communities are now comprised of a subset of the original fauna, together with salt-tolerant, halophilic and estuarine opportunistic colonisers.

- Despite the highly modified nature of the river and its pool faunas, Smith (1996) is correct in asserting that the river is not in its death throes, as was colourfully suggested by Kendrick (1976). The original communities may have partly disappeared but the river and its pools still support taxonomically and ecologically diverse invertebrate communities. These are a significant component of functioning ecosystems that will benefit from ongoing protection and restoration.

- There is still great ecological value in the pools. It is likely that the occurrence of some species is largely dependant on the presence of deep pools within the system. This would apply to species with a preference for the more lentic habitats within the river, but also to species for which the pools act as summer drought refuges, allowing them to quickly recolonise the broader river as flow returns in winter.

- There are numerous anthropogenic pressures on the Avon pools. However, one of the main pressures, salinisation, seems to have stabilised, at least under current climatic and land management regimes. Sedimentation, by contrast, is an ongoing threat that will continue to require active and expensive management and can be said to be a threat to the pool faunas. Protection and restoration of the freshwater western tributaries should be a priority within the lower Avon catchment as these are a last refuge for some taxa and the tributaries ameliorate salinity in parts of the main Avon River.

- There is both ecological and social amenity in the pools and there are benefits to be gained through management of the river system for conservation irrespective of whether the invertebrates are deemed to constitute a TEC.

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