Baseline study on the fish and freshwater crayfish fauna in the Blackwood River and its tributaries receiving discharge from the Yarragadee Aquifer

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Summary

Water from the Yarragadee Aquifer surfaces in Poison Gully and Milyeannup Brook, and maintains flow in these Blackwood River tributaries throughout the year. It also enters Layman Brook during winter and spring, yet this stream dries during summer. The aim of this study was to provide baseline information on the fish and freshwater crayfish fauna in these Yarragadee aquifer-fed tributaries, and compare them to both those upstream tributaries devoid of any flow from the aquifer, and those tributaries entering the Blackwood River immediately downstream of the aquifer discharge area. A comparison was also made of the fish fauna of the Blackwood River main channel that receives flow from the Yarragadee Aquifer to a number of main channel sites upstream of the discharge area, i.e. main channel sites that do not receive any flow from the Yarragadee.

There was a significant difference between the fish fauna associated with main channel sites when compared to tributaries and there were substantial differences in the fauna of the downstream and upstream main channel sites. Main channel sites downstream of the Yarragadee Aquifer discharge area had a much higher diversity of fish and freshwater crayfish than main channel sites upstream of the discharge area. For example, within the main channel sites that receive summer input from the Yarragadee, 11 species of fish and 4 species crayfish were captured compared to 4 species of fish and 2 species of crayfish upstream of the discharge zone. Furthermore, the 4 species of fish in the main channel in the upper riverine part of the study area were all halotolerant, whereas most of the additional species present in the sites in the lower section of the river tolerate only low salinities.

A number of species found in the main channel are absent from the tributary sites sampled and vice versa. For example, Freshwater Cobbler, Western Hardyheads, Swan River Gobies and South-western Gobies were only captured in the main channel, while Mud Minnows and Balston's Pygmy Perch were restricted to tributaries.

The tributaries that receive direct flows from the Yarragadee Aquifer, i.e. Milyeannup Brook and Poison Gully provide important refuges for Balston's Pygmy Perch and Mud Minnows. Ninety percent of all Balston's Pygmy Perch were found in Milyeannup Brook and with the exception of one site in the tributaries upstream of the Yarragadee (Leederville Aquifer sites), all Mud Minnows were only found in excavated waterpoints.

Water extraction and the lowering of water tables have the potential to reduce surface water in Milyeannup Brook and Poison Gully and may lead to the elimination of Balston's Pygmy Perch from the Blackwood River. It may also impact on aestivating fish and freshwater crayfish by drying out the substrates that they burrow into. The main channel section of the Blackwood River that receives flow from the Yarragadee Aquifer supports a number of recreational fisheries, the most important being the Marron fishery, and reduced freshwater input from the Yarragadee Aquifer may comprise these fisheries. Reduced inflow of freshwater could potentially lead to an increase in salinity of this part of the river and may be intolerable to a number of species (see Discussion).

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Background

The extraction of groundwater from the South West Yarragadee Aquifer may lead to reduced aquifer discharge into the Blackwood River main channel and specific tributaries, and this in turn has the potential to negatively impact on the prevailing aquatic fauna. The fish fauna of the Blackwood River catchment was documented by Morgan *et al*. (1998, 2003) and there is some distributional information on freshwater crayfish in the region (Austin and Knott 1996, Horwitz and Adams 2000, Morgan *et al*. 2004). The three tributaries that receive water directly from the Yarragadee Aquifer include Milyeannup Brook, Layman Brook and Poison Gully (Department of Environment pers. com.).

All eight species of teleost that are endemic to south-western Australia are found within the Blackwood catchment (Morgan *et al*. 1998, 2003). The forested tributaries in this part of the Blackwood are known to support the endemic fish of the river, with salinised waters in many tributaries and much of the main channel being responsible for the exclusion of non-halotolerant species (Morgan *et al*. 2003). The freshwater input from the Yarragadee into these tributaries and the main channel may thus be important in maintaining these fish assemblages. There is little historical information on the fish and freshwater crayfish fauna of the receiving environment surrounding the Yarragadee discharge area, however, the Centre for Excellence in Natural Resource Management (CENRM) (2005) recorded a maximum of four native and one introduced fish species from 19 main channel sites and a maximum of three native fish species from 13 tributary sites from sapling during July 2004. The species CENRM (2005) captured in the main channel included the South-western Goby (*Afurcagobius suppositus*) (7 of 19 sites), Nightfish (*Bostockia porosa*) (2 sites), Western Pygmy Perch (*Edelia vittata*) (1 site), Western Minnow (*Galaxias occidentalis*) (6 sites), Balston's Pygmy Perch (*Nannatherina balstoni*) (1 site), Freshwater Cobbler (*Tandanus bostocki*) (1 site) and the introduced Mosquitofish (*Gambusia holbrooki*) (4 sites). The four species captured in the tributary sites sampled include Nightfish (4 sites), Western Pygmy Perch (1 site), Western Minnow (7 sites) and they list two species as one, i.e. Mud/Black-stripe Minnow (*Galaxiella munda/nigrostriata*) from 1 site. Morgan *et al.* (2003) lists a further four introduced fish species (i.e. Goldfish (*Carassius auratus*), Rainbow Trout (*Oncorhynchus mykiss*), Brown Trout (*Salmo trutta*) and Redfin Perch (*Perca fluviatilis*)) and two native fish species (i.e. Western Hardyhead (*Leptatherina wallacei*) and Swan River Goby (*Pseudogobius olorum*)) from the Blackwood River near the study area.

Of the fish species known from the Blackwood River catchment, four are listed on the Australian Society for Fish Biology's List of Threatened Fishes. Nominations for listing Balston's Pygmy Perch and the Mud Minnow as *Vulnerable* under the *EPBC Act 1999* are currently being assessed. These species are not currently listed in Western Australia under the *Wildlife Conservation Act 1950*, however they are listed as a *Priority 1* and *Priority 4*, respectively, on *CALM's List of Priority Fauna* (CALM 2005). Both species have undergone massive reductions in their overall range (Morgan *et al*. 1998).

Similar to the high rate of endemism of the south-west's freshwater fishes (80% endemic), all of the 11 species of freshwater crayfishes native to Western Australia are endemic to the south-west. Six of these belong to the genus *Cherax*, i.e. Margaret River Hairy Marron *Cherax tenuimanus* (restricted to Margaret River), Smooth Marron *Cherax cainii* (found from the Hutt River to the Esperance region), the widespread Gilgie *Cherax quinquecarinatus* (Moore River to just east of Albany), the widespread Koonac *Cherax preissii* (Moore River to just east of Albany), the restricted Gilgie *Cherax crassimanus* (Margaret River to Denmark region) and restricted Koonac *Cherax glaber* (Dunsborough to Windy Harbour) (Austin and Knott 1996, Beatty and Morgan unpublished data). Although *Cherax* is the most widely distributed freshwater crayfish genus in Australia, the native Western Australian species have been shown to be monophyletic likely due to the long period of separation of south-western Australia (Crandall *et al.* 1999). The remaining five native species of freshwater crayfish in Western Australia belong to the endemic genus *Engaewa*, i.e. *Engaewa reducta* (Dunsborough to just north of Margaret River, *Engaewa pseudoreducta* (Margaret River region), *Engaewa similes* (Margaret River to Windy Harbour region); *Engaewa subcoerulea* (Windy Harbour region to Denmark); and *Engaewa walpolea* (Walpole region) (Riek 1967, Horwitz and Adams 2000). Horwitz and Adams (2000) also proposed that *E. reducta*, *E. pseudoreducta* and *E. walpolea* fulfil the IUCN criteria to be listed as endangered, critically endangered and vulnerable, respectively.

The Blackwood River catchment is therefore known to house five of the six endemic *Cherax* species and at least one (i.e. *E. similes*) of the five *Engaewa* species. CENRM (2005) reports two species of freshwater crayfish from the main channel (i.e. the Marron (*Cherax cainii*) (1 site) and Gilgie (*Cherax quinquecarinatus*) (1 site)) and three species from the tributary sites (Marron (8 sites), Gilgie (5 sites) and the Koonac (*Cherax preissii*) (1 site)). However, as with many taxa, the phylogenetics and biogeography of freshwater crayfish in this region is continually being revised and the catchment may indeed contain populations of other *Engaewa* sp. The major threats to native freshwater crayfishes and fishes includes habitat change (particularly secondary salinisation and eutrophication of inland waterways that has reduced inland ranges, Morrissy (1978), Molony *et al*. (2002)); hydrological change, i.e. damming of water courses and groundwater extraction; predation by introduced teleosts (particularly Redfin Perch *Perca fluviatilis* (Morgan *et al.* (2002)); and riparian degradation that results in reduced instream habitat. Any large-scale perennial extraction of groundwater therefore falls into one of the major categories of threats posed to the freshwater crayfish of the region.

As part of the allocation planning process currently under way in the south-west region, the Department of Environment is investigating the potential impacts of groundwater extraction on the aquatic fauna of the Blackwood River. As part of this assessment, and since the CENRM (2005) study occurred during winter flows, additional baseline studies are required during periods of low flow to describe the key aquatic fauna of this region and to identify the potential adverse impacts of water extraction on these communities. Furthermore, the importance of specific habitats needs to be assessed.

Aims of the study:

1. Document the fish and freshwater crayfish in the Yarragadee Aquifer-dependant Milyeannup Brook, Layman Brook and Poison Gully and Leederville Aquifer-dependant St John's Bk, Spearwood Ck and Red Gully. Compare the key aquatic fauna of the two sets of tributaries and determine the conservation significance of the key aquatic fauna of these systems.
2. Document fish and freshwater crayfish in the pools of the Blackwood River main channel immediately below and upstream of the Yarragadee discharge area during periods of low flow. Compare the key aquatic fauna of the different parts of the main channel and determine the conservation significance of the key aquatic fauna of these systems.
3. Describe the fish and crayfish fauna of a range of ephemeral wetlands that are associated with the tributaries. Ephemeral wetlands (pools) habitats in the region have a significantly different suite of fishes than the streams (Morgan and Gill 2000). This is important in the absence of data indicating that ephemeral wetlands associated with the streams of the study area are dependant on surface flows rather than the aquifer as aestivation in fish and crayfish would be dependant on the substrate retaining moisture.
4. Based on this study make recommendations on future monitoring necessary to understand the effects of potential groundwater extraction on key aquatic fauna.

Methodology

Site selection and sampling techniques

During early April 2005 (end of the dry season), fish and freshwater crayfish were captured using a variety of seine nets (3 mm woven mesh), composite gill nets, a Smith-Root backpack electrofisher, a portable generator-powered electrofisher, scoop nets and crayfish traps in a number of sites in the main channel of the Blackwood River and within tributaries between the river's junction with Great North Road (downstream) and Agg Road (upstream) (Figures 1 and 2, Table 1).

Six sites in the main channel were sampled for fish and freshwater crayfish, including: the junction with Great North Road, downstream of Sues Bridge, near the mouth of Rosa Brook, near the mouth of Layman Brook, Stacey Road crossing and Agg Road (Figures 1 and 2, Table 1). The following tributaries were also sampled: Adelaide Brook, Rosa Brook, Layman Brook, Poison Gully, Milyeannup Brook, Red Gully, Sturcke Creek, McAfee Brook and St John Brook (Figures 1 and 2, Table 1). Note that with the exception of Adelaide, Rosa and Layman Brooks, which were sampled previously by the authors, all sites were sampled during April 2005. Layman and Adelaide Brooks were dry at the time of sampling in April 2005.

Environmental variables

Water temperature, dissolved oxygen, pH and conductivity were recorded at each site sampled. These environmental variables were averaged through a cross section of habitats for each site. Differences in environmental variables were determined using ANOVA in SPSS.

Data analysis

On capture, fish species were identified, the total length (TL) (mm) of a sub-sample measured and recorded, and the majority of native fish released. Feral species were retained and euthanased in an ice slurry before being transferred to 100% EtOH. Some samples of native species were retained for future genetic analyses.

On capture, freshwater crayfishes were identified and the majority released. A small number were retained for further morphological examination.

Densities of fish and freshwater crayfish species were estimated from the total number of each species captured over a given area.

In order to test for any difference on the community structure between the different sites a species presence/absence data set was developed and sites were classified into the following categories: (1) Those that receive discharge from the Yarragadee Aquifer, (2) those that receive discharge from the Leederville Aquifer, (3) those downstream of Yarragadee Aquifer discharge area and the main channel sites (4) upstream and (5) downstream of the Yarragadee discharge area. This data set was used to construct a similarity matrix employing the Bray-Curtis similarity coefficient in the PRIMER package (Clarke and Gorley 2001). Presence/absence data is more appropriate to use in this circumstance as sampling methodologies varied greatly depending on site characteristics. For example, gill nets, seine nets and the generator-powered electrofisher were the preferred sampling method in the main channel sites while a back-pack electrofisher was the most commonly utilised method for sampling the smaller, shallow tributary sites (Figure 1). The significance of faunal associations in relation to the main habitat types was analysed using ANOSIM in the PRIMER package. Thus, comparisons were main between the faunal associations in the main channel sites upstream and downstream of the Yarragadee Aquifer discharge zone and those in the different tributary sites.

Table 1 The sites sampled in the main channel of the Blackwood River below and above the Yarragadee Aquifer discharge area. Also included are the tributary sites that receive discharge from the Yarragadee Aquifer, those tributaries immediately downstream of the discharge area and those tributaries immediately upstream of the discharge area. See Figure 2 for site locations.

Site Number	Site Name	Longitude	Latitude
Main channel downstream of discharge			
BW1	Great North Road	115.2930	34.0778
BW2	Sues Bridge	115.3890	34.0748
BW3	Denny Road near Rosa Brook confluence	115.4505	34.1081
BW4	Layman Brook confluence	115.5052	34.0721
Main channel upstream of discharge			
BW5	Stacey Road	115.6025	34.0421
BW6	Agg Road	115.8056	33.9215
Tributary sites in discharge area			
PG1	Poison Gully (Blackwood Road)	115.5543	34.1201
PG2	Poison Gully (near confluence with main channel)	115.5509	34.1094
MB1	Milyeannup Bk (near confluence with main channel)	115.5656	34.0933
MB2	Milyeannup Bk (Brockman Highway)	115.5699	34.0988
LB1	Layman Brook (Denny Road)	115.5039	34.0701
LB2	Layman Brook (Crouch Road)	115.5114	34.0169
Tributary sites downstream of discharge area			
RB1	Rosa Brook (Denny Road)	115.4235	34.0653
RB2	Rosa Brook (Crouch Road)	115.4569	34.0205
RB3	Rosa Brook (Lawson Road)	115.4695	33.9328
RB4	Rosa Brook (Mowen Road)	115.4715	33.9164
AB1	Adelaide Brook (Denny Road)	115.3380	34.0699
AB2	Adelaide Brook (Crouch Road)	115.3525	34.0141
Tributary sites upstream of discharge area (Leederville Aquifer dependant)			
RG1	Red Gully (waterpoint on Great South Road)	115.6874	34.1143
RG2	Red Gully (waterpoint on Blackwood Road)	115.7107	34.1224
RG3	Red Gully (Brockman Highway)	115.6209	34.0721
MC1	McAfee Brook (Denny Road)	115.5880	34.0425
MC2	McAfee Brook (Crouch Road)	115.5827	34.0249
SC1	Sturcke Creek (waterpoint on Great South Road)	115.6934	34.0664
SJ1	St John Brook (Mowen Road)	115.6865	33.9578
SJ2	St John Brook (St John Road)	115.6629	33.9016
SJ3	St John Brook (Baker Road)	115.6612	33.8365

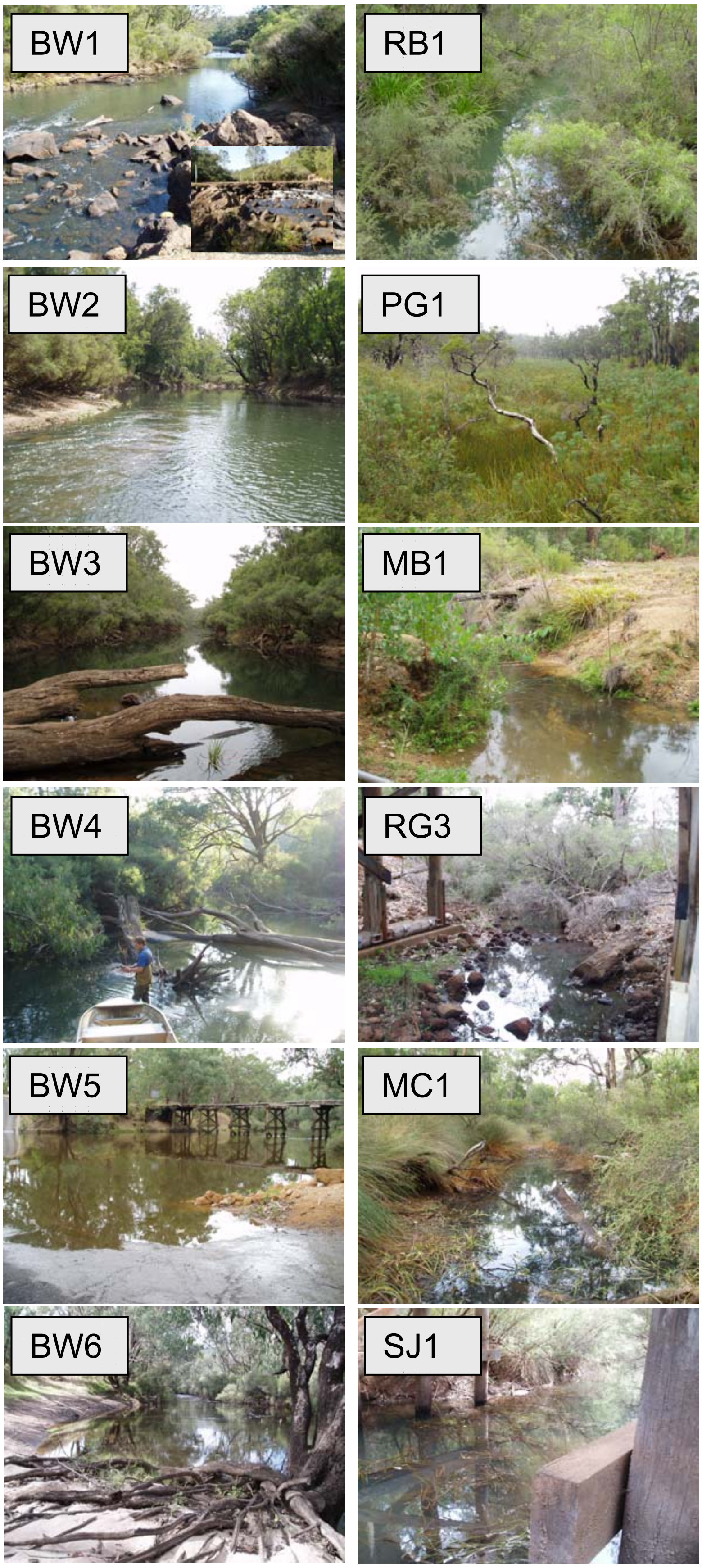

Figure 1 Photographs of the Blackwood River main channel sites and a selection of tributary sites that were sampled for fish and freshwater crayfish. See Table 1 for site codes and locations.

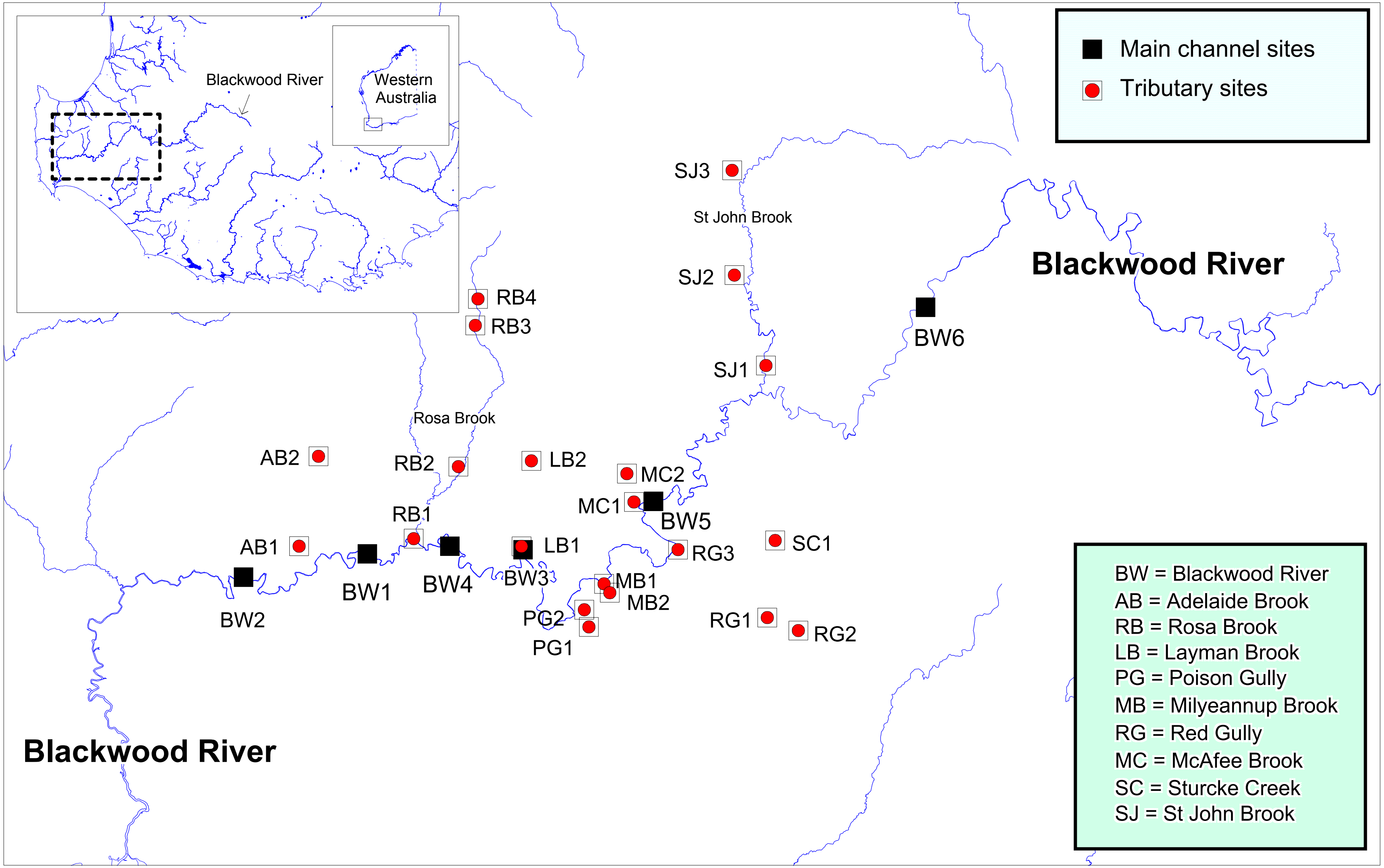

Figure 2 The sites sampled in the Blackwood River and its tributaries during April 2005. N.B. Adelaide Brook, Rosa Brook and Layman Brook were sampled during the summer of 2003/4.

Results

Environmental variables

Blackwood River

The conductivities and salinities recorded in the main channel of the Blackwood River during April 2005 were generally brackish (Table 2, Figure 3). The main channel sites that were downstream of the Yarragadee discharge zone (sites BW1-BW4) had lower mean conductivities and salinities at the time of sampling than those upstream of the zone (sites BW5-BW6) (Table 2, Figure 3). The main channel sites receiving Yarragadee discharge had mean conductivities ranging from 1.46 (±0.01) mS/cm (0.76 ppt) at Sues Bridge (BW2) to 1.9 mS/cm (1 ppt) upstream near the confluence with Layman Brook (Table 2, Figure 3). However, a major flood pulse resulting from heavy and widespread inland rainfall in the week prior to sampling had not yet reached the sites downstream of the Yarragadee discharge (BW1-BW4: sampled between the 4th-7th/4/2005), but had reached the upstream channel sites BW5 and BW6 at the time they were sampled (8-13th/4/2005) (Figure 3). This flow resulted in the river rising by a maximum of approximately 2 m over a 24 hour period and would have likely have resulted in salt loads upstream in the catchment entering the main channel. This was highlighted by the nearly three-fold increase in the conductivity at Stacey Rd Crossing (BW5) from 2.81 (±0.02) mS/cm (1.5 ppt salinity) during the initial rise in the water levels that occurred from the 7th-8th of April to 7.85 (±0.02) mS/cm (4.3 ppt) on the 12th of April at which time the pulse had largely subsided (Table 2, Figure 3).

The flood pulse that occurred between the 7th-8th of April may have also contributed to the lower mean water temperatures recorded at the upstream Blackwood River sites BW5 (17.95°C ±0.05) and BW6 17.7°C (±0.00) following the pulse, compared with those recorded at the downstream sites that ranged from 18.5°C (±0.07) at BW3 to 19.32°C (±0.02) at BW4 (Figure 3, Table 2). Mean dissolved oxygen levels in the main channel sites ranged from 5.05 (ppm) at BW5 to 8.17 (mg/L) at BW6 with no clear differences between those sites upstream of the Yarragadee discharge zone to those downstream sites receiving flows (Table 2).

Tributaries

The sites sampled on the tributaries of the Blackwood River were generally fresh (Figure 3, Table 2). No clear differences existed in environmental variables between the tributaries within the Yarragadee discharge zone to those upstream of the zone (Figure 3, Table 2). However, aside from MC1 (downstream-most site on McAfee Brook) and the waterpoint sites on Sturcke Creek (SC1) and Red Gully (RG1) (i.e. excavated holes into the water table), the conductivity of those tributaries within the Yarragadee discharge zone (maximum of 0.47 mS/cm (±0.01)) were lower than those upstream of the zone (maximum of 1.48 mS/cm (±0.01)) (Figure 3, Table 2). Mean dissolved oxygen levels in the tributary sites were more variable than those in the main channel sites and ranged from 2.58 ppm at waterpoint site SJ3 to 8.68 ppm at PG2 (Table 2).

Table 2 The mean values of the environmental variables recorded at the sites sampled in the current study during April 2005. ^Recorded 12 hours following the major flood pulse that occurred on the 7/4/2005, ^^Recorded five days after flood pulse (following subsidence of water level). *Sites at CALM fire-fighting waterpoints.

SITE	Temp (°C)	pH	Cond (mS/cm)	Salinity (ppt)	Dissolved oxygen (ppm)
Main channel downstream of discharge					
BW1	19.17 (0.13)	7.30 (0.01)	1.58 (0.04)	0.77 (0.02)	6.62 (0.28)
BW2	18.88 (0.11)	7.27 (0.03)	1.46 (0.01)	0.76 (0.00)	7.81 (0.02)
BW3	18.50 (0.07)	7.13 (0.00)	1.57 (0.06)	0.78 (0.02)	8.11 (0.11)
BW4	19.32 (0.02)	6.79 (0.00)	1.90 (0.00)	1.00 (0.00)	7.97 (0.03)
Main channel upstream of discharge					
BW5^	18.95 (0.13)	7.09 (0.02)	2.81 (0.02)	1.50 (0.00)	5.05 (0.02)
BW5^^	17.95 (0.05)	7.42 (0.01)	7.85 (0.02)	4.30 (0.00)	6.87 (0.05)
BW6	17.70 (0.00)	7.54 (0.08)	9.33 (0.19)	5.37 (0.02)	8.17 (0.34)
Tributary sites in discharge area					
PG1	16.47 (0.04)	5.44 (0.03)	0.27 (0.02)	0.10 (0.00)	3.59 (0.99)
PG2	17.40 (0.07)	6.34 (0.01)	0.29 (0.01)	0.10 (0.00)	8.68 (0.31)
MB1	15.93 (0.04)	5.71 (0.26)	0.44 (0.00)	0.20 (0.00)	3.30 (1.14)
MB2	15.70 (0.00)	5.80 (0.01)	0.47 (0.01)	0.20 (0.00)	6.02 (0.21)
Tributary sites upstream of discharge area (Leederville Aquifer dependant)					
RG1*	20.30 (014)	5.46 (0.05)	0.43 (0.00)	0.20 (0.00)	5.47 (1.51)
RG2	20.53 (0.22)	7.33 (0.02)	0.73 (0.00)	0.40 (0.00)	6.17 (1.03)
RG3	18.33 (0.04)	7.10 (0.04)	0.92 (0.12)	0.47 (0.04)	8.33 (0.29)
MC1	17.32 (0.30)	5.85 (0.03)	0.22 (0.01)	0.10 (0.00)	4.68 (0.04)
MC2	20.80 (0.26)	5.34 (0.08)	1.48 (0.01)	0.70 (0.00)	7.46 (0.24)
SC1*	19.47 (0.39)	7.16 (0.03)	0.28 (0.00)	0.10 (0.00)	4.45 (1.24)
SJ1	16.08 (0.29)	6.27 (0.01)	1.05 (0.00)	0.50 (0.00)	6.31 (0.13)
SJ2	14.12 (0.38)	5.87 (0.02)	0.63 (0.02)	0.30 (0.00)	6.45 (0.08)
SJ3*	14.83 (0.21)	6.15 (0.00)	0.64 (0.00)	0.30 (0.00)	2.58 (0.20)

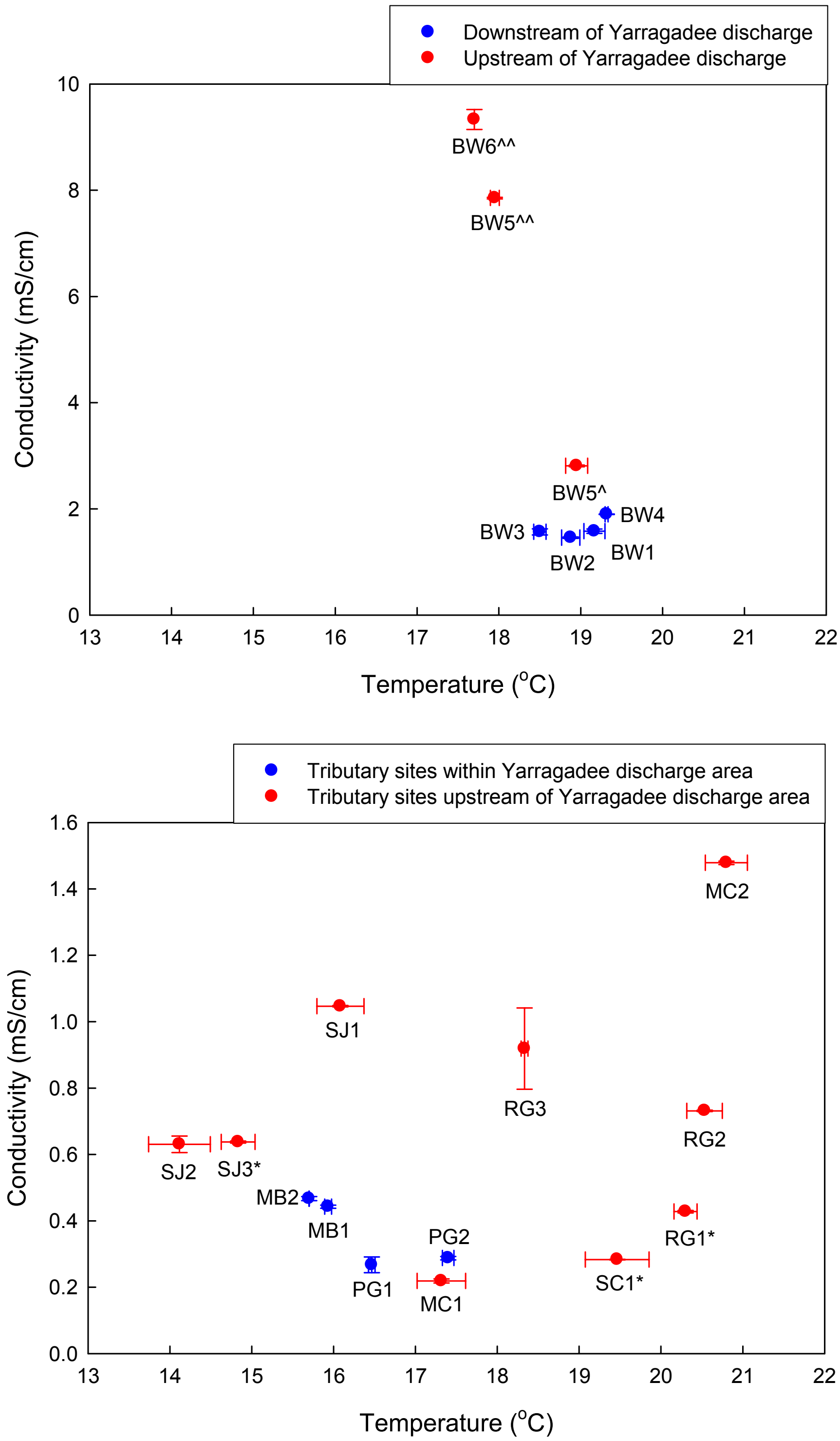

Figure 3 The mean (± 1 SE) conductivity and temperature recorded in the main channel of the Blackwood River (top) and its tributaries (below), during April 2005. N.B. ^Recorded 12 hours following the major flood pulse that occurred on the 7/4/2005, ^^Recorded five days after flood pulse (following subsidence of water level). *Sites at CALM fire-fighting waterpoints.

Fish species captured

A total of 13 fish species were captured in the 19 sites sampled in April 2005, including data incorporated from Rosa, Layman and Adelaide Brooks that were sampled in the spring and summer of 2003/4 (Table 3, Figure 4). Of these species, six are freshwater obligates that are endemic to the South West Coast Drainage Division, four are estuarine species, two of which are endemic to the south-west and the remaining three are introduced fishes. Of 5324 fish captured, ~49% were introduced, predominantly Eastern Mosquitofish, while a further 36% were estuarine species, leaving ~15% of captures being endemic freshwater species (Appendix 1 and 2). For a synopsis of the fish species captured see Appendix 2.

Fish in main channel sites

Within the main channel sites that receive discharge from the Yarragadee Aquifer, a total of five endemic freshwater species, four estuarine species and two introduced species were captured (Table 3). In contrast, the fish fauna in the main channel of the sites sampled upstream of the discharge area housed only one endemic freshwater species, three estuarine species and one feral species. The only endemic freshwater species captured upstream of the discharge area was the Western Minnow (*G. occidentalis*) being in both higher numbers and higher densities than in the main channel sites in the discharge area. The Swan River Goby (*Pseudogobius olorum*) was also found in both higher numbers and densities in the sites upstream of the discharge area. Contrastingly, the abundance of the South-western Goby (*A. suppositus*) was much lower in the upstream sites compared to the downstream sites (Table 3).

While the Freshwater Cobbler (*T. bostocki*), Western Pygmy Perch (*E. vittata*), Balston's Pygmy Perch (*N. balstoni*) and Nightfish (*B. porosa*) were not found in the main channel sites upstream of the discharge area, only the Freshwater Cobbler is restricted to the main channel, being captured on only one occasion in a tributary site in Rosa Brook (Table 3, Morgan *et al*. 2004). Only one Balston's Pygmy Perch was captured in the main channel, with 90% of all captures of this species being in Milyeannup Brook, a tributary that receives direct flows from the Yarragadee Aquifer.

Figure 4 The fish species captured in the Blackwood River during this study.
Photographs: D. Morgan and M. Allen (Freshwater Cobbler and Western Hardyhead).

Table 3 The species of fish captured in the different sites sampled in the Blackwood River and its tributaries. *Tb* = *Tandanus bostocki*, *Go* = *Galaxias occidentalis*, *Gm* = *Galaxiella munda*, *Ev* = *Edelia vittata*, *Nb* = *Nannatherina balstoni*, *Bp* = *Bostockia porosa*, *As* = *Afurcagobius suppositus*, *Po* = *Pseudogobius olorum*, *Lw* = *Leptatherina wallacei*, *Ca* = *Carassius auratus* and *Gh* = *Gambusia holbrooki*. ^*Oncorhychus mykiss* was also captured at RB1 but were fish that were stocked by the Department of Fisheries WA.

	FISH SPECIES CAPTURED											
	Endemic freshwater fishes						Estuarine fishes				Ferals	
SITE	***Tb***	***Go***	***Gm***	***Ev***	***Nb***	***Bp***	***As***	***Po***	***Lw***	***Ab***	***Ca***	***Gh***
Main channel downstream of discharge												
BW1	*	*		*			*	*	*	*		*
BW2	*	*				*	*	*	*		*	*
BW3	*	*		*	*	*	*		*			*
BW4	*	*		*		*	*		*			*
Main channel upstream of discharge												
BW5		*					*	*	*			*
BW6		*						*	*			*
Tributary sites in discharge area												
PG1		*		*								
PG2		*	*			*						
MB1		*	*	*	*							*
MB2		*		*	*	*						
LB1		*	*			*						
LB2												
Tributary sites downstream of discharge area												
RB1^		*	*	*		*	*	*	*			*
RB2	*	*	*	*		*						
RB3		*	*	*		*						
RB4		*	*	*		*						
AB1		*				*						
AB2												
Tributary sites upstream of discharge area (Leederville Aquifer dependant)												
RG1		*	*			*						
RG2												
RG3		*		*	*						*	*
MC1												
MC2		*	*	*		*						
SC1			*			*						
SJ1				*		*						
SJ2				*		*						
SJ3		*	*	*		*						
Total sites	5	20	12	14	4	16	6	5	7	1	2	9

The number of fish captured and the density recorded are presented in Appendix 2 and Appendix 3, respectively. Notably, the abundance of the Western Minnow, Western Hardyhead and Swan

River Goby increases in an upstream direction, suggesting that the salinised sections of the Blackwood River are more favourable for these species (Figure 5). Conversely, the density of the South-western Goby declined with distance from the river mouth. The introduced Eastern Mosquitofish showed no discernable trend in density, although this species is very tolerant of high salinities.

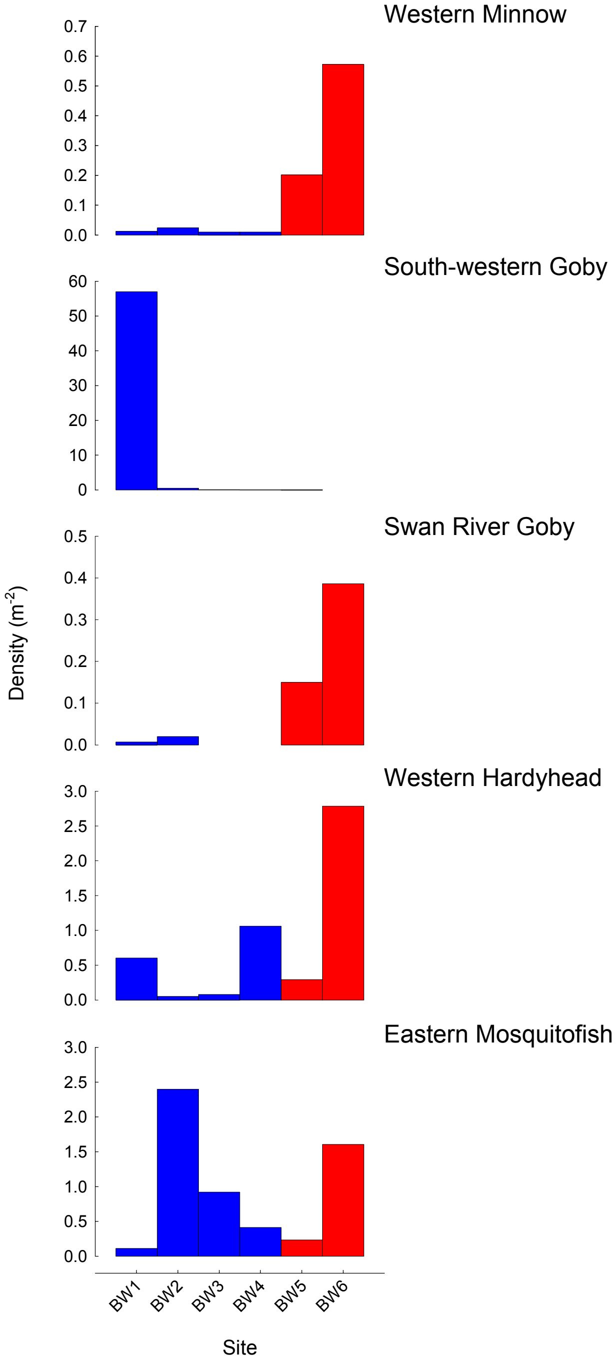

Figure 5 The density of the Western Minnow, South-western Goby, Swan River Goby, Western Hardyhead and Eastern Mosquitofish in the main channel of the Blackwood River. BW1-BW4 receive flows from the Yarragadee Aquifer, while the upstream BW5 and BW6 do not.

Fish in tributary sites

Compared to main channel sites, a number of fish species were absent from the tributary sites, with the exception of one site sampled at the mouth of Rosa Brook (Table 3). These included all of the estuarine species recorded during the study and the Freshwater Cobbler. Tributary sites sampled during April 2005, i.e. those that receive direct flow from the Yarragadee Aquifer (Poison Gully and Milyeannup Brook) and those that receive water from the Leederville Aquifer (Red Gully, McAfee Brook, Sturcke Creek and St John Brook) were dominated by endemic freshwater teleosts (Table 3, Appendix 1). However, while only three Eastern Mosquitofish were found in Yarragadee fed sites (MB2), 460 were found in Leederville dependant sites (RG3). Five Goldfish were also found in RG3.

The rare Balston's Pygmy Perch was essentially restricted to the two sites sampled in Milyeannup Brook (i.e. Yarragadee fed), which accounted for ~90% of captures of this species (Appendix 1), with only one individual being found in the Leederville dependant sites. The other rare species encountered during this study, i.e. the Mud Minnow, was well represented in the tributary sites but was never encountered in the main channel. While this species was found in both Poison Gully and Milyeannup Brook, within the Leederville dependant sites it was only found in one natural stream site in McAfee Brook (MC2). For example, at the sites RG1, SC1 and SJ3, they were only captured in waterpoints that were constructed as water reserves for fire fighting, i.e. these sites were dry other than the presence of waterpoints (see below).

Waterpoint sites in Red Gully (RG1), Sturcke Creek (SC1) and St John Brook (SJ3) provide a refuge in tributaries during summer.

Analysis of similarity (ANOSIM) between the fish fauna of the sites sampled

Both classification and ordination divide the sites sampled, based on fish species presence/absence, into a number of groups (Figure 6). The major split is between sites in the main channel and those tributary sites. The main channel sites are further divided depending on whether they received flow from the Yarragadee Aquifer or whether they are upstream of such flows. ANOSIM however, suggested that while there are obvious differences between the fish fauna of the sites in these respective regions of the main channel, these differences were not significant at the 5% level (p = 0.067) (Table 4). The division in these groups is due to the upstream main channel sites being dominated mostly by salt tolerant species such as, the Western Hardyhead, Swan River Goby, Western Minnow and the Eastern Mosquitofish, whereas the downstream main channel sites were additionally dominated by the above species but also a number of endemic freshwater fishes (Table 3).

There were significant differences in the fish fauna associated with both groups of main channel sites compared to each group of tributary sites, i.e. the Yarragadee fed tributaries of Poison Gully, Milyeannup Brook and Layman Brook; tributary sites downstream of the Yarragadee receiving environment (Rosa Brook and Adelaide Brook); and the upstream tributary sites that receive flows from the Leederville Aquifer (Red Gully, McAfee Brook, Sturcke Creek and St John Brook) (Table 4).

While both classification and ordination separated the different tributaries based on their prevailing fish fauna (Figure 6), these differences where not considered to be significant at the 5% level (Table 4). The main factor separating the Yarragadee tributaries in the dendrogram and MDS plots was the presence of Balston's Pygmy Perch is those sites (Figure 6)

Table 4 R-stat values for pairwise comparisons between the fish fauna found in: the main channel sites that receive flow from the Yarragadee Aquifer (BW-Y); main channel sites upstream of the Yarragadee Aquifer (BW); tributary sites that receive flow from the Yarragadee Aquifer (Yarragadee); tributary sites below the Yarragadee Aquifer (below Yarragadee); and the upstream tributaries that receive flows from the Leederville Aquifer (Leederville). Significant differences are represented by $^{*}p<0.05$, $^{**}p<0.01$.

SITE	BW-Y	BW	Yarragadee	Below Yarragadee
BW	0.786	-	-	-
Yarragadee	0.813^{**}	0.945^{*}	-	-
Below Yarragadee	0.675^{*}	0.782^{*}	-0.132	-
Leederville	0.644^{**}	0.841^{*}	-0.021	-0.058

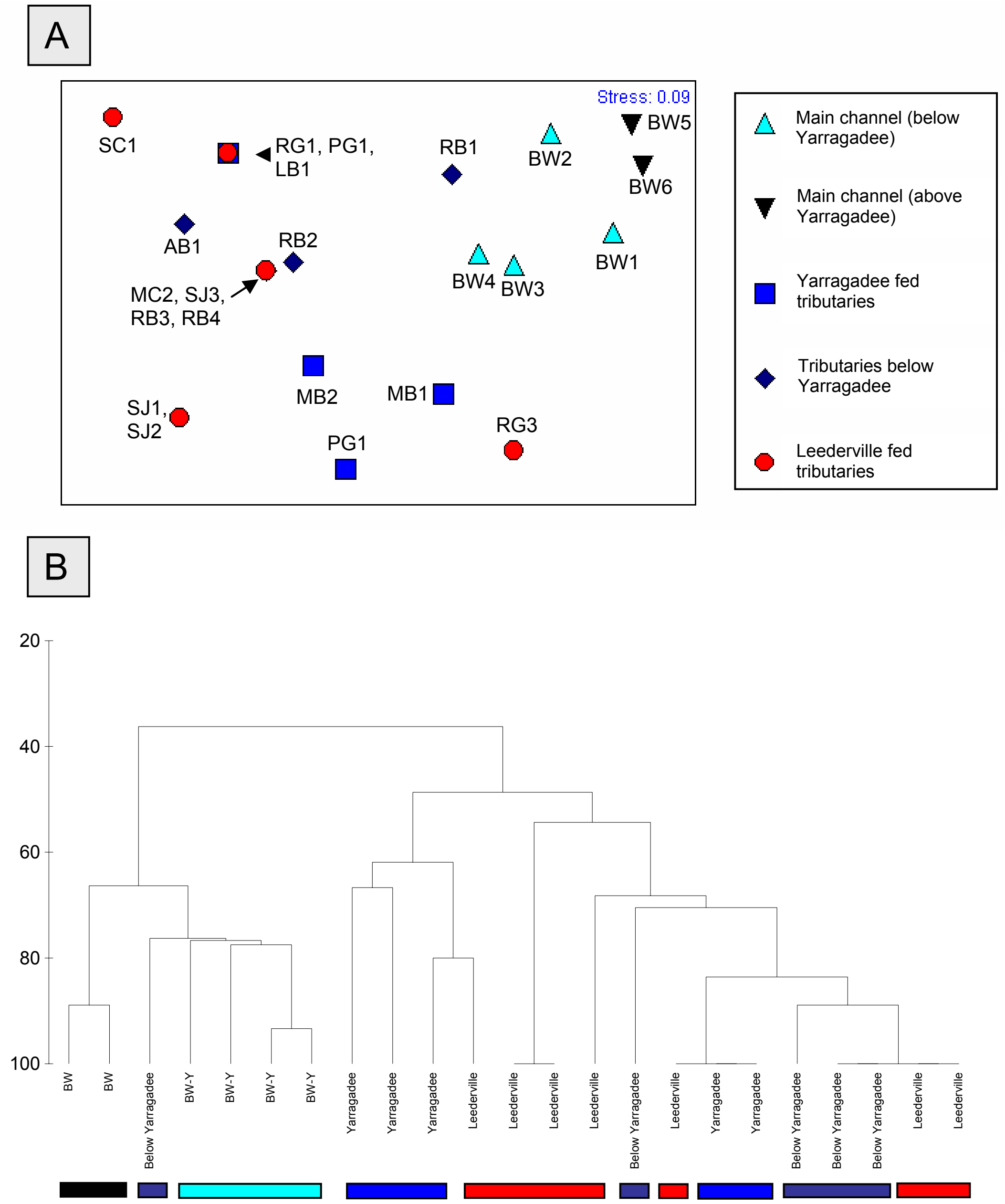

Figure 6 A) MDS plot (ordination) and B) dendrogram (classification), created using Primer, of the fish species associated with each site sampled in the Blackwood River and its tributaries during the study. BW-Y = main channel sites that receive Yarragadee discharge; BW = main channel sites upstream of discharge zone; Leederville = tributary sites that receive input from the Leederville Aquifer; Yarragadee = tributary sites that receive flow from the Yarragadee Aquifer; and, Below Yarragadee = tributary sites that lie downstream of the discharge zone.

Freshwater crayfish species captured

Freshwater crayfish were captured from 17 of the 19 sites sampled during April 2005. They were also recorded from all four sites sampled on Rosa Brook in October, 2003 by Morgan *et al.* (2004). Four of the six *Cherax* species endemic to south-western Western Australia were captured from 16 of those 17 sites during April 2005 (Table 5, Figure 7, Appendix 4). The introduced Yabbie (*C. destructor*) was also recorded from a single site, a waterpoint on Red

Gully (RG2) (Table 5). A total of four unidentifiable *Cherax* individuals (having intermediate morphological characteristics commonly used to differentiate between Gilgies (*C. quinquecarinatus*), Koonacs (*C. preissii*) and the restricted Gilgie (*C. crassimanus*) (Figure 7)) were recorded from three sites. Gilgies (*C. quinquecarinatus*) was the most common species captured (321 individuals in 16 sites, followed by *C. preissii* (190 individuals in 10 sites), *C. cainii* (65 individuals, 8 sites) and *C. crassimanus* (8 individuals, 4 sites).

The four Blackwood River sites downstream of the Yarragadee discharge zone (BW1-BW4) contained relatively large numbers of *C. cainii* with a total of 50 individuals (77% of total captured during the study) captured at all four sites. *Cherax quinquecarinatus* (54 individuals, 17% of total) were also present at all four of those sites with *C. preissii* (37 individuals, 19% of total) present at three sites and *C. crassimanus* only present at the Sues Rd site (BW2) (Table 5, Appendix 3). The two Blackwood River sites upstream of the Yarragadee discharge zone (BW5, BW6) contained relatively small numbers of *C. quinquecarinatus* at both sites and a single *C. cainii* was captured at BW6 (Table 5, Appendix 4).

The four tributary sites (two each within Poison Gully and Milyeannup Brook) within the Yarragadee discharge zone contained *C. quinquecarinatus* (65 individuals, 20% of total) (Table 5, Appendix 4). *Cherax preissii* was recorded at three of the four sites (55 individuals, 29% of total) with PG2 also containing *C. cainii* and *C. crassimanus* (i.e. housed all four endemic species recorded during the study).

The nine tributary sites (from four tributaries) upstream of the Yarragadee discharge area contained all four endemic crayfishes and also the introduced *C. destructor*. Three of the sites did not contain any crayfishes (i.e. SJ2, SJ3, and RG2) and RG2 (water point) was the site that *C. destructor* (35 individuals) was captured. The six sites that contained crayfish all housed *C. quinquecarinatus* (197 individuals, 61% of total) with *C. preissii* being recorded from four sites (98 individuals, 52% of total), *C. cainii* from two sites (12 individuals, 18% of total) and *C. crassimanus* from two sites (4 individuals, 50% of total) (Table 5, Appendix 4).

Figure 7 The species of freshwater crayfish captured in the different sites sampled in the Blackwood River and its tributaries. Photographs: D. Morgan

Table 5 The species of freshwater crayfish captured in the different sites sampled in the Blackwood River and its tributaries. *C. cainii* = Marron, *C. quinquecarinatus* = widespread Gilgie, *C. crassimanus* = restricted gilgie, *Cherax* sp. = an unidentified species, and *C. destructor* = the introduced Yabbie. N.B. [1]Records of freshwater crayfish were not made in Layman and Adelaide Brooks which were sampled prior to the current study.

	FRESHWATER CRAYFISH SPECIES CAPTURED					
			Endemic			Feral
SITE	*C. cainii*	*C. quinquecarinatus*	*C. crassimanus*	*C. preissii*	*Cherax* sp.	*C. destructor*
Main channel downstream of discharge						
BW1	*	*				
BW2	*	*	*	*		
BW3	*	*		*		
BW4	*	*		*		
Main channel upstream of discharge						
BW5		*			*	
BW6	*	*				
Tributary sites in discharge area						
PG1		*		*		
PG2	*	*	*	*	*	
MB1		*		*		
MB2		*				
LB1[1]						
LB2[1]						
Tributary sites downstream of discharge area						
RB1		*				
RB2	*	*	*			
RB3		*	*			
RB4		*				
AB1[1]						
AB2[1]						
Tributary sites upstream of discharge area (Leederville Aquifer dependant)						
RG1		*				
RG2						*
RG3		*	*	*		
MC1		*		*		
MC2	*	*	*	*	*	
SC1		*				
SJ1	*	*		*		
SJ2						
SJ3						
Total sites	9	20	7	8	5	1

Analysis of similarity (ANOSIM) between the freshwater crayfish fauna of the sites sampled

Based on both species presence/absence and abundance data, ANOSIM suggested that there was no significant difference between the freshwater crayfish fauna found in the different habitats sampled in the Blackwood River, the exception being between the section of main channel that receives flow from the Yarragadee Aquifer (BW1-4) and the tributaries immediately downstream of the Yarragadee output. However, sites SJ2 and SJ3 did not house freshwater crayfish (Group II in Figure 7, Table 5), while the waterpoint site RG2 was infested with the introduced Yabbie (Group I in Figure 7). Primer separated the sites, based on the presence/absence of freshwater crayfish, into four main groups, including the two listed above (Figure 7). Group III consists solely of those sites that only were inhabited by the Gilgie (*C. quinquecarinatus*) and one site on the main channel that also contained *Cherax* sp. Group IV contained the majority of sites, and divided sites based on either the presence of *C. preissii* and *C. quinquecarinatus* (PG1, MC1 and MB1), *C. cainii* and *C. quinquecarinatus* (BW1 and BW6) or through a combination of species occurrences (Figure 7).

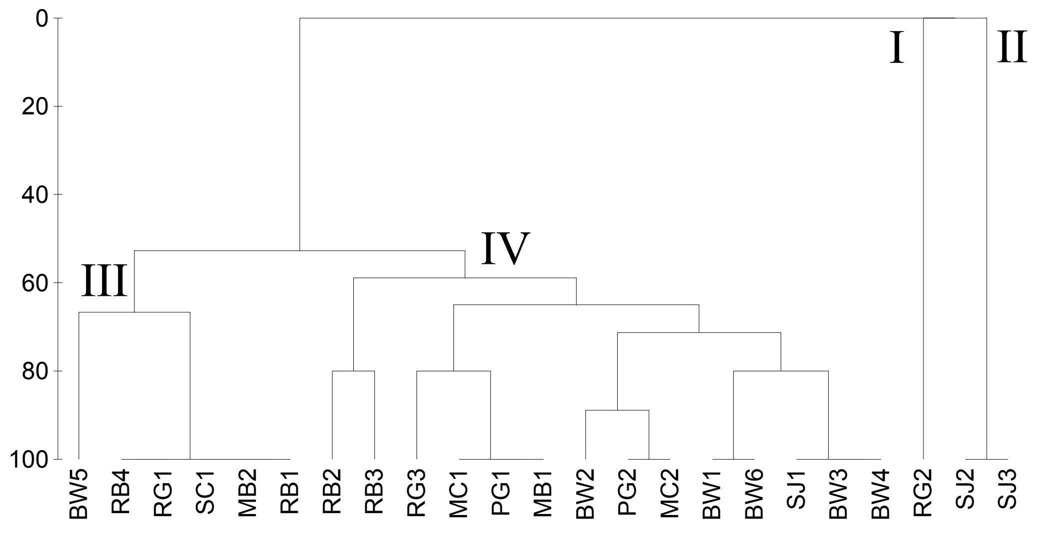

Figure 7 Classification of the freshwater crayfish fauna found in the sites sampled in the Blackwood River main channel and its tributaries.

Discussion

Significance of flows from the Yarragadee Aquifer on the fish fauna of the receiving environment

Salinisation

One of the greatest threats to freshwater habitats in south-western Western Australia is salinisation, and this is no more evident than in the Blackwood River, whereby over 85% of the catchment has been cleared (Morrissy 1974, Anon 1996, Morgan and Gill 2000, Beresford *et al*. 2001, Morgan *et al*. 2003). Morrissy (1974) and Nickoll and Horwitz (2000) attributed the decline of Marron in the upper Blackwood River to salinisation, while Morgan *et al*. (2003) demonstrated a relationship between salinisation and the prevailing fish fauna in the Blackwood. This latter study, which incorporated species occurrences for 151 sites throughout the catchment, found that there were highly significant (p<0.001) differences in the fish fauna associated with the different sections of the main channel compared to the forested tributaries. They also demonstrated, with the aid of historical Museum Records of species occurrences at the top of the catchment, that the range of the non-halotolerant endemic freshwater species in the river had been reduced substantially in the last few decades. Conversely, the upstream range of halotolerant species, such as the Western Hardyhead and Swan River Goby, had been extended considerably as a result of salinisation.

The fish fauna of the main channel of the Blackwood River that receive flows from the Yarragadee Aquifer is very different to that of the upstream sections river. For example, while the former sites host a range of endemic freshwater teleosts (Freshwater Cobbler, Western Minnow, Western Pygmy Perch and Nightfish), the upstream sections of the are dominated by one endemic freshwater species (Western Minnow), two estuarine species (Western Hardyhead and Swan River Goby) and the introduced Eastern Mosquitofish. The absence of most freshwater native species from the upper main channel of the Blackwood River is probably a result of their inability to tolerance the higher salinities experienced in much of the main channel and upper catchment (Morgan *et al*. 2003). There is little information with regard to salinity tolerances of south-western Australian native fishes. However, Western Pygmy Perch in the Blackwood have been recorded in conductivities up to 11.6 $mScm^{-1}$, while Nightfish, Mud Minnows and Freshwater Cobbler have been found in conductivities up to 8, 3 and 8.3 $mScm^{-1}$ (Morgan *et al*. 2003). In contrast, Western Minnows, Western Hardyheads and Mosquitofish have been recorded in salinities up 40, 68.7 and 37 $mScm^{-1}$, respectively in the river (Morgan *et al*. 2003). The above upper salinity levels of the different species need to be treated with caution, as larval fish (due to a greater surface area to volume ratio, the possession of undeveloped kidneys and skin and osmoregulatory ability) are generally not as tolerant to salt as adults (Hart *et al*. 1991). However, a reduction in output from the Yarragadee Aquifer that results in salinities within the study sites being >8 $mScm^{-1}$, may be detrimental to the freshwater species. Furthermore, many freshwater invertebrates are extremely sensitive to increases in salinity, and it is possible that invertebrates that are critical to specific fish developmental stages (e.g. newly hatched, preflexion or flexion larvae) may disappear at critical salinity levels (see Gill and Morgan 1996, Morgan *et al*. 2003).

Dissolved oxygen

Although a marked reduction in dissolved oxygen was recorded in the main channel and tributary sites in April 2005 compared to those recorded by CENRM (2005) in July 2004, all mean values were greater than 2 ppm, the threshold below which difficulties in fish respiration occurs (ANZECC/ARMCANZ, 2000). As noted by CENRM (2005), lower levels would be expected to occur in summer and therefore the dissolved oxygen should be determined diurnally during this period (at a greater number of sites) as part of future evaluation of the potential impact of reduction of the Yarragadee Aquifer discharge.

Rare fishes

Due to the salinised main channel of the Blackwood River and the cleared upper tributaries, CERM (2005) highlighted the importance of the forested tributaries in conserving genetic integrity of the region's endemic teleosts. However, they only captured the rare Balston's Pygmy Perch at one site in the Scott River, and the Mud Minnow was caught only in Rosa Brook. It is noteworthy that many of the tributaries surveyed during the current study April 2005, were not sampled in the study by Morgan *et al*. (2003). The report by CENRM (2005) also only lists these species from one locality, although there is some confusion as to their identification of the Mud Minnow, due to the difficulty in differentiating between it and the Black-stripe Minnow (*G. nigrostriata*).

Our study captured Balston's Pygmy Perch in four sites, two of which are fed directly by the Yarragadee Aquifer (Milyeannup Brook) (Table 3, Appendix 2 and 3). The population is substantially larger in Milyeannup Brook than in the two other sites where they were recorded (one individual at site BW3 and RG3), with the densities in Milyeannup Brook being between 15-30 fold greater than in the other sites. While ANOSIM did not suggest that the Yarragadee fed tributaries that we sampled were significantly different to adjacent tributaries, the presence of a robust population of Balston's Pygmy Perch in Milyeannup Brook is an important finding. As the species: has a one year life-cycle (Morgan *et al*. 1995), is only ever locally abundant and genuinely rare, is known from nowhere else in the Blackwood River, and requires a specialised diet of cladocerans when <25 mm TL before 'switching' to prey almost exclusively on terrestrial insects when >25 mm TL (Gill and Morgan 1996). They are therefore vulnerable to habitat modifications such as those that have led to a massive range reduction of the species (Morgan *et al*. 1998). Furthermore Balston's Pygmy Perch has been nominated as *Vulnerable* under the *EPBC Act 1999*, and is listed as a *Priority 1* on *CALM's List of Priority Fauna* (CALM 2005). As it is not known to what extent, if at all, Balston's Pygmy Perch utilises the main channel of the Blackwood River, for conservation purposes it should be assumed that they remain in the tributaries. Thus, reduction in flows and depths by reducing aquifer input to Milyeannup Brook may indeed be detrimental to the sustainability of this species in the Blackwood River catchment.

The Mud Minnow has also been nominated as *Vulnerable* under the *EPBC Act 1999* and is listed as a *Priority 4* species on *CALM's List of Priority Fauna* (CALM 2005) and, like Balston's Pygmy Perch it is small, has a one year life-cycle and a specialised diet (Pen *et al*. 1991). This species has undergone a considerable reduction in range, presumably in response to modification of habitats (salinisation, water regulation) and predation by introduced teleosts (Morgan *et al*. 1998, 2002). While previous studies have only reported its presence in the Blackwood catchment from Poison Gully (CENRM 2005) and Rosa Brook (Morgan *et al*. 2003), during this study we recorded them in Poison Gully, Milyeannup Brook, Red Gully, McAfee Brook, Sturcke Creek and St John Brook (Table 3, Appendix 1 and 2). However, the importance of the perennial Yarragadee fed tributaries and Rosa Brook as critical habitats for the species is highlighted when considering that, with the exception of their capture in McAfee Brook (site MC2), all other sites that they were captured in are artificial environs (i.e. waterpoints – see Figure 5). These artificial environments are purposefully built to be drained during fire fighting. Furthermore, there was a high percentage (~33%) of spinal deformity of Mud Minnows at one of these sites (RG1), suggesting that this population may be inbreeding within a small gene pool (see Tave 1986, Thorburn and Morgan 2004).

The restriction of both Balston's Pygmy Perch and the Mud Minnow to tributaries, rather than the main channel, together with a high proportion of inbreeding in at least one population of Mud Minnows, may suggest that the different tributary populations of these species are reproductively isolated. Their isolation into tributaries may be driven by either ecological requirements or the higher salinities in the main channel, coupled with the presence of large nocturnal predators (e.g. Marron, Freshwater Cobbler) that persist within the main channel. Conversely, it may be freshwater input from the Yarragadee and Leederville Aquifers that reduce salinities in the main channel in this part of the river that allows them to survive in the tributaries. Any reduction of flows and depth in Poison Gully and Milyeannup Brook (generally 10-20 cm deep during April 2005) may impact on these important populations.

Aestivating fishes and a reduction in water tables

Other issues include ecological events that can not be ascertained without ongoing monitoring include the importance and availability of the tributaries to seasonal migrations of species. Further, groundwater is important in maintaining aestivating species such as the Salamanderfish, Black-stripe Minnow and burrowing crayfishes (see below) over summer. These species seldom live in permanent waters but complete their life cycle in temporary systems. The aestivation period of the Salamanderfish and Black-stripe Minnow can last up to five or six months, with the former species burrowing to depths of 2-60 cm (Berra and Allen 1989, Pusey 1989, Morgan *et al*. 2000). It is imperative that water tables are not lowered during their annual aestivation phase to the point that the soil in their pools dries beyond the level that is required for maintaining the populations of these species. Their distribution within the Blackwood catchment is restricted (Morgan *et al*. 2003) and although they were not captured during this study, they are best located when their habitat is inundated.

Genetics

Recent research has revealed that there is considerable genetic divergence between populations of Western Pygmy Perch (Unmack *et al*. in prep.). These authors found that at a genetic level, there is 25% fixed difference between the Canning River and Gardner River populations, and on that basis have separated these populations into different species. However, they only examined a few river systems and have not provided morphological characters to differentiate these separate species. Accepting these findings without a morphological key presents a conundrum as to which species inhabits the Blackwood River. Furthermore, are there similar levels of genetic divergence between the 'species' in other systems, i.e. does the Blackwood River harbour a distinct component of within species genetic diversity or even a distinct species of Western Pygmy Perch, and for that matter other native fishes? The above mentioned study was the first to examine the intraspecific genetic diversity of any of the Western Pygmy Perch populations and it is likely (as with the freshwater crayfish of the region) that considerable diversity exists between populations of other species. Therefore, in the absence of such data, the conservation of these species should be on a catchment scale.

Recreational fishing

Within the study area Freshwater Cobbler and Marron are the main species targeted. While the study area incorporates ~8% of all Marron fishing in the south-west of Western Australia (see below) (Molony and Bird 1999), ~10% of all freshwater angling during 2002/3 occurred in the Blackwood River (Molony *et al*. unpublished Western Australian Fisheries Document 1). In 2002/3, Freshwater Cobbler contributed to ~9% of freshwater species caught. Greater recreational fin-fishing effort is likely to occur in the lower Blackwood River from the lower estuary up to Alexander Bridge, where species such as Black Bream are targeted. During this study Black Bream were found as far upstream as site BW1 (Great North Road crossing) (see Appendix 2). While decreased inflow from the Yarragadee Aquifer has the potential to reduce the abundances of recreational fish and freshwater crayfish in the study area, the influence on the estuarine fisheries is unknown. Reduced flows however may reduce the ability of species such as Black Bream to move upstream over obstacles when water levels fall.

Freshwater Crayfish

Distribution and abundance of freshwater crayfishes in the study area

The study area was found to contain four of the six *Cherax* species endemic to Western Australia (Figure 8). It is also likely to contain at least one (i.e. *E. similes*) of the five species of *Engaewa* restricted to the south-west corner of the State (Horwitz and Adams 2000).

All groups of Blackwood River and tributary sites within, upstream and downstream of the Yarragadee discharge zone were generally dominated by *C. quinquecarinatus* (Table 5, Appendix 4). This dominance, coupled with the relatively low number of freshwater crayfish taxa present, resulted in multivariate analysis only finding significant differences between the Blackwood River sites downstream of the Yarragadee discharge zone and those tributary sites downstream of the zone. The tributary sites as a whole had the greatest abundance and density of crayfishes compared with the Blackwood River sites due to large numbers of *C.*

quinquecarinatus, and also considerable numbers of *C. preissii* at a number of sites within and upstream of the Yarragadee discharge zone (although they were also present at downstream main channel sites) (Table 5).

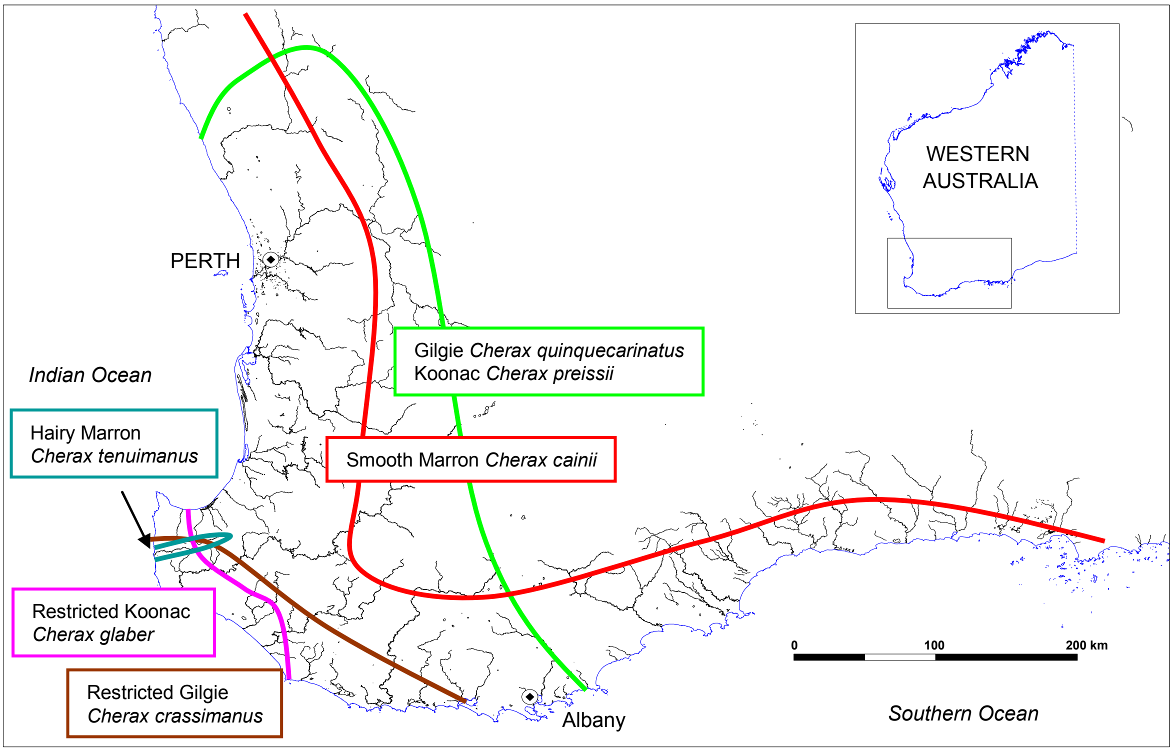

Figure 8 The approximate distribution of the six endemic *Cherax* spp. in Western Australia. N.B. the *C. cainii* distribution includes translocations. (Riek 1967, Austin and Knott 1996, Beatty and Morgan unpublished data).

The Blackwood River sites receiving downstream input from the Yarragadee discharge had greater species diversity (four versus two species - with one specimen unidentifiable from the upstream sites) and abundance of crayfishes than those not receiving input. Furthermore, 50 of the 66 (75%) Marron captured during the study were captured in Blackwood River sites downstream of the Yarragadee Aquifer discharge zone. This reflects the fact that it is a relatively large species and is generally found in larger permanent waterbodies throughout its range and, unlike the other three burrowing species recorded here, does not burrow to escape drought and therefore is generally less abundant or absent in smaller tributaries (Riek 1967, Austin and Knott 1996).

Smooth Marron is known to have an approximate upstream distribution in the Blackwood River as far as Boyup Brook, some 100 km downstream of the estimated pre-European distribution

(Morrissy 1978, Nickoll and Horwitz 2000). This reduction is likely due to deoxygenation of bottom water during summer (Morrissy 1978), salinisation, eutrophication or synergistic effects of all of these factors (Nickoll and Horwitz 2000, Molony *et al.* unpublished Western Australian Fisheries Document 2). The upper lethal salinity tolerance of Marron is 17ppt (Morrissy 1978); a level that is not recorded in the Blackwood River until upstream of Boyup Brook (Morgan *et al.* 2003). However, Nickoll and Horwitz (2000) also noted that the role of salinisation of the water on the decline of Marron needed further investigation, particularly with regard to reproduction and thus sustainability of wild populations. The input of fresh water from the Yarragadee Aquifer may have contributed to the greater abundances recorded downstream in the current study (see below).

There were no clear differences in the freshwater crayfish faunas of the tributary sites upstream, within and downstream of the Yarragadee discharge zone (Table 5). The ability of *C. quinquecarinatus*, *C. preissii* and *C. crassimanus* to survive in permanent and temporary systems (Austin and Knott 1996) would have resulted in this relative uniformity of distribution. However, it is necessary to resample these systems during elevated water levels to better ascertain the distributions abundances of these burrowing species when crayfish exit their burrows into seasonal surface flows as differences may exist depending on the hydrology of the various streams (i.e. length of flow period and the distance upstream of permanent).

Significance of the freshwater crayfishes in the study area and potential impact of groundwater extraction

Marron C. cainii

The Blackwood River receives more recreational Marron fishing effort (~22%) than any other river (Molony and Bird 1999, Molony pers. comm.). A large proportion of this effort (~35% in 1999) occurs downstream of Nannup, i.e. within the study area. This fishery has been in decline for the last decade due to habitat change, hydrological change and introduced teleosts (Molony *et al.* 2002). A study to determine the causes for this decline is underway and preliminary results indicate that rainfall and river discharge account for the majority of the variation in catches (Molony *et al.* unpublished data).

Being able to consume a wide variety of food items, Marron are known to be a keystone member of aquatic systems and have the potential to structure benthic communities (Beatty 2005). They have also been described as fulfilling the appropriate criteria to be regarded as a flagship species for use in river restoration projects (Nickoll and Horwitz 2000). The latter study, that used the middle catchment of the Blackwood River as a case study, found the Blackwood community regards the Marron as the most appropriate biotic symbol of the Blackwood River (Nickoll and Horwitz 2000).

Therefore, it is of utmost importance to assess the potential impacts on the Marron population of the Blackwood River that the proposed Yarragadee groundwater extraction will have. More intensive, standardised sampling (including an assessment of their biology, i.e. percentage berried, spawning period) (see Beatty *et al.* 2003, 2004) of Marron upstream, within and downstream of the Yarragadee groundwater discharge zone should occur seasonally in order to determine the degree to which the Yarragadee freshwater input contributes to the sustainability of the Marron population downstream.

Other Cherax species

Cherax quinquecarinatus has a life-history strategy that allows it to occupy almost the full range of permanent and temporary aquatic systems of the region (Austin and Knott 1996, Beatty *et al.* 2005). This ability to occupy a diverse range of environments (from irrigation drains and seasonal wetlands, to deep rivers), was reflected in its wide distribution in the sites sampled in the Blackwood catchment in the present study. This species is known to have a high degree of intraspecific electrophoretic and morphological intraspecific variation between populations throughout its natural range.

Cherax preissii and *C. crassimanus* also exploit full range of habitats, however, generally regarded as burrowing species and found in streams and swamps that dry in summer (Austin and Knott 1996). Morphological variation relating to habitat type exists within all three of these species. Those populations occupying temporary environments often display morphological characteristics more similar to *C. glaber* (a strictly burrowing species) and those in permanent waterbodies more resemble small Marron (e.g. more distinct carina on their cephalon, narrower claws). These habitat-mediated morphological variations are of similar scale to those variations often recorded between species (Austin and Knott 1996). Thus, identification of these species becomes difficult due this variability in morphology, particularly with small individuals <~15 mm orbital carapace length OCL). This difficulty was also noted by CERNM (2005).

More geographic sampling of these species is required to adequately understand this intraspecific genetic and morphological variability (Austin and Knott 1996). Therefore, although not specifically threatened on species levels (although *C. crassimanus* has the potential to be due to its relatively restricted distribution and low local abundance), catchment scale conservation of *C. quinquecarinatus*, *C. preissii* and *C. crassimanus* is important to protect their considerable intraspecific diversity.

The importance of conserving intraspecific variation of freshwater crayfish has recently been highlighted in the case of Hairy Marron (*Cherax tenuimanus*) from Margaret River. The widespread form of Marron *C. cainii* (recorded in the current study) has only recently been described (previously known as *C. tenuimanus*) as a recent study (Austin and Ryan 2002) considered that the small population of Hairy Marron from Margaret River was distinct from other populations in south-western Australia. As *C. tenuimanus* was originally described from that river, they proposed that *C. tenuimanus* should refer to the species in that system, and proposed the new name *C. cainii* for the more widespread form. The Hairy Marron is *Critically Endangered* as its abundance within the Margaret River has been severely reduced due largely to competition by the Smooth Marron, which was introduced into the river in the 1980s (Bunn 2004).

The potential reduction in flows in those tributaries receiving Yarragadee groundwater input (i.e. Poison Gully, Milyeannup Brook and Layman Brook) may significantly impact on the populations of *C. quinquecarinatus*, *C. preissii* and *C. crassimanus*. Depending on the degree of water table fall, the extraction may result in a reduction or elimination of these species from these tributaries. Although these species are known to be able to escape drought, if the reduction in water table results in the complete drying of the streams in summer, the populations in those streams may not be locally adapted to such a drying regime and thus population decline or extinction could occur. Should the extraction result in lowering of the water table to a depth greater than the burrowing capability of these species, then (as may occur with the aestivating Salamanderfish and Black-Stripe Minnow) those populations will not survive in affected tributaries.

Further, more rigorous seasonal sampling of these crayfish species should occur seasonally to fully ascertain their distribution and reliance on these tributaries.

Burrowing crayfishes <u>Engaewa</u>

The present study did not record any of these species, however, the sampling was focussed on surface waters. The five obligate burrowing species of *Engaewa* have a relatively restricted distribution in the south-western corner of Western Australia (Figure 9).

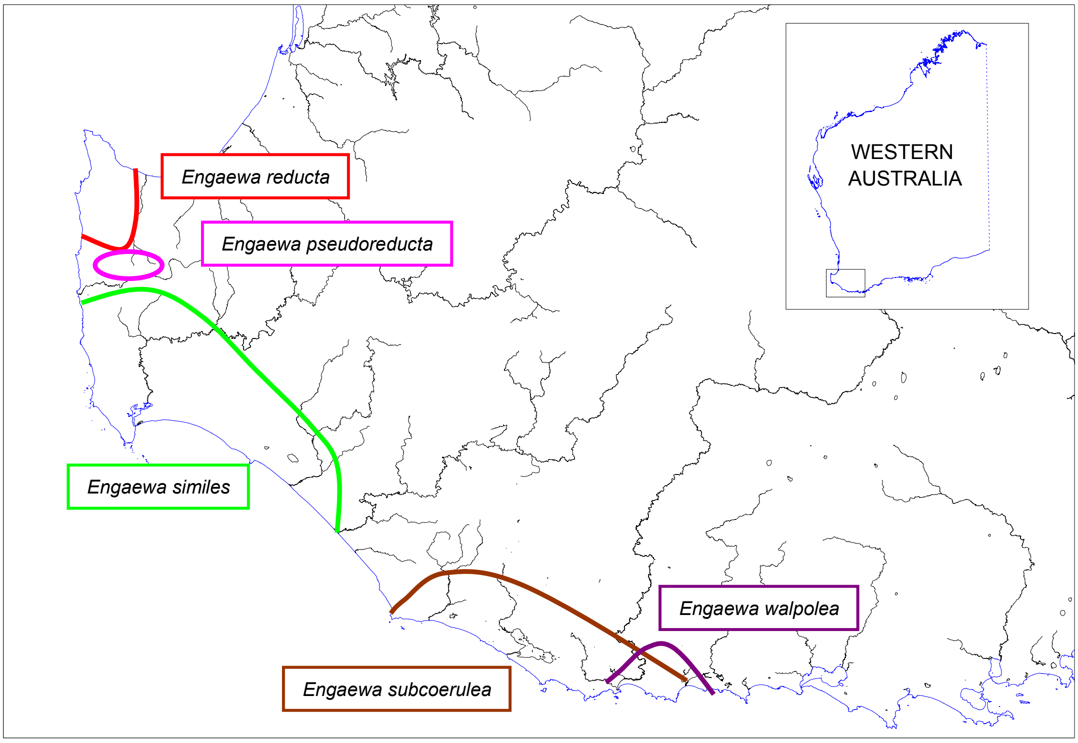

Figure 9 The approximate distribution of the five *Engaewa* species in south-western Western Australia (Riek 1967, Horwitz and Adams 2000).

Little is known of the life-history or ecology of any of the *Engaewa* species with two only recently being described (Horwitz and Adams 2000). Three of the species belong to the *Engaewa reducta* complex, (i.e. *E. reducta, E. pseudoreducta* and *E. similes*). *Engaewa similes* is known to occur within the Blackwood catchment (Figure 9, Horwitz and Adams 2000). The complex is generally found in sandy, loamy soils in heathlands where the water table never reaches the surface and burrow to depths of between 0.3-2m (Horwitz and Adams 2000). They are often found with *C. quinquecarinatus* and *C. glaber* throughout their range (Figures 8 and 9). *Engaewa subcoerulea* are known to burrow up to 1 m depth (Horwitz and Adams 2000) and *C. crassimanus* and *C. preissii* have been found amongst the burrow systems (Horwitz and Adams 2000). *Engaewa walpolea* has an extremely limited distribution in the Walpole region. Although relatively little is known on the degree of reliance of *Engaewa* species to groundwater, it is likely to be of great importance to the survival of populations of these species.

Engaewa similes was listed as Endangered in the IUCN Red List of Threatened Animals. However, Horwitz and Adams (2000) reviewed this classification and found the identification to be erroneous, and found the species should have been called *E. reducta* and further proposed that three of the five species of *Engaewa*, i.e. *E. reducta*, *E. pseudoreducta* and *E. walpolea*, fulfil the IUCN criteria to be listed as *Endangered*, *Critically Endangered* and *Vulnerable*, respectively.

There should be a rigorous examination of the *Engaewa* spp. within the Yarragadee Aquifer zone in order to assess the potential impact of groundwater extraction on these species (likely to be *E. similes*). This study should involve locating and excavating *Engaewa* burrows in the zone in order to determine the distribution and burrow depths of the species, allowing an assessment of the potential impact that the lowering of the water table may have on these crayfish.

Conclusions and Recommendations

CONCLUSIONS

- There was a significant difference between the fish fauna associated with the Blackwood River main channel sites when compared to its tributaries in the study area and there were substantial differences in the fauna of the downstream and upstream main channel sites.

- Main channel sites downstream of the Yarragadee Aquifer discharge area had a much higher diversity of fish and freshwater crayfish than main channel sites upstream of the discharge area.

- The four species of fish in the main channel in the upper riverine part of the study area are known to be halotolerant, whereas most of the additional species present in the sites in the lower section of the river tolerate only low salinities.

- The tributaries that receive direct flows from the Yarragadee Aquifer, i.e. Milyeannup Brook and Poison Gully, provide important refuges for the rare Balston's Pygmy Perch and Mud Minnow. Ninety percent of all Balston's Pygmy Perch were found in Milyeannup Brook and with the exception of one site in the tributaries upstream of the Yarragadee discharge (Leederville Aquifer sites), all Mud Minnows were only found in excavated waterpoints.

- Extraction of Yarragadee Aquifer groundwater and potential subsequent lowering of the water table has the potential to reduce surface water in

Milyeannup Brook and Poison Gully and may lead to the elimination of Balston's Pygmy Perch from the Blackwood River.

- Lowering of water tables may impact aestivating fish and freshwater crayfish.

- Reduction of Yarragadee flow into the Blackwood River has the potential to negatively impact recreational fisheries, such as the Marron and Freshwater Cobbler fisheries.

- Reduced inflow of Yarragadee water could potentially lead to an increase in salinity of this part of the river and may be intolerable to a number of freshwater species.

RECOMMENDATIONS

- Seasonal sampling should occur at the sites assessed in the current study to fully determine the importance of the Yarragadee groundwater input to the maintenance of the native fish populations in those systems. This should include an examination of fish migrations into the various tributaries and particularly ascertain the degree of importance of the Yarragadee-fed tributaries to the sustainability of populations of the rare Mud Minnow and Balston's Pygmy Perch.

- Rigorous sampling should occur during winter in the tributary sites sampled in the current study and seasonally inundated wetlands to determine the distribution of the aestivating fish species (Salamanderfish and Black-stripe Minnow) and an assessment be made of the potential impact on these populations of lowered groundwater resulting from extraction from the Yarragadee Aquifer.

- An assessment should be made of the importance of the Yarragadee freshwater input to the sustainability of the Marron population downstream. Intensive, standardised sampling of Marron upstream, within and downstream of the Yarragadee groundwater discharge zone should occur seasonally to determine whether differences in the biology of the species exists between these zones.

- Rigorous, seasonal sampling of *Cherax* species should occur within the sites in the current study to fully ascertain their dependence on the Yarragadee groundwater level and discharge and the potential impacts that a reduction in those groundwater levels and discharge would have on those populations.

- There should be a rigorous examination of the distribution and burrow depths of *Engaewa* spp. (likely to be *E. similes*) within the Yarragadee Aquifer zone in order to assess the potential impact of lowered groundwater may have on these animals.

- Molecular and morphological studies of the freshwater fish and crayfish fauna are required to ascertain the degree of genetic and morphological differences between those in the Blackwood River and adjacent catchments.

Acknowledgements

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Appendices

Appendix 1 The total number of each species of fish captured in the different sites sampled in the Blackwood River and its tributaries. *Tb* = *Tandanus bostocki*, *Go* = *Galaxias occidentalis*, *Gm* = *Galaxiella munda*, *Ev* = *Edelia vittata*, *Nb* = *Nannatherina balstoni*, *Bp* = *Bostockia porosa*, *As* = *Afurcagobius suppositus*, *Po* = *Pseudogobius olorum*, *Lw* = *Leptatherina wallacei*, *Ca* = *Carassius auratus* and *Gh* = *Gambusia holbrooki*. ^*Oncorhychus mykiss* was also captured at RB1 but were fish that were stocked by the Department of Fisheries WA. Total numbers were only generated for the sites sampled during this study.

FISH SPECIES CAPTURED												
	Endemic freshwater fishes						Estuarine fishes				Ferals	
SITE	*Tb*	*Go*	*Gm*	*Ev*	*Nb*	*Bp*	*As*	*Po*	*Lw*	*Ab*	*Ca*	*Gh*
Main channel downstream of discharge												
BW1	4	4		3			171	2	181	16		34
BW2	1	12				2	250	10	25		1	1200
BW3	6	4		6	1	6	33		31			357
BW4	1	4		1		1	24		425			165
Main channel upstream of discharge												
BW5		121					13	89	176			139
BW6		83						56	404			233
Tributary sites in discharge area												
PG1		8		14								
PG2		5	5			2						
MB1		13	3	5	10							3
MB2		20		3	6	10						
LB1			*									
LB2												
Tributary sites downstream of discharge area												
RB1^		*	*	*		*	*	*	*			*
RB2	*	*	*	*		*						
RB3		*	*	*		*						
RB4		*	*	*		*						
AB1		*				*						
AB2												
Tributary sites upstream of discharge area (Leederville Aquifer dependant)												
RG1		10	65			1						
RG2												
RG3		3		1	1						5	460
MC1												
MC2		3	3	42		4						
SC1			2			37						
SJ1				25		2						
SJ2				107		2						
SJ3		9	23	43		61						
Total number	12	299	101	250	18	128	491	157	1242	16	6	2604

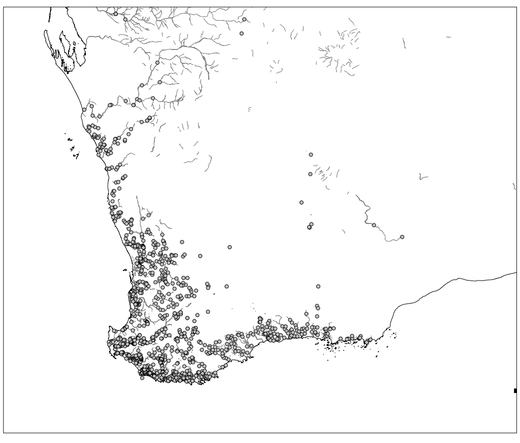
Appendix 2 The abundance (m^{-2}) of each species of fish captured in the different sites sampled in the Blackwood River and its tributaries. *Tb* = *Tandanus bostocki*, *Go* = *Galaxias occidentalis*, *Gm* = *Galaxiella munda*, *Ev* = *Edelia vittata*, *Nb* = *Nannatherina balstoni*, *Bp* = *Bostockia porosa*, *As* = *Afurcagobius suppositus*, *Po* = *Pseudogobius olorum*, *Lw* = *Leptatherina wallacei*, *Ca* = *Carassius auratus* and *Gh* = *Gambusia holbrooki*. Abundances were only generated for the sites sampled during this study.

FISH SPECIES CAPTURED												
	Endemic freshwater fishes						Estuarine fishes				Ferals	
SITE	*Tb*	*Go*	*Gm*	*Ev*	*Nb*	*Bp*	*As*	*Po*	*Lw*	*Ab*	*Ca*	*Gh*
Main channel downstream of discharge												
BW1	0.013	0.013		0.01			057	0.007	0.603	0.053		0.113
BW2	0.002	0.024				0.004	0.5	0.02	0.05		0.002	2.4
BW3	0.015	0.01		0.015	0.003	0.015	0.085		0.08			0.92
BW4	0.002	0.01		0.002		0.002	0.06		1.062			0.412
Main channel upstream of discharge												
BW5		0.202					0.022	0.15	0.293			0.232
BW6		0.572						0.386	2.786			1.607
Tributary sites in discharge area												
PG1		0.08		0.14								
PG2		0.053	0.053			0.021						
MB1		0.13	0.03	0.05	0.10							0.03
MB2		0.267		0.04	0.08	0.133						
LB1			*									
LB2												
Tributary sites downstream of discharge area												
RB1^		*	*	*		*	*	*	*			*
RB2	*	*	*	*		*						
RB3		*	*	*		*						
RB4		*	*	*		*						
AB1		*				*						
AB2												
Tributary sites upstream of discharge area (Leederville Aquifer dependant)												
RG1		0.333	2.167			0.033						
RG2												
RG3		0.019		0.006	0.006						0.031	2.875
MC1												
MC2		0.012	0.012	0.175		0.017						
SC1			0.04			0.74						
SJ1				0.25		0.02						
SJ2				1.07		0.02						
SJ3		0.3	0.767	1.433		2.033						
Total number	12	299	101	250	18	128	491	157	1242	16	6	2604

Appendix 3 – Fish species synopsis

Ten native species of freshwater fish are found within south-western Western Australia, of which eight are endemic. The eight endemic species include: the enigmatic Salamanderfish (*Lepidogalaxias salamandroides*), which is the sole member of the Lepidogalaxiidae; three species of the Galaxiidae (galaxiids), the Western Minnow (*Galaxias occidentalis*), the Mud Minnow (*Galaxiella munda*) and the Black-stripe Minnow (*Galaxiella nigrostriata*); three species of the Percichthyidae (Australian cods, basses and pygmy perches), the Western Pygmy Perch (*Edelia vittata*), Balston's Pygmy Perch (*Nannatherina balstoni*) and the Nightfish (*Bostockia porosa*); and one member of the Plotosidae (eel tailed catfishes), the Freshwater Cobbler (*Tandanus bostocki*). A further two galaxiids, the Trout Minnow (*Galaxias truttaceus*) and the Common Jollytail (*Galaxias maculatus*) are also found within the south-west, but both also occur in south-eastern Australia. A number of estuarine fishes are also often encountered in south-western Western Australian rivers and lakes, some of which occur hundreds of kilometres inland. For example, the Swan River Goby (*Pseudogobius olorum*), the South-western or Big-headed Goby (*Afurcagobius suppositus*) and Western Hardyhead (*Leptatherina wallacei*) are commonly found in salt-affected waters while Black Bream (*Acanthopagrus butcheri*), Yellow-tail Trumpeter (*Amniataba caudavittata*) and Sea Mullet (*Mugil cephalus*) will also move into freshwaters.

The distribution of fishes outlined in this report is from over a decade of fish monitoring by the Centre for Fish & Fisheries Research at Murdoch University. The distribution maps provided in this report represent species occurrences at over 1000 sites in the south-west of Western Australia (see below).

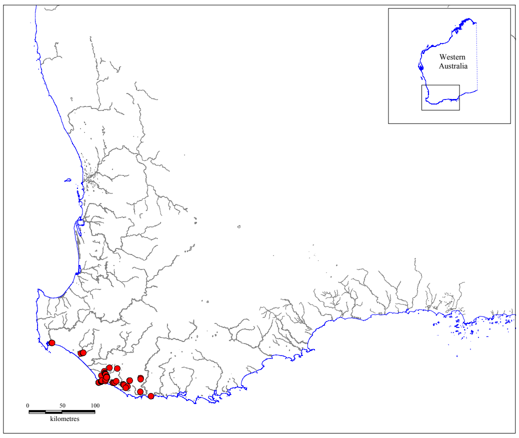


The sites sampled for freshwater fish in south-western Australia
by the Centre for Fish & Fisheries Research.

Salamanderfish *Lepidogalaxias salamandroides*

The Salamanderfish is known from the south coast between Augusta and Albany, and with the exception of an outlying population north of Margaret River (from the Western Australian Museum records), the species is not known from anywhere else. While not captured during this study, within the Blackwood River catchment they are known from pools on the Scott River floodplain (see below). Salamanderfish are generally only known from ephemeral pools throughout their range, however they have been captured in the Walpole River and a number of small streams between Walpole and Windy Harbour. The species aestivates when their habitats become dry each year. Thus, any reduction in water tables may impact on this species during their aestivation phase

Further reading: Berra & Allen (1989), Pusey (1989), Morgan *et al*. (2000), Gill & Morgan (2003)

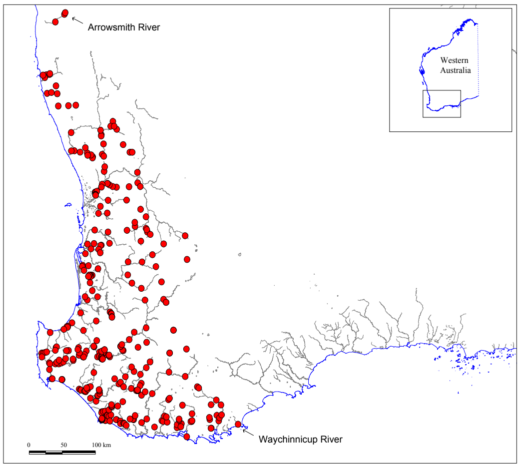


Distribution of the Salamanderfish.

Western Minnow *Galaxias occidentalis*

The Western Minnow is widespread in south-western Western Australia and is known from the Arrowsmith River in the north to the Waychinnicup River in the south-east. This species is found in all the major rivers of the region excluding the Goodga and Angove Rivers surrounding Two People's Bay. Maximum size 170 mm TL. Western Minnows occur in all habitat types including small streams, lakes and floodwaters and have a diet that consists largely of terrestrial insects. They migrate on mass in late winter and spring to spawn and often become accumulated below weirs or other barriers.

Further reading: Pen & Potter (1991a, 1991b), Morgan *et al*. (1998).

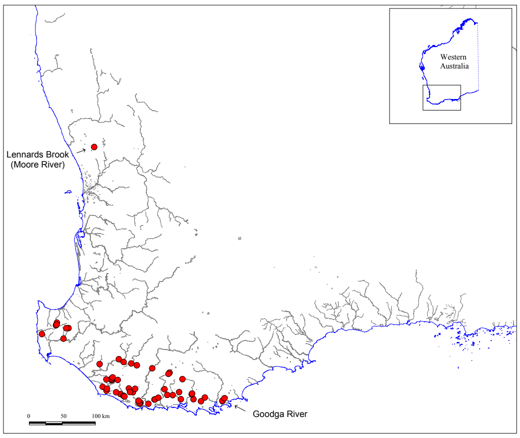


Distribution of the Western Minnow.

Mud Minnow *Galaxiella munda*

The Mud Minnow is a species that is currently restricted to a small tributary on the Moore River, one small pool on the upper Vasse River, the upstream section of the Margaret River, a number of sites between the Warren and Goodga Rivers, and within the Blackwood River it is only known from the sites that it was captured in during this study, with the unnatural salinisation of the system likely resulting in their elimination from most tributaries. The Western Australian Museum also has records of this species from the Donnelly River. They have apparently been lost from all rivers between the Moore River and the Vasse River as a result of land degradation and dewatering of habitats, compounded by the presence of feral fishes. Maximum size 60 mm TL. Mud Minnows are generally restricted to headwater streams where they are usually found in low numbers. Live for only 1 year and feed on terrestrial insects. They are vulnerable to habitat degradation primarily as they only live for one year, can't tolerate high salinities and are generally confined to headwater streams, rather than the main channel.

Further reading: Pen *et al*. (1991), Morgan *et al*. (1998, 2002, 2003),.

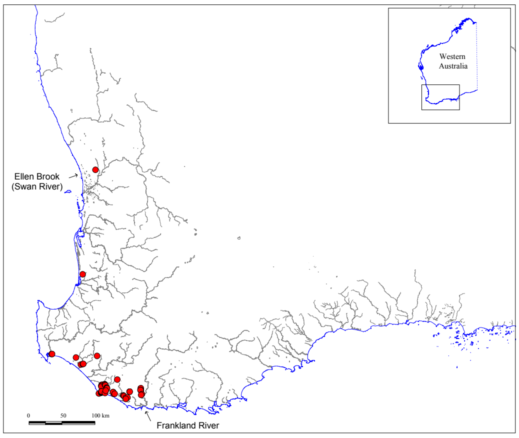


Distribution of the Mud Minnow.

Black-stripe Minnow *Galaxiella nigrostriata*

The distribution of the Black-stripe Minnow is severely fragmented, with isolated populations found in one small wetland adjoining Ellen Brook and one small wetland near the Wellesley River. The centre of the distribution is between Augusta and Walpole. They have presumably been lost from all rivers between the Swan River and the Blackwood River as a result of land degradation (salinisation, eutrophication) and dewatering of habitats, compounded by the presence of feral fishes. Similar to the Salamanderfish, within the Blackwood catchment they are only known from the ephemeral pools on the Scott River plain. Black-stripe Minnows are generally restricted to ephemeral pools where they survive dry periods by burrowing into the substrate. Live for only 1 year and feed on terrestrial insects.

Further reading: Pen *et al*. (1993), Morgan *et al*. (1998), Gill & Morgan (2003).

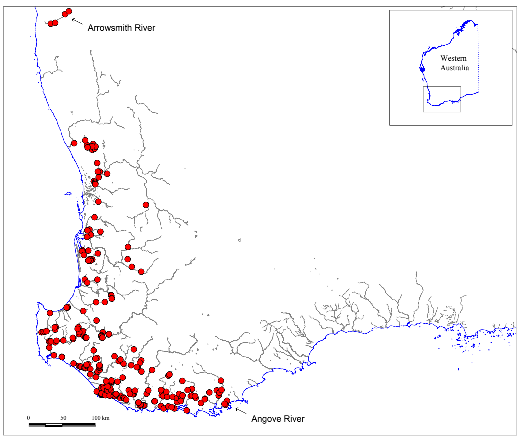


Distribution of the Black-stripe Minnow.

Western Pygmy Perch *Edelia vittata*

The Western Pygmy Perch is widespread throughout south-western Australia, being found from the Arrowsmith River in the north to the Angove River in the south-east. Its absence from the main channel of some of the region's larger salt-affected rivers (e.g. Swan-Avon, Blackwood, Moore) suggests a relatively low tolerance to dissolved salts. They are also susceptible to *Gambusia* attack. Maximum size 70 mm TL. Occur in lakes, rivers and floodplains generally associated with slower moving waters that comprise complex instream habitat. Spawn in spring and live for up to five years.

Further reading: Pen & Potter (1991c), Morgan *et al*. (1998).

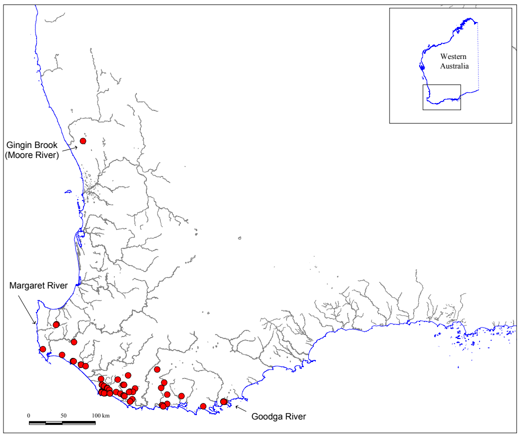


Distribution of the Western Pygmy Perch.

Balston's Pygmy Perch *Nannatherina balstoni*

Balston's Pygmy Perch is rare, and is restricted to small streams and lakes between the upper Margaret River and the Goodga River where it is very uncommon. Within the Blackwood River they are only known from the sites that they were captured in during this study. A sample exists in the Western Australian Museum from Gingin Brook, but recent survey work suggests that the species has been lost from this region. It has also presumably been lost from rivers between the Margaret and Moore. Maximum size 90 mm TL. Occur in very low numbers in lakes, rivers and floodplains generally associated with slower moving waters that comprise complex instream habitat. Spawn in spring and live for up to five years.

Further reading: Morgan *et al*. (1995, 1998), Gill & Morgan (1998).

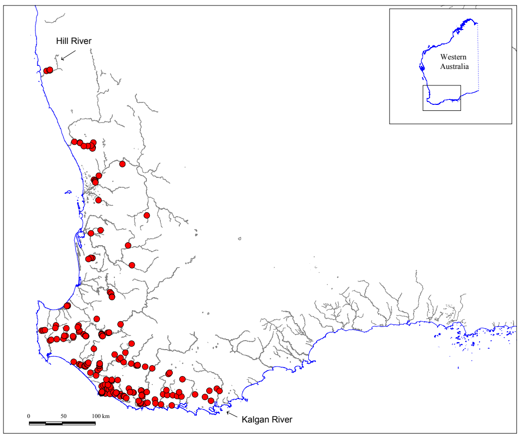


Distribution of Balston's Pygmy Perch.

Nightfish *Bostockia porosa*

Nightfish are found in most of the rivers between the Hill River in the north and the Kalgan River in the south-east. Its absence from the main channel of some of the region's larger salt-affected rivers (e.g. Swan-Avon, Blackwood, Moore) suggests a relatively low tolerance to dissolved salts. They are also susceptible to *Gambusia* attack. Maximum size 140 mm TL. Occur in lakes, rivers and floodplains generally associated with slower moving waters that comprise complex instream habitat. Spawn in spring and live for up to five years.

Further reading: Pen & Potter (1990), Morgan *et al*. (1998).

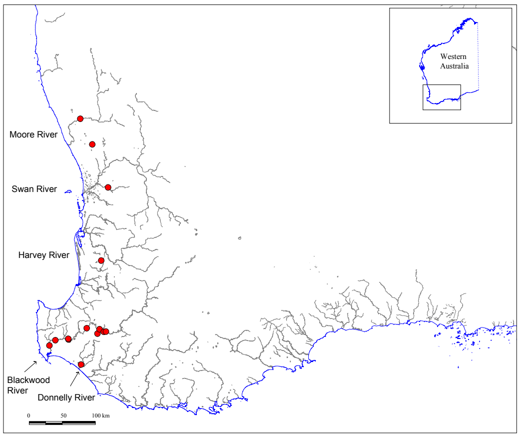


Distribution of the Nightfish.

Freshwater Cobbler *Tandanus bostocki*

The Freshwater Cobbler has a sporadic distribution throughout the south-west and during recent studies it has been captured in the Moore, Swan, Harvey, Blackwood and Donnelly Rivers, however it is also known from the Canning, Murray and Collie Rivers and apparently is found as far south-east as the Frankland River. Maximum size 600 mm TL. Freshwater Cobblers are generally associated with deeper waters in riverine habitats where they are nocturnal and are fished for. Spawning occurs during summer. Regarded by some freshwater anglers.

Further reading: Morrison (1988), Hewitt (1992).

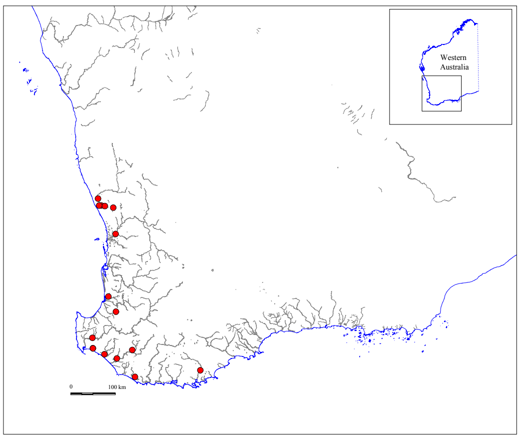


Distribution of the Freshwater Cobbler.

South-western Goby *Afurcagobius suppositus*

The South-western Goby is common in most rivers between the Moore River and Albany and has previously been found considerable distances inland in the Blackwood River, Moore River and Warren River. Little is know with regard to the biology of this endemic goby.

Further reading: Morgan *et al*. (1998).

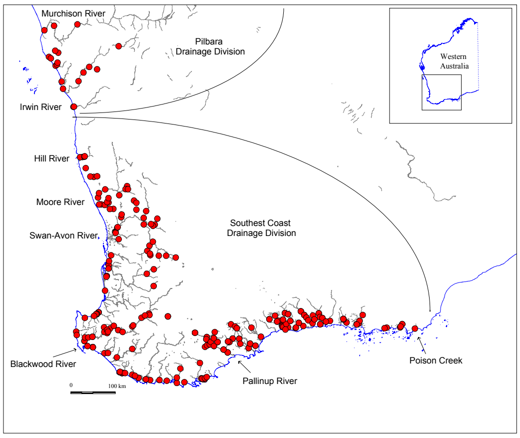


Distribution of the South-western Goby.

Swan River Goby *Pseudogobius olorum*

The Swan River Goby is common in most rivers of the Southwest Coast Drainage Division, and also extends into the Pilbara Drainage Division as far north as the Murchison River. While considered an estuarine species it assumes a coastal distribution in non-saline rivers, but extends throughout those catchments that are either salt-affected (e.g. Moore, Swan-Avon, Blackwood) or are subjected to natural salinisation (e.g. Pallinup to Thomas Rivers). Maximum size 60 mm TL. A benthic species that is often abundant in shallows. Generally spawns from late Spring to early Autumn.

Further reading: Gill *et al*. (1996), Morgan *et al*. (1998).

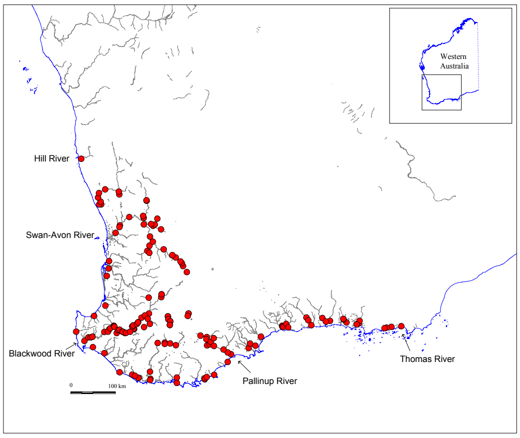


Distribution of the Swan River Goby.

Western Hardyhead *Leptatherina wallacei*

The Western Hardyhead is common in most rivers of the Southwest Coast Drainage Division from the Hill River to the Thomas River (Fig. 14). While considered an estuarine species it assumes a coastal distribution in non-saline rivers, but often extends throughout those catchments that are either salt-affected (e.g. Moore, Swan-Avon, Blackwood) or are subjected to natural salinisation (e.g. Pallinup). Maximum size ~70 mm TL. Often with a vivid red to coppery lateral stripe, particularly during the breeding period. It is often very abundant.

Further reading: Prince *et al*. (1982a, 1982b), Prince & Potter (1983).



Distribution of the Western Hardyhead.

Black Bream ***Acanthopagrus butcheri***

Black Bream are essentially an estuarine species that occasionally penetrate fresh water. Their presence at site BW1 (Figure 1, Table 3) represents a migration a considerable distance up into freshwater habitats. In July 2000 FRDC project 2000/180 entitled the "Restocking of the Blackwood River Estuary with Black Bream (*Acanthopagrus butcheri*)" commenced in response to concerns that the stock of this species had been significantly depleted within the Blackwood River. In 2001, brood stock were collected from the estuary by Murdoch University and Fremantle TAFE staff and transported to Fremantle TAFE Aquaculture Development Unit. Over the next 18 months, these fish were used to spawn approximately 220,000 juvenile Black Bream, which were all otolith-tagged using Alizarin complexone. As a result, 70,000 Black Bream (~ 50 mm TL) were released from Molloy Island Caravan Park and Warner Glen in March 2002, and 150,000 juveniles were released into the same locations one year later.

Subsequent monitoring of the Blackwood River Estuary by Murdoch University has shown that the restocked fish released into the system have exhibited a high rate of survival and currently contribute to between 80-90% of the 2001 and 2002 year class of Black Bream in this system. Fish released in 2002 are currently entering the fishery (i.e. they are beginning to reach the minimum legal length of 250 mm TL) and are contributing to improved recreational and professional catch rates. Restocked fish have been caught throughout the estuary.

The capture of Black Bream at the Great North Road site (BW1) on the main channel (approx. 42km upstream) during this study represents their most upstream capture. Four of the five fish examined by Dan French (Murdoch University) revealed that they had been otolith tagged and are thus stocked fish. The road crossing (see Figure 1 (inset)) appears to act as a barrier to their (and other species) migration further upstream.

Appendix 4 The number and density (m^{-2}, in parenthesis) of freshwater crayfish captured in the different sites sampled in the Blackwood River and its tributaries. *C. cainii* = Marron, *C. quinquecarinatus* = widespread Gilgie, *C. crassimanus* = restricted gilgie, *Cherax* sp. = an unidentified species, and *C. destructor* = the introduced Yabbie. N.B. [1]Records of freshwater crayfish were not made in Layman and Adelaide Brooks which were sampled in 2004.

	FRESHWATER CRAYFISH SPECIES CAPTURED					
			Endemic			**Feral**
SITE	***C. cainii***	***C. quinquecarinatus***	***C. crassimanus***	***C. preissii***	***Cherax* sp.**	***C. destructor***
Main channel downstream of discharge						
BW1	1 (0.03)	2 (0.007)				
BW2	6 (0.012)	38 (0.076)	2 (0.004)	20 (0.004)		
BW3	40 (0.103)	9 (0.023)		11 (0.028)		
BW4	3 (0.008)	5 (0.012)		6 (0.015)		
Main channel upstream of discharge						
BW5		3 (0.005)			1 (0.002)	
BW6	1 (0.007)	2 (0.014)				
Tributary sites in discharge area						
PG1		1 (0.01)		4 (0.04)		
PG2	1 (0.011)	10 (0.105)	2 (0.021)	6 (0.063)	2 (0.021)	
MB1		52 (0.52)		45 (0.45)		
MB2		2 (0.027)				
LB1[1]						
LB2[1]						
Tributary sites downstream of discharge area						
RB1		10 (0.1)				
RB2	1 (0.005)	56 (0.28)	8 (0.04)			
RB3		50 (0.33)	5 (0.03)			
RB4		1 (0.02)				
AB1[1]						
AB2[1]						
Tributary sites upstream of discharge area (Leederville Aquifer dependant)						
RG1		5 (0.167)				
RG2						35 (0.389)
RG3		71 (0.444)	2 (0.012)	66 (0.412)		
MC1		28 (0.197)		1 (0.007)		
MC2	2 (0.008)	60 (0.25)	2 (0.008)	30 (0.125)	1 (0.004)	
SC1		6 (0.12)				
SJ1	10 (0.1)	27 (0.27)		1 (0.01)		
SJ2						
SJ3						
Total number	65	438	21	190	4	35