AQUATIC MACROFAUNA OF ELLEN BROOK AND THE BROCKMAN RIVER: FRESH WATER REFUGES IN A SALINISED CATCHMENT

Report to

Ellen Brockman Integrated Catchment Group

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Centre for Fish & Fisheries Research
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Freshwater Fish Group & Fish Health Unit
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ACKNOWLEDGEMENTS:
THIS PROJECT WAS FUNDED BY LOTTERYWEST. WE WOULD LIKE TO THANK AMY SALMON AT CHITTERING LANDCARE FOR CO-ORDINATING THE PROJECT. THANKS TO THE ELLEN BROCKMAN INTEGRATED CATCHMENT GROUP , THE SWAN RIVER TRUST AND THE MANY LANDHOLDERS IN THESE CATCHMENTS THAT PROVIDED ACCESS TO SITES.

Frontispiece: Western Mud Minnow in Lennard Brook; a critical habitat for the species.

Summary

The South West Coast Drainage Division houses a highly endemic assemblage of aquatic fauna. For example, the region's freshwater fish (80% endemic) and crayfish (100% endemic) endemicity is unsurpassed within the continent. However, this fauna has been severely impacted by habitat change and introduced aquatic species. Understanding the distribution and population viability of these aquatic organisms allows for the development and implementation of effective river action plans that can utilise these organisms as long-term bioindicators of ecosystem health, but can also aid in the recognition of fauna that is in need of special protection.

The Brockman River and Ellen Brook are both major tributaries of the Swan River. While the fishes of the Swan River and the Swan-Canning estuary have been well studied, the freshwater fishes of its major tributaries have received far less research attention. This study aimed to collate previously existing data on the fishes in the freshwaters of Brockman River and Ellen Brook and survey additional sites in both systems in spring and summer 2009/2010 to gather information on the distribution and abundance of native freshwater and estuarine fishes, feral fishes, native and feral freshwater crayfishes, and a freshwater mussel. By undertaking this research, the study aimed to determine whether changes in the fish fauna had occurred and to set a basis for predicting future changes of the aquatic fauna.

A total of 11342 fish, crayfish and turtles were captured during the survey of 10 sites on the Brockman River and seven sites on Ellen Brook in 2009/2010. Of these captures, 1707 (15.1%) were native freshwater fish, 4392 (38.7%) were native estuarine fish, 3323 (29.3%) were feral freshwater fish, 421 (3.7%) were native freshwater crayfish, 1431 (12.6%) were native freshwater shrimp, 25 (0.2%) were a feral freshwater crayfish, and 43 (0.4%) were the native Oblong Turtle (*Chelodina oblonga*).

There were six species of native endemic freshwater fishes recorded during the survey and from the collated existing information, including: the Western Minnow (*Galaxias occidentalis*), Western Pygmy Perch (*Edelia vittata*) and Nightfish (*Bostockia porosa*) which were all present in both the Brockman River and Ellen Brook catchments. The Freshwater Cobbler (*Tandanus bostocki*) and Western Mud Minnow (*Galaxiella munda*) were recorded only from the Brockman River and Ellen Brook catchment, respectively, the latter species only being found in Lennard Brook. A further native endemic freshwater fish species recorded within the Ellen Brook system is the Black-stripe Minnow (*Galaxiella nigrostriata*), which is known from Melaleuca Swamp (Smith *et al*. 2002a, b) and very recently from Lake Chandala (McLure and Horwitz 2009). As these represent the only known populations of these two species in the

entire Swan-Canning catchment (which is south-western Australia's largest), and that they are outlying populations compared to their next nearest populations, indicates that they require specific conservation consideration.

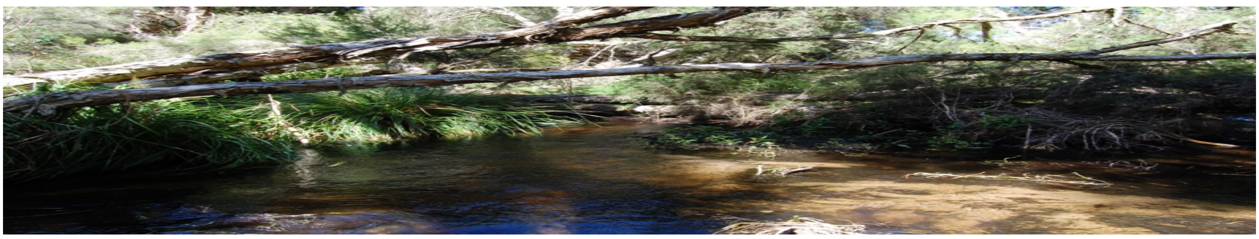
There were two estuarine species recorded in both systems: the Western Hardyhead (*Leptatherina wallacei*) and the Swan River Goby (*Pseudogobius olorum*) that have penetrated these systems. The feral fish species captured consisted of the Eastern Mosquitofish (*Gambusia holbrooki*) and the Goldfish (*Carassius auratus*). While the Eastern Mosquitofish was widespread, the Goldfish was restricted in distribution. The native freshwater crayfishes recorded were the Gilgie (*Cherax quinquecarinatus*), which was the most widespread species and the Marron (*Cherax cainii*) that was much more restricted in distribution in both systems. The feral Yabbie (*Cherax destructor*) was also recorded in the Ellen Brook catchment. Eradication of these established feral species would be very unlikely, however, there is the potential to control or remove the Goldfish given its apparent restricted distribution in both systems.

The extreme rarity of Carter's Freshwater Mussel (*Westralunio carteri*), the south-west's only endemic freshwater mussel, in both these systems is cause for concern. This species is likely to play an important role in ecosystem health and its larval phase is reliant on fish hosts. Although the life-cycle is poorly understood, but is under current investigation by one of the authors, this study implies that it may have undergone a large range reduction in Ellen Brook, the Brockman River and other salt-affected systems in the region. Further, if the range reductions of fishes that are hosts to the larval stage of the mussel have occurred, then this may have led to a concomitant decline in mussel distribution.

Key points

- The study has demonstrated that these systems are of conservation significance as they provide refuges for a significant proportion (75%) of the endemic freshwater fishes of south-western Australia, two species of endemic freshwater crayfish, and viable populations of the Oblong Turtle and Carter's Freshwater Mussel.
- The study has identified Lennard Brook, Melaleuca Park and Chandala Lakes as particularly important conservation areas as they house outlying and very restricted populations of the threatened Western Mud Minnow (Lennard Brook) and Black-stripe Minnow (Melaleuca Park and Chandala Lakes).
- Lennard Brook (two sites) and Yalyal Brook (one site) comprised three of the four sites where Carter's Freshwater Mussel was found.

- It is recommended that the resident aquatic fauna identified in the Brockman River and Ellen Brook should be incorporated into monitoring programs that aim to ensure sustainable surface and groundwater water use within these catchments, as well as assessing the effectiveness of the implementation of river action plans.
- Along with ensuring that levels of groundwater and surface extraction do not result in the loss of critical aquatic faunal habitat, the maintenance, protection and rehabilitation of riparian zone vegetation would increase the long-term viability of these aquatic fauna.
- Continued monitoring and genetic analysis of rare taxa should be undertaken.
- Determination of fish hosts for Carter's Freshwater Mussel is vital for the management of this threatened species.



Contents

Introduction

Freshwater fish and crayfish of south-western Australia

The freshwater fishes of the South West Coast Drainage Division of Western Australia (WA) belong to four families and are few in terms of number of species, but highly endemic with eight of the 10 being found nowhere else (Morgan *et al.* 1998, Allen *et al.* 2002). In fact, this drainage division has the highest proportion of endemic freshwater fishes of any of Australia's 11 major drainage divisions (Morgan *et al*. 1998). None of the south-west freshwater fishes is shared with the other two WA divisions; the Pilbara and Kimberley (Morgan *et al.* 1998; Allen *et al.* 2002). Two species are listed Federally under the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act 1999*): the Trout Minnow (*Galaxias truttaceus*), Australia's only *Critically Endangered* freshwater fish, and Balston's Pygmy Perch (*Nannatherina balstoni*) listed as *Vulnerable*. A few species, including those mentioned above and the Western Mud Minnow (*Galaxiella munda*), are listed as Schedule 1 (rare or likely to become extinct and in need of special protection) under State legislation (*Wildlife Conservation Act 1950*).

Much of the region's other aquatic organisms are also unique. For example, each of the 11 freshwater crayfish species is endemic to the south-west region. This includes six species in the genus *Cherax*; the most widely distributed freshwater crayfish genus in Australia (Austin & Knott 1996; Austin & Ryan 2000). The long period of separation of south-western Australia from the rest of the continent, has led to the native Western Australian *Cherax* species being monophyletic (Crandall *et al.* 1999). There are also five native species of obligate burrowing freshwater crayfish that belong to the endemic genus *Engaewa* (Horwitz & Adams 2000), with three of these recently being listed under the *EPBC Act 1999* as Critically Endangered (Dunsborough Burrowing Crayfish (*Engaewa reducta*) and Margaret River Burrowing Crayfish (*Engaewa pseudoreducta*)) or Endangered (*Engaewa walpolea*).

These aquatic fauna have undergone major declines in population range due to a combination of habitat change, such as riparian vegetation degradation and secondary salinisation of inland reaches of the major rivers (Morgan *et al.* 1998, 2003) and impacts of introduced species such as Eastern Mosquitofish and Redfin Perch (e.g. Morgan *et al*. 1998, 2002, 2004, Gill *et al*. 1999). The major impact on the distribution of these populations has been dryland secondary salinisation of inland areas, which has resulted in only ~44% of flow in the largest 30 rivers in the south-west of WA being fresh (Mayer *et al.* 2005).

Exacerbating these impacts on our unique aquatic fauna is the continuing decline in rainfall. Average annual rainfall in the south-west of WA has declined by 10% since 1970. The ranges of predicted future average annual rainfall declines are: by 2030 between 3-22% and 0-22%

for the extreme south-west and the remainder of the region, respectively (Suppiah *et al.* 2007). By 2070, models predict annual average rainfall to decline by 7-70% and 0-70% for the extreme south-west and the remainder of the region, respectively (Suppiah *et al.* 2007). The reduction in stream flow and groundwater recharge due to the continued decline in rainfall has considerable implications in sustainably managing surface and groundwater resources.

The freshwater fishes of the region have recently been identified as important bioindicators of water quality decline (such as salinisation, Beatty and Morgan (in press)) and, being at the top of the aquatic food chain, play an important role in the structuring of aquatic food webs. Freshwater fishes of this region should therefore be a key consideration in developing and monitoring the success of river management plans.

The Brockman River and Ellen Brook are both major tributaries of the Swan River. While the fishes of the Swan and Canning estuaries have been well studied (e.g. Chubb *et al*. 1979, 1981, Prince & Potter 1983, Chub & Potter 1984, 1986, Gill & Potter 1993, Humphries & Potter 1993, Wise *et al*. 1994, Gill *et al*. 1996, Potter & Hyndes 1999, Kanandjembo *et al*. 2001, Sarre *et al*. 2000, Sarre & Potter 2000), the freshwater fishes of its major tributaries have received far less research attention. The majority of published studies that have been conducted on the freshwater fishes of the tributaries of the Swan River are almost exclusively related to the presence and/or impact of introduced species in these systems. These include a review of feral fishes in WA by Morgan *et al*. (2004), predation of Marron (*Cherax cainii*) by a self-maintaining population of Rainbow Trout (*Oncohynchus mykiss*) in Churchman Brook Reservoir by Tay *et al*. (2007), the spread of One-spot Livebearers (*Phalloceros caudimaculatus*) by Maddern (2008), and the presence of an introduced parasitic crustacean *Lernea* on freshwater fish in the Canning River by Marina *et al*. (2008). Watts *et al*. (1995) examined the genetics and morphology of the Western Minnow (*Galaxias occidentalis*) in the Canning River and Smith *et al*. (2002a, b) for an outlying population of Black-stripe Minnow (*Galaxella nigrostriata*) in a wetland of Ellen Brook. There are also a number of unpublished technical reports and theses on fishes in the catchment. For the Canning River system this includes studies reported by Aquatic Research Laboratory (1988), Morrison (1988), Hewitt (1992), Morgan & Sarre (1995), Beatty *et al*. (2003a, 2005a), Maddern (2003), Tay (2005), Beatty & Morgan (2006) and Morgan *et al*. (2007). For the Swan-Avon, unpublished reports on freshwater fishes are limited to those tributaries in the lower catchment including Ellen Brook (Bamford *et al*. 1998, Morgan *et al*. 2000, Maddern 2003). In light of the lack of published data and/or technical reports detailing the freshwater fishes of the Swan-Avon, it is important to note that there is a large unpublished data set of fishes in the 'freshwaters' of the Swan-Avon catchment (~200 sites), which is maintained by the Freshwater Fish Group in the Centre for Fish & Fisheries Research, Murdoch University and, in particular, this includes species data for a number of sites within the Ellen Brook and Brockman River catchments.

Freshwater mussels

Freshwater mussels are sedentary benthic bivalve molluscs, which play an important functional role in aquatic ecosystems via biological flirtation of water, contributing to clarity and sediment oxygenation (Vaughn and Hakenkamp 2001). Freshwater mussels are sensitive to environmental changes (Ponder and Walker 2003) and, like freshwater fish fauna, can be considered important bioindicators of aquatic ecosystem condition. Globally, freshwater mussels, of the order Unionoida, includes 854 species (Graf and Cummings 2007, 2009) in two superfamilies (Unionoidea and Etherioidea) that are distinguished by larval forms. The larvae of members of the super-family Unionoidea, (including the families Hyriidae, Margaritiferidae and Unionidae) are known as glochidia, which are obligate parasites of their host fish (Bauer and Wächtler 2001). Unionoids utilise fish to complete development and as a dispersal mechanism. Glochidial attachment to host fish is necessary to facilitate metamorphosis to the juvenile stage in their life-cycle, when they detach from the fish to begin a benthic lifestyle, and potentially expanding their geographic range (Bauer and Wächtler, 2001, Strayer, 2008). Fish endemic to a particular region where unionoids occur are the usual hosts for their glochidia (Pelseneer 1906, Coker *et al*. 1921, Pennak 1953, Negus 1966, Hiscock 1972, Yokley 1972, Atkins 1979).

In Australia, freshwater mussels are represented by 18 species (eight genera) from the family Hyriidae (Walker *et al*. 2001, Ponder and Walker 2003, Ponder and Bayer 2004), two of which are listed as species to monitor, which could become threatened. Carter's freshwater Mussel (*Westralunio carteri* (Iredale, 1934)) is the only freshwater mussel species (Unionoida: Hyriidae) endemic to south-western WA, ranging from the Moore River to the south coast, west of Esperance (Graf and Cummings, 2009). Population decline of *W. carteri* in salt-affected systems such as the Avon River (Kendrick, 1976) has resulted in its current listing as 'Vulnerable' by the IUCN, meaning the species is facing a high risk of extinction in the wild in the medium-term future, under international criteria (IUCN 1996) and as a "Priority 4" species, which is defined as taxa in need of monitoring, DEC (WA) inter-departmental fauna rankings. Currently, there is a lack of information regarding the precise distribution, biology and ecology of *W. carteri* in south-western Australia.

Aims of the study

The aims of this study were to:

- Determine the distribution of fish, decapods and freshwater mussels in the Brockman River and Ellen Brook.
- Assess the overall conservation significance of this fauna.
- Provide species synopses for use by natural resource managers.
- Provide recommendations that will aid in sustaining populations of these organisms.

Black-stripe Minnow and Western Mud Minnow, two of south-western Australia's rare fishes (photographs G. Allen and S. Beatty)

Methods

Sampling sites

A total of 18 sites were assessed using qualitative (presence/absence) and quantitative (abundance and density) methods to provide details of the aquatic macrofauna of Ellen Brook and the Brockman River. In particular, we examined fishes, decapods and freshwater mussels in the Brockman River (nine sites) and Ellen Brook (eight sites) during spring and summer 2009-2010 (Table 1, Figures 1a, b, 2), and also provide information on freshwater turtles.

In order to provide an overall summary of the previously known distribution of fishes in the Swan-Canning catchment, the Freshwater Fish Group distributional database was accessed in February 2010. The distribution of each species in these catchments were then mapped and included in the species synopses (Figure 3).

Freshwater fish and crayfish sampling

A variety of sampling techniques were deployed during the study, depending on the type of instream habitat present at each site (Figure 2). The use of such a variety of specialised sampling techniques helped to ensure that all species present at each site were recorded. Fyke nets (0.8 m height, 5 m wide wings, 1.2 m wide opening, 5 m long pocket with two funnels all comprised of 2 mm woven mesh) were set at a number of sites for a 24 hr period, ensuring an adequate proportion of the funnel was above the water surface to ensure survival of any incidentally captured air-breathing animals such as reptiles, birds and mammals. Seine netting (10 m net with 2 mm woven mesh) and a Smith-Root (Model LR20) backpack electrofisher were also used at other sites. The majority of fish captured were measured and released

Mussel Sampling

At each site, a 50 m stretch of stream was examined for freshwater mussels by visually searching from the water surface or feeling for mussels by hand where depth was shallow (<1m) and visibility was poor. To determine the relative density of freshwater mussels, 10 x 1 m^2 quadrats were randomly placed on the stream bed. Quadrats were constructed of 15 mm diameter round PVC tubing and elbows and only used in areas where mussels were present. The number of mussels in each quadrat were then counted to estimate population density, as recommended by Downing and Downing (1992), illustrated in Figure 4. At each site, we recorded substrate type on the river bottom (rock, gravel, sand, mud, silt and/or detritus). For each mussel collected from the quadrats, the maximum length (ML), maximum height (MH) and width (W) of the shell was measured with vernier callipers to the nearest 0.01 mm (see Figure 5). Mussels were identified to species level using taxonomic keys of McMichael and Hiscock (1958) and Walker (2004). The majority of mussels were released after being measured, with a small number retained for future genetic analyses. Using these measurements, Maximum Height Index (MHI) according to McMichael and Hiscock (1958) was derived from the following formula: MHI = MH/ML x 100.

Fish that were captured in fyke nets and through electrofishing were examined for glochidial cysts, which appeared as small, white, bladder-like cysts on fish epithelial tissue. Glochidia prevalence (GP) was calculated as a percentage of fish infected of the total number of each individual fish species examined. Glochidia intensity (GI) was calculated by counting the number of cysts on each infected fish.

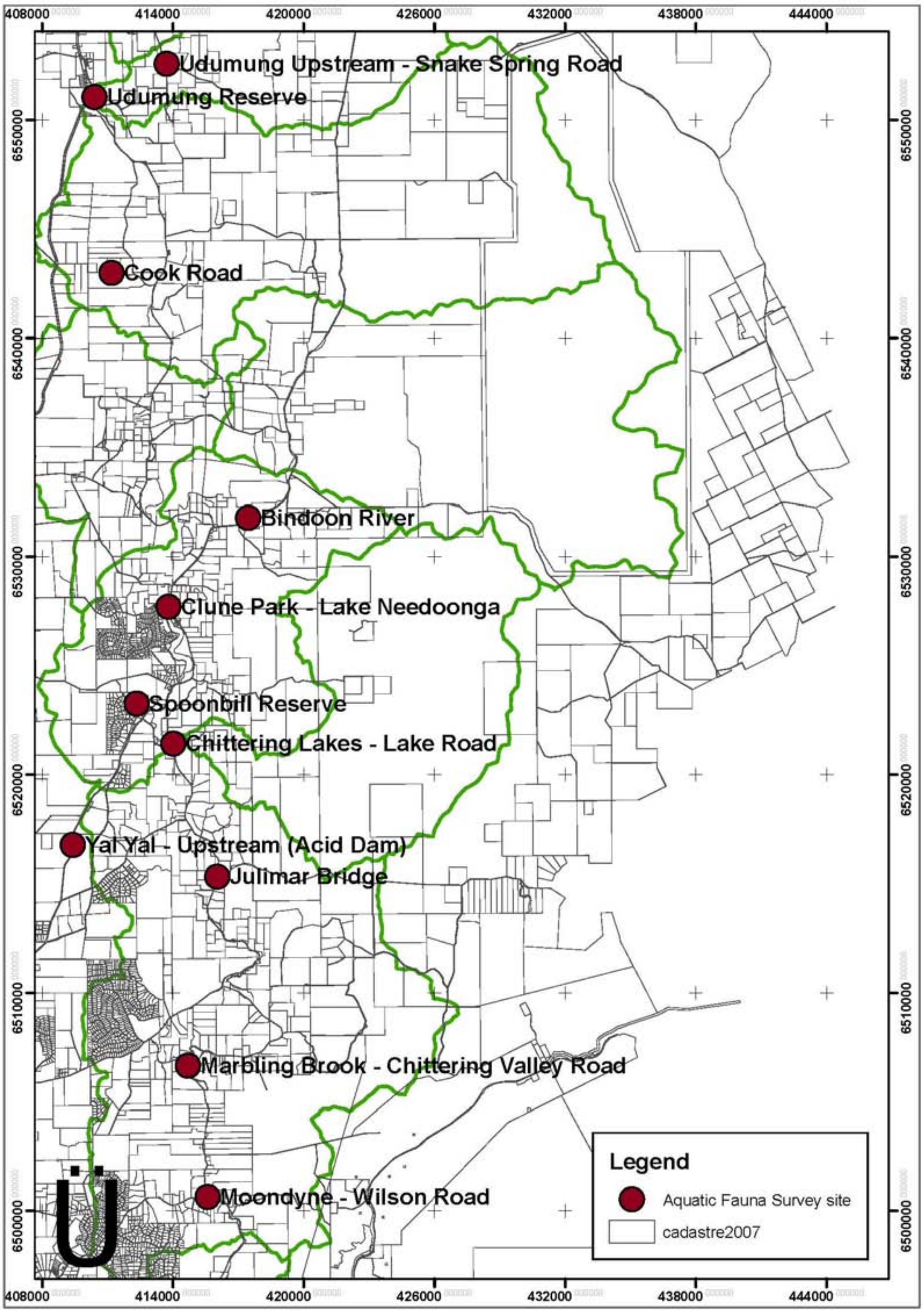


Figure 1a Sites sampled for fish, decapods and freshwater mussels in Brockman River (excluding Chittering Lakes) during the current study.

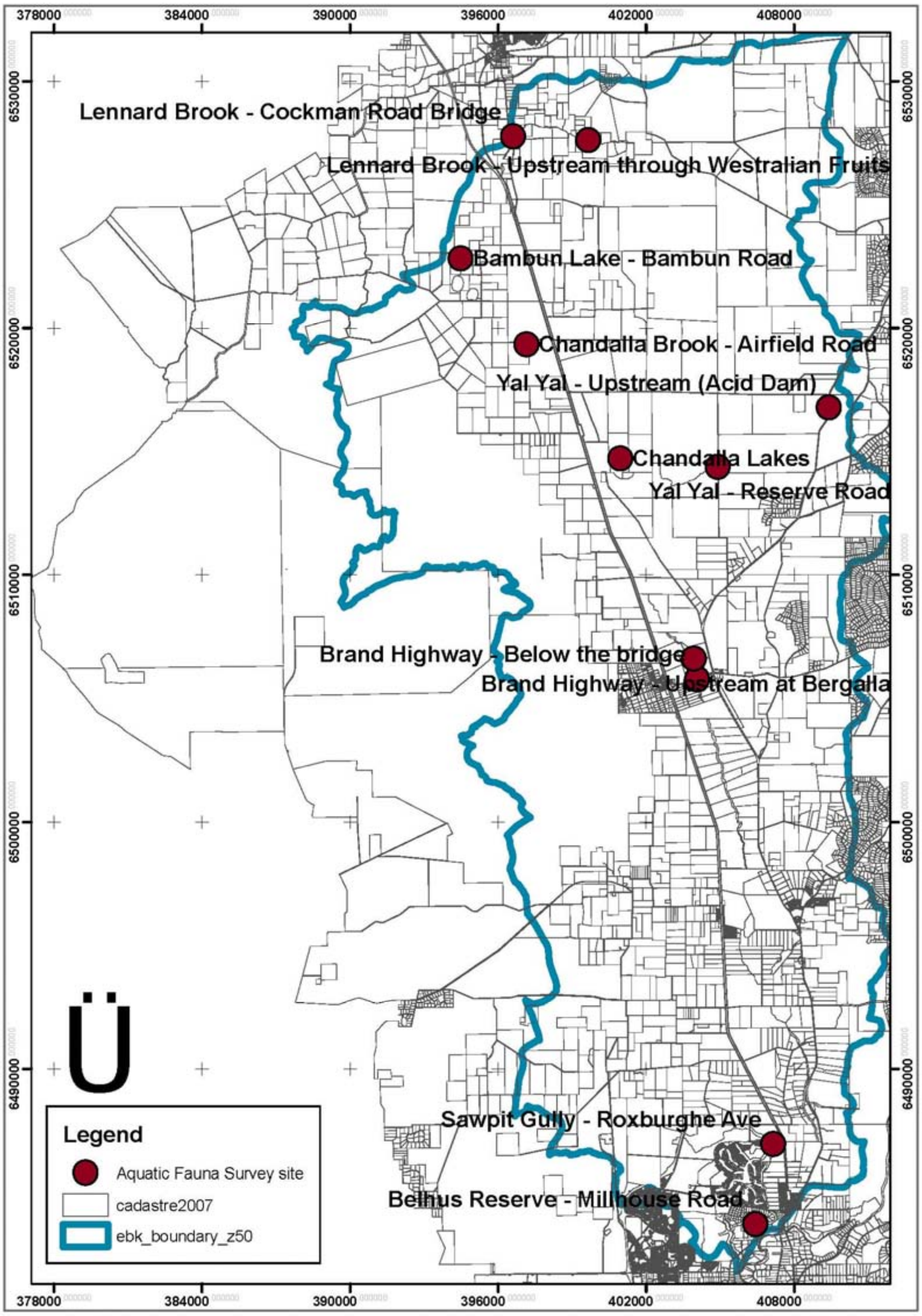


Figure 1b Sites sampled for fish, decapods and freshwater mussels in Ellen Brook (excluding Sawpit Gully, Brand Hwy upstream at Bergalla and Yal Yal Acid Dam) during the current study (see Figure 1a).

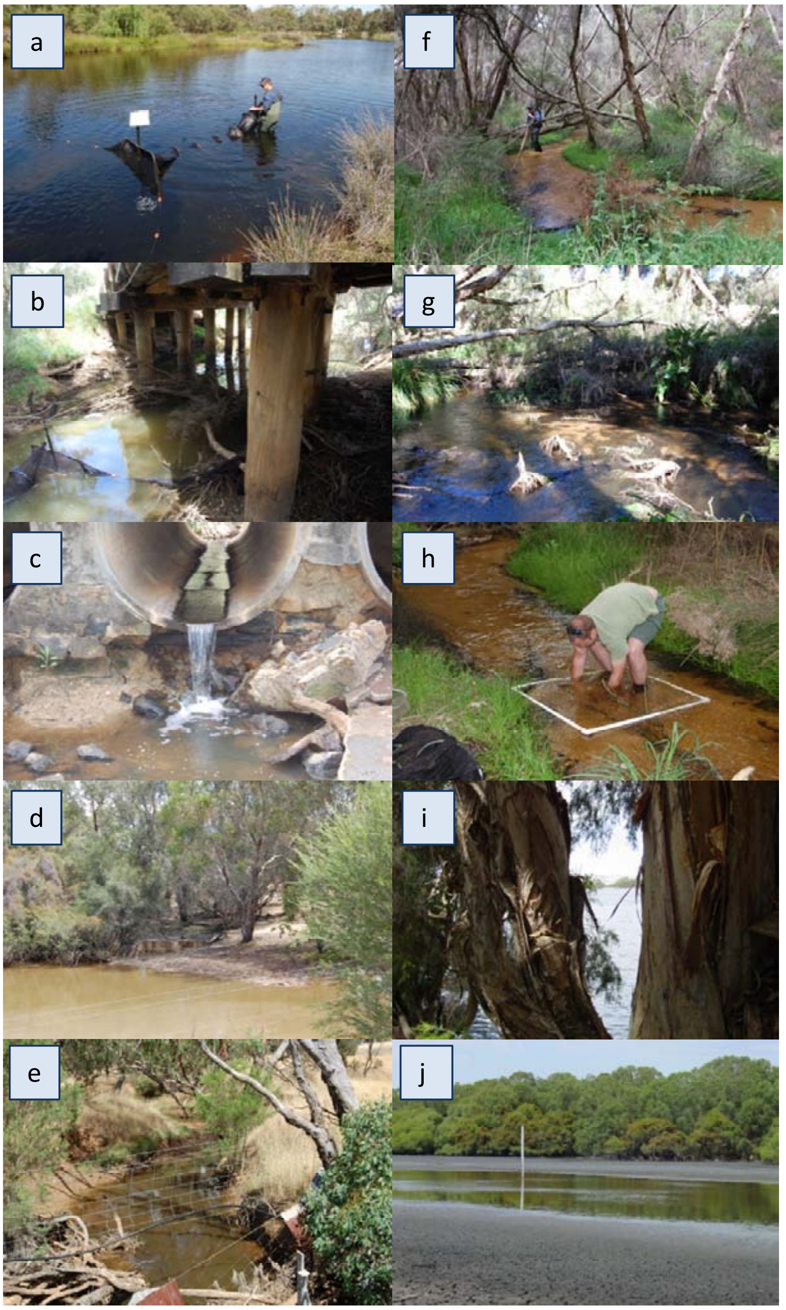


Figure 2 Examples of sites sampled in the Brockman River and Ellen Brook in spring-summer 2009-10, including, (a) Spoonbill Reserve, (b) Julimar Bridge, (c) Moondyne, (d) Cook Rd, (e) Udumung Brook, (f) Yalyal Brook, (g) Lennard Brook, (h) mussel quadrat (Yalyal Brook), (i) Bambun Lake, and (j) Chandala Lake.

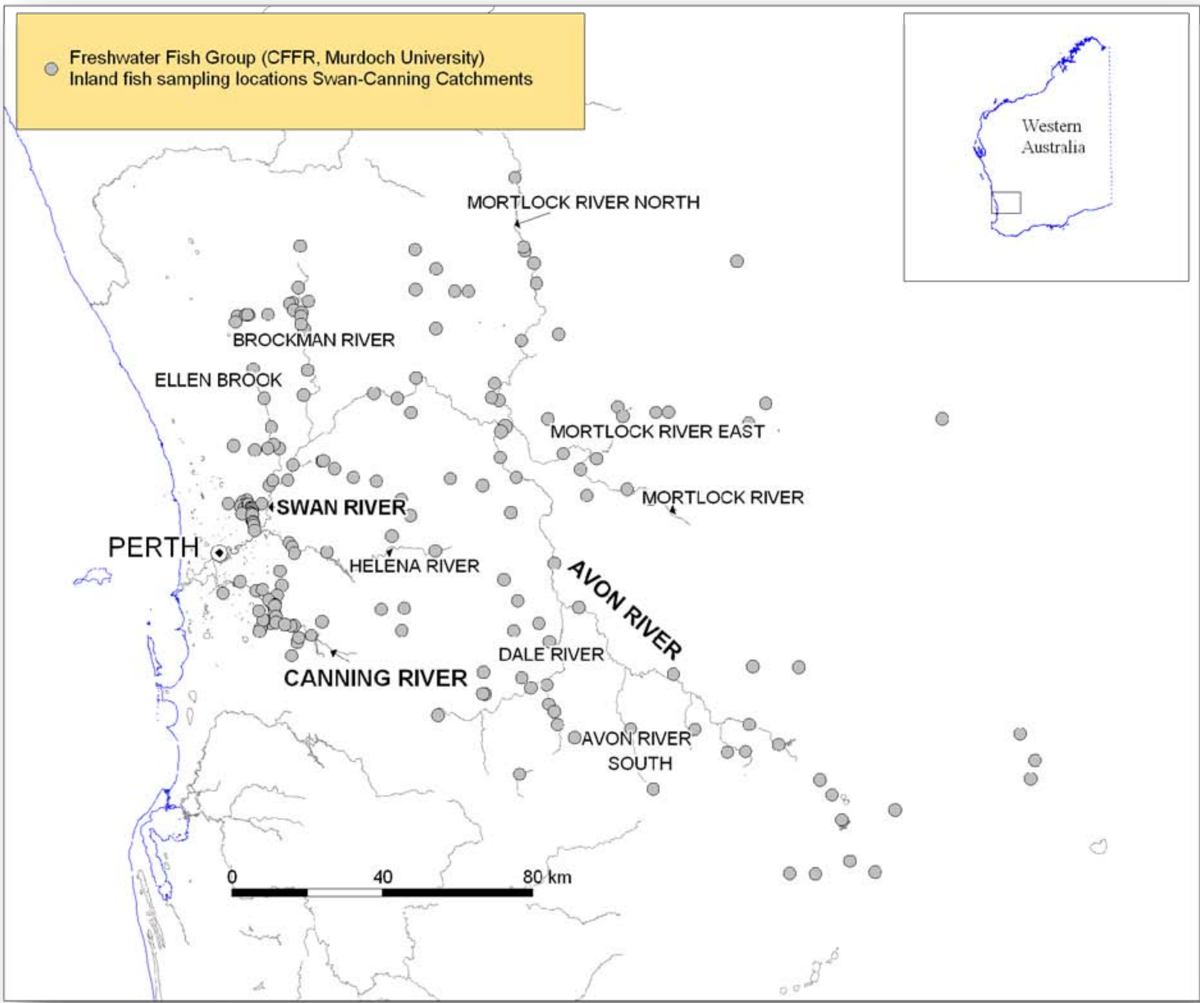


Figure 3 Sites sampled for freshwater fish in the Swan-Canning catchment by the Freshwater Fish Group, Murdoch University (excluding this study).

Figure 4 Morphological measurements for the Freshwater Mussel (*Westralunio carteri*).

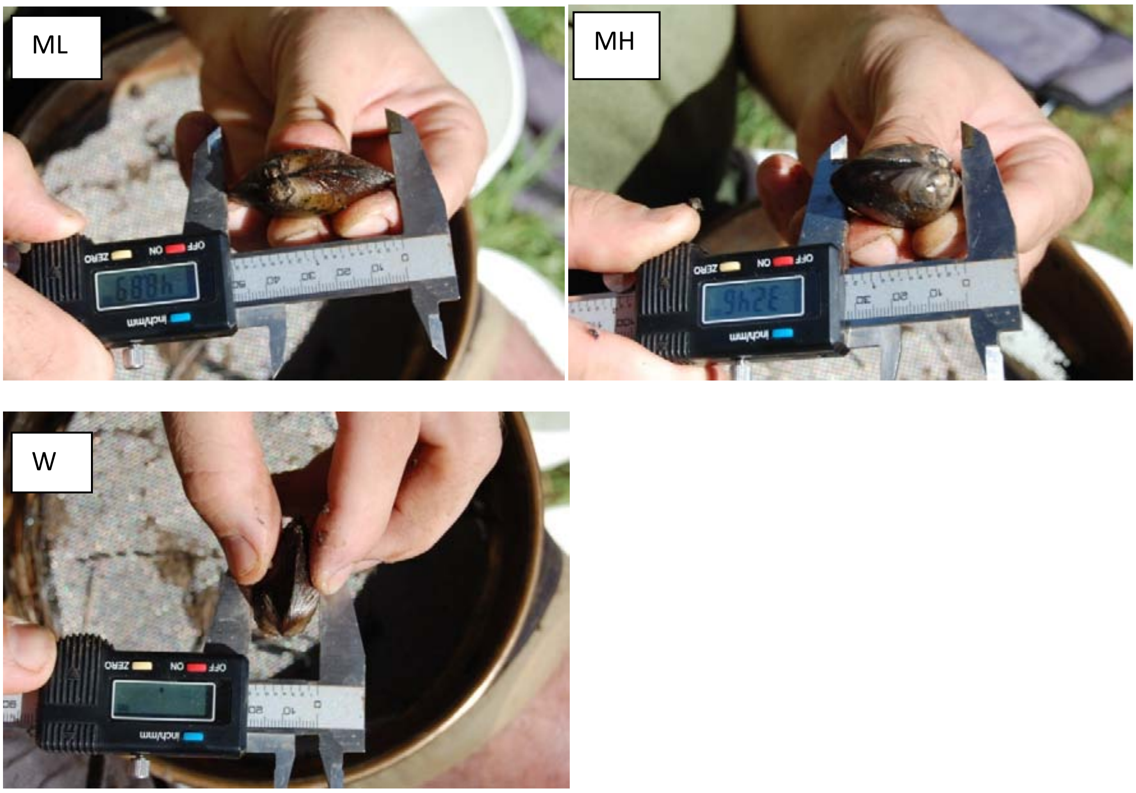


Figure 5 Shell measurements adapted from McMichael and Hiscock (1958). MH = maximum height, ML = maximum length, W = width.

Water quality sampling methods

Physico-chemical parameters of water quality (temperature (°C), pH, dissolved oxygen (% and ppm), NaCl concentration (ppt), total dissolved solids (ppt) and conductivity (µS/cm)) were measured using an Oakton™ PCD650 waterproof portable multimeter at three locations at each site and a mean and standard error (SE) determined.

Statistical Analysis

Mapping of faunal distributions was undertaken using MapInfo. Graphical and statistical analysis of the fish, decapods and mussel abundance, densities, and length-frequencies were undertaken using Excel and SigmaPlot™11.0.

Results and discussion

Summary of fish, decapod and turtle captures

A total of 11342 fish, crayfish and turtles were captured during the survey of 10 sites on the Brockman River and eight sites in Ellen Brook in 2009/2010 (Tables 1 and 2). Of these captures, 1707 (15.1%) were native freshwater fish, 4392 (38.7%) were native estuarine fish, 3323 (29.3%) were feral freshwater fish, 421 (3.7%) were native freshwater crayfish, 1431 (12.6%) were native freshwater shrimp, 25 (0.2%) were feral freshwater crayfish, and 43 (0.4%) were native Oblong Turtle (*Chelodina oblonga*) (see *Species synopses*).

There were five species of native endemic freshwater fishes recorded during the survey (Tables 1 and 2), including: Western Minnow (*Galaxias occidentalis*) (842 individuals, 49.3% of native freshwater fish captured), Western Pygmy Perch (*Edelia vittata*) (325 individuals, 19.0%) and Nightfish (*Bostockia porosa*) (262 individuals, 15.2%) which were present in both the Brockman River and Ellen Brook catchments. The Freshwater Cobbler (*Tandanus bostocki*) (269 individuals, 15.8%) were recorded only from the Brockman River and Western Mud Minnow (*Galaxiella munda*) (nine individuals, 0.5%) from only Lennard Brook in the Ellen Brook catchment (Tables 1 and 2). A further native endemic freshwater fish species recorded within the Ellen Brook system is the Black-stripe Minnow (*Galaxiella nigrostriata*), which is known from Melaleuca Swamp (Smith *et al*. 2002a, b) and very recently from Lake Chandala (McLure and Horwitz 2009). The populations of this species, and the Western Mud Minnow in the Ellen Brook catchment, represent outlying populations and are in need of special consideration for their conservation (see Morgan *et al*. 1998, Smith *et al*. 2002a).

There were two estuarine species recorded in both systems: the Western Hardyhead (*Leptatherina wallacei*) (1689 individuals) and the Swan River Goby (*Pseudogobius olorum*) (2703 individuals). The feral fish species captured consisted of the Eastern Mosquitofish (*Gambusia holbrooki*) (3320 individuals) and the Goldfish (*Carassius auratus*) (three individuals) (Tables 1 and 2). While the Eastern Mosquitofish was widespread, the Goldfish was restricted in distribution (see *Species synopses*).

The native freshwater crayfishes were the Gilgie (*Cherax quinquecarinatus*) (412 individuals) and the Marron (nine individuals). The feral Yabbie (*Cherax destructor*) was also recorded (25 individuals) (Tables 1 and 2).

Water quality

Physico-chemical parameters of water quality for all sites sampled are summarized in Table 3. Water temperature was highest in February with a maximum temperature of 30.53°C and lowest at spring-fed sites (Lennard Brook and Yal Yal Brook). Salinity (NaCl) and conductivity ranged from very fresh (0.42-0.53 ppt NaCl and 0.84-1.00 mS/cm) at spring-fed sites to brackish, with peak salinity and conductivity (5.91 ppt NaCl and 10.16 mS/cm) occurring at the Clune Park site. In Yalyal – Reserve Rd, Julimar Bridge, Marbling Brook, Moondyne and Spoonbill sites, were characterised by slightly acidic (pH<7) water. Great Northern Hwy, Udumung – Reserve Rd and Clune Park sites were slightly alkaline (pH>7), while Chandala Brook and Cockram Rd sites had near neutral water (pH~7). Dissolved oxygen concentration was lowest in Chandla Brook (2.52 ppm) and highest in the Belhus Reserve sites (13.58 ppm).

Table 3 Physico-chemical parameters of water quality in Ellen Brook and the Brockman River.

Site	Date	Temperature (°C)	Conductivity (mS/cm)	NaCl (ppt)	pH	Dissolved oxygen (ppm)
Yalyal, Reserve Rd	5-Nov-09	20.30	1.00	0.53	6.16	7.64
Julimar Bridge	5-Nov-09	20.97	6.08	3.67	6.21	5.89
Marbling Brook	5-Nov-09	20.67	2.40	1.33	6.14	8.08
Moondyne	5-Nov-09	22.53	3.04	1.71	6.19	7.69
Spoonbill	5-Nov-09	25.93	1.48	0.80	6.23	7.73
Great Northern Hwy	13-Nov-09	25.10	5.52	3.07	7.89	6.73
Cook Rd	13-Nov-09	26.70	8.24	4.76	-	9.88
Udumung – Boondoon -Moora Rd	13-Nov-09	24.77	7.98	4.62	7.59	6.41
Chandala Brook	13-Nov-09	22.93	1.16	0.59	6.92	2.52
Bambun Lakes	19-Feb-10	28.03	2.31	1.27	6.90	7.72
Udumung, Reserve Rd	13-Nov-09	24.93	7.47	4.25	7.58	6.57
Brand Hwy	3-Dec-09	18.30	1.99	1.04	6.64	1.57
Clune Park	3-Dec-09	21.80	10.16	5.91	7.61	7.19
Lennard Brook (Cockram Rd)	3-Dec-09	20.17	0.84	0.42	7.22	8.29
Lennard Brook (Westralia Fruits)	5-Feb-10	18.97	0.87	0.44	-	7.12
Belhus Reserve	5-Feb-10	30.53	4.56	2.52	-	13.58

Species synopses

Native Freshwater Fishes

Western Minnow (*Galaxias occidentalis*)

The Western Minnow is one of five members of the family Galaxiidae found in south-western Australia. It is currently the most widespread freshwater native species in the Swan-Canning Catchment (Figure 6) (Morgan and Beatty unpublished data, CFFR Database). In the current survey, it was recorded at all nine sites in the Brockman River but only three of the eight sites in Ellen Brook (Tables 1 and 2). The current study is in agreement with previous captures for the species in these systems (see Figure 6, and Morgan *et al*. 2000, CFFR Database). Figure 7 illustrates that the species was captured in similar numbers moving upstream and downstream in the Brockman River and was only recorded moving upstream in Ellen Brook. This probably reflects the fact that sampling occurred well after the known winter spawning period of this species (Pen and Potter, 1991a). The species is relatively salt-tolerant, having previously been recorded in salinities up to ~24 ppt or ~two thirds the salinity of seawater (Morgan and Beatty 2004). However, recent acute salinity trials have revealed that its tolerance is ~14 ppt (Beatty *et al*. 2008) and therefore population viability is likely affected at salinities above that point.

The length-frequency distribution suggested that the dominant cohort of Western Minnow in both systems were 0+ fish (new recruits or 2009 year class) with modal lengths of 45-49 and 55-59 mm TL in the Brockman River and Ellen Brook, respectively. The difference in these sizes was probably due to the later sampling occasion when Western Minnows were captured in Ellen Brook (i.e. February, 2010) compared to Brockman River (i.e. November 2009). Furthermore, the majority of the measured individuals in Ellen Brook were from Lennard Brook and this population clearly had a greater number of larger, older cohorts present, suggesting this groundwater-fed system may allow greater longevity of the species. A similar situation was found in the groundwater-maintained Milyeannup Brook in the Blackwood River catchment (Beatty *et al*. 2006), with spawning occurring earlier, and greater numbers of older fish being recorded in that system compared with nearby, surface water-fed tributaries.

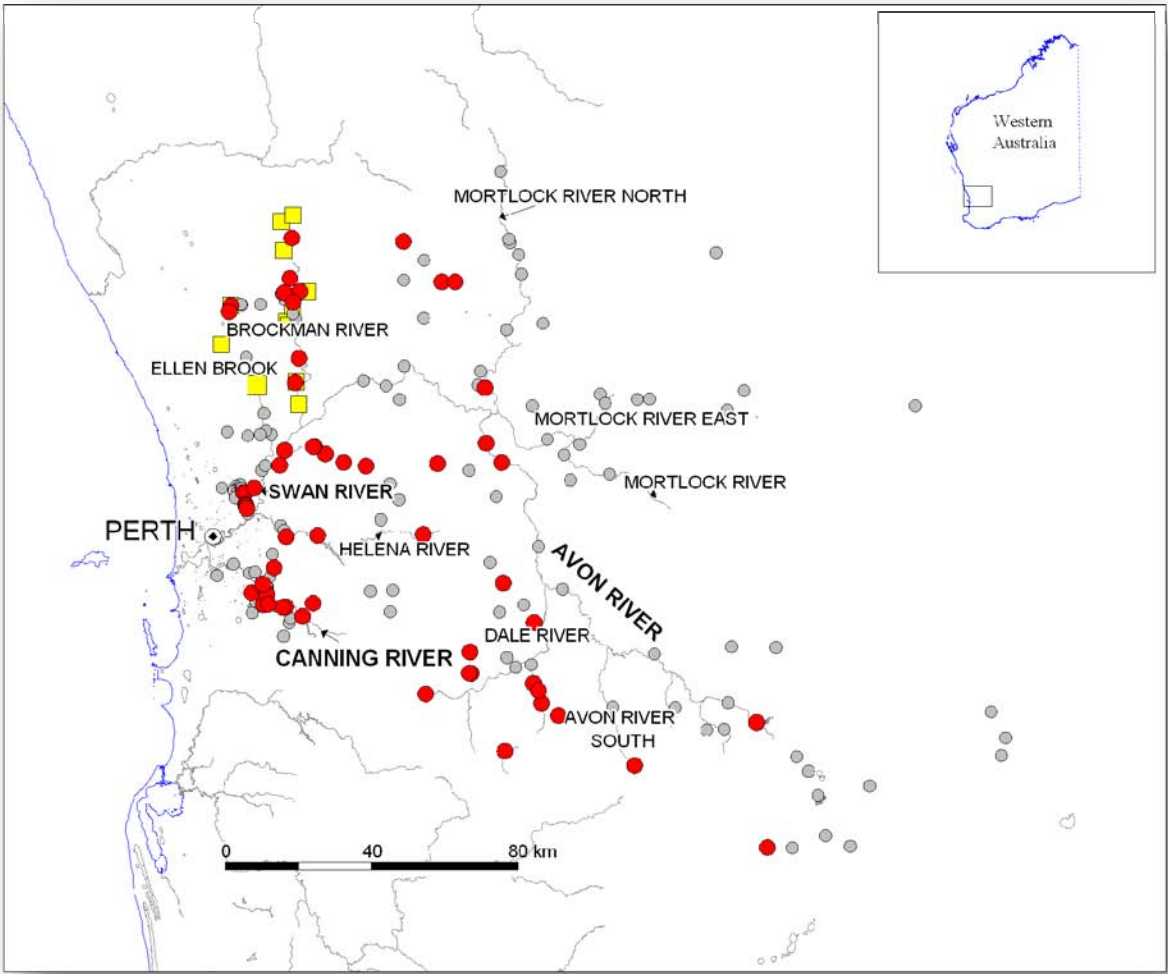


Figure 6 Distribution of Western Minnow in the Swan-Canning catchment. N.B. Boxes are capture sites in the current survey, red circles are our historical capture sites and grey circles non-capture sites from the Freshwater Fish Group (CFFR, Murdoch University) database.

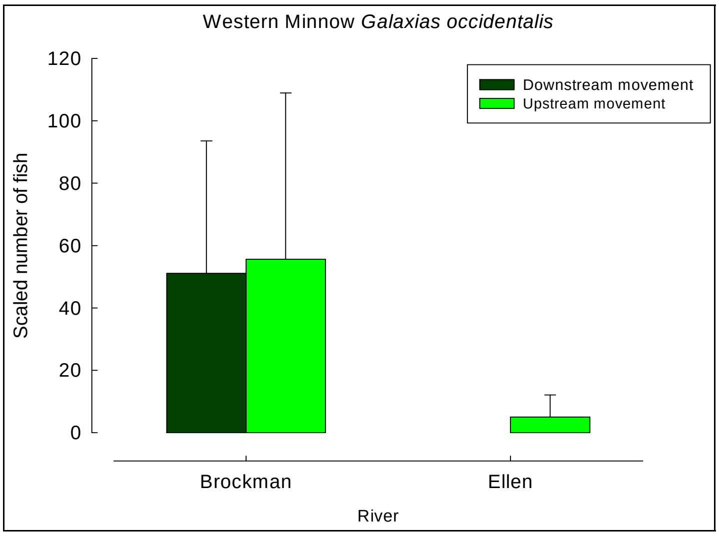


Figure 7 Upstream and downstream movement of the Western Minnow within Brockman River and Ellen Brook.

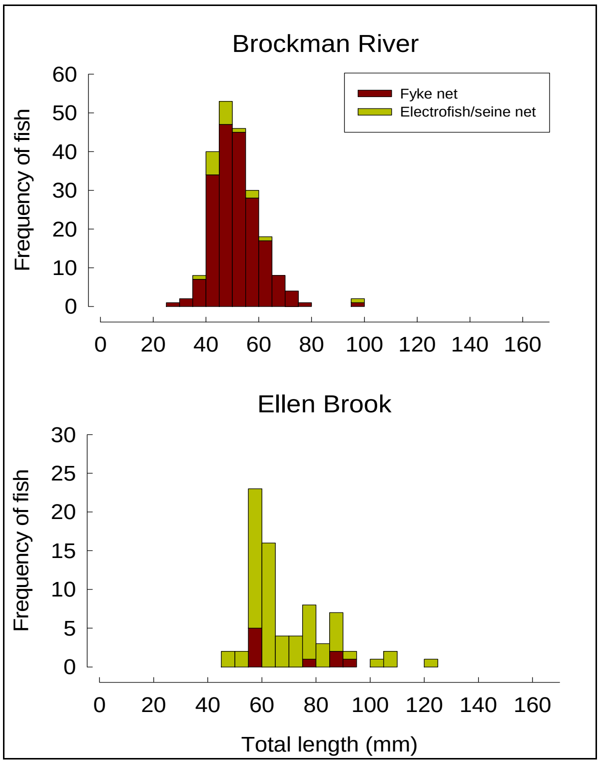


Figure 8 Length-frequency histograms according to capture method of the Western Minnow in the Brockman River and Ellen Brook.

Western Mud Minnow (*Galaxiella munda*)

The Western Mud Minnow is one of five members of the family Galaxiidae found in south-western Australia, one of the three endemic galaxiids in the south-west and one of only three species of *Galaxiella* (Allen *et al.* 2002). Its contemporary distribution is patchy and recent research suggests that this may be due to loss of suitable habitats and competition with introduced species such as the Eastern Mosquitofish (which fills the same niche) and from predation by Eastern Mosquitofish (in the form of fin-nipping, noting that *G. munda* only attains a small size), introduced trout (*Oncorhynchus mykiss* and *Salmo trutta*) and Redfin Perch (*Perca fluviatilis*) (Gill and Morgan 1997, Morgan *et al*. 1998, 2002, Beatty *et al*. 2006). Indeed, Redfin Perch and trout led to the species being extirpated from Big Brook Dam in the Warren River catchment (Morgan *et al*. 2002).

This is the most restricted species of native freshwater fish in the entire Swan-Canning catchment and is likely to disappear in the future without considerable management efforts, as the species has a one-year life-cycle (Pen *et al*. 1991), and it is only known from Lennard Brook in the Swan-Canning system. The species was monitored in this stream between 1996 and 1998 (Morgan *et al*. 2000, and Figure 9) and was reported from Ellen Brook in McDowall and Frankenberg (1981) and Allen (1982). There are also two specimens in the Western Australian Museum that were collected from an excavation in 1973 (locality between Gingin and Muchea) (see Figure 9). This suggests that the species was once more widespread in Ellen Brook. The population in Lennard Brook is most likely maintained by the perennial groundwater discharge that the brook receives, which acts as a buffer to extreme temperatures and oxygen levels and the flows apparently reduce the success of Eastern Mosquitofish. It is also likely that due to a long period of isolation (noting that the nearest population of the species is ~300 km to the south in the Vasse River near Busselton) the population is genetically distinct, as are populations elsewhere, even within single catchments (see Phillips *et al*. 2007). It is recommended that more intensive survey efforts in Lennard Brook and Yalyal Brook which looks very suitable as habitat, are undertaken. Yalyal Brook may be a potential site for the translocation of the species, provided adequate numbers of the species remain in Lennard Brook.

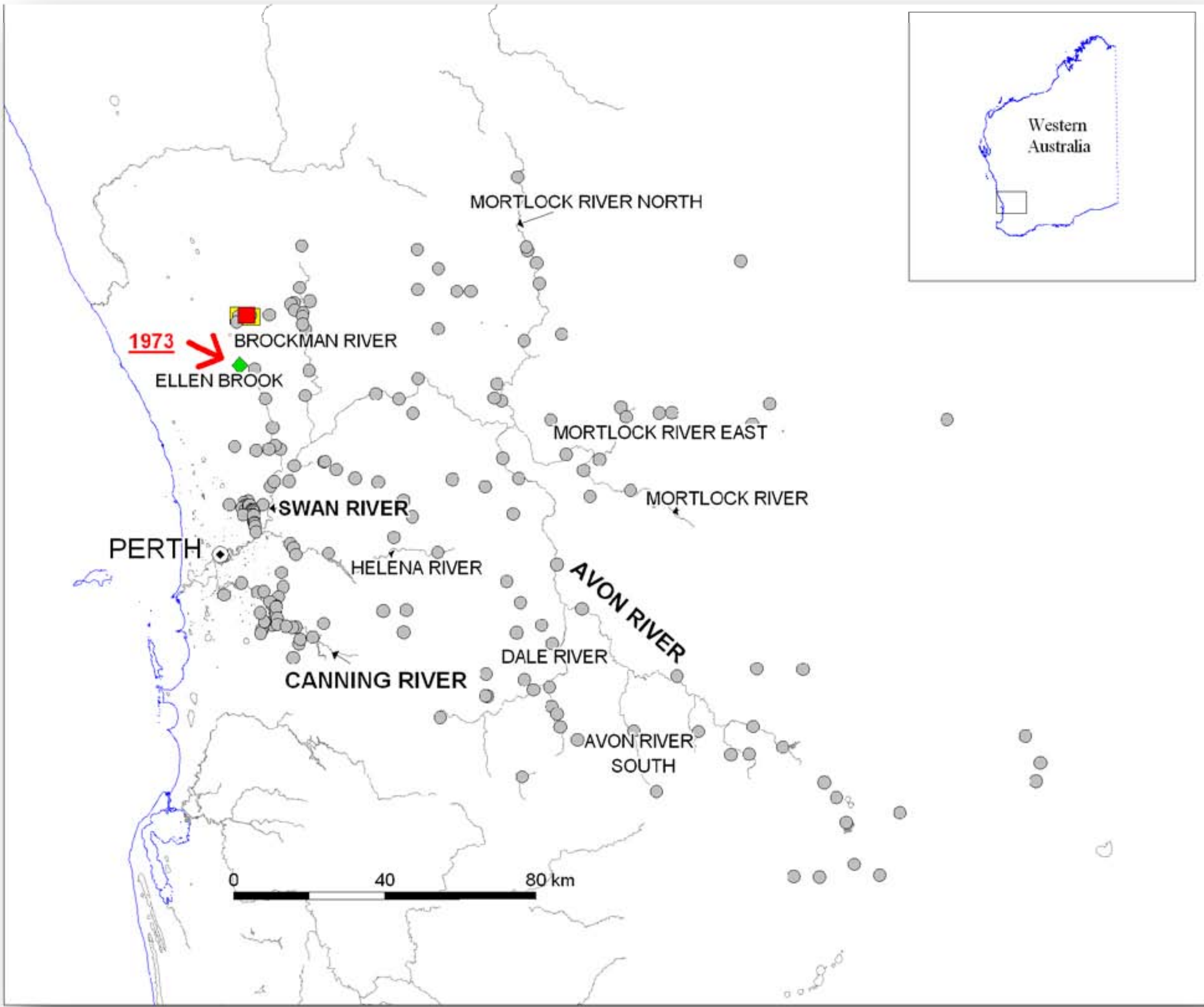


Figure 9 Distribution of the Western Mud Minnow in the Swan-Canning catchment. N.B. Yellow boxes are capture sites in the current survey, red squares are our historical capture sites and grey circles non-capture sites from the Freshwater Fish Group (CFFR, Murdoch University) database. Note the 1973 record (from collections in the Western Australian Museum).

Black-stripe Minnow (*Galaxiella nigrostriata*)

Photo: G. Allen

The Black-stripe Minnow is one of five members of the family Galaxiidae found in south-western Australia, one of the three endemic galaxiids in the south-west and one of only three species of *Galaxiella* (Allen *et al.* 2002). This species has a one-year life-cycle, a protracted breeding period and aestivates to some extent; the precise mechanisms behind this process, however, are largely unknown (Pen *et al*. 1993, Gill and Morgan 1996, Morgan *et al*. 1998). Its contemporary distribution is patchy and recent research suggests that this may be due to loss of suitable habitats (Morgan *et al*. 1998, Gill and Morgan 2003). Until 2009, this species was known only from Melaleuca Park (Ellen Brook) in the entire Swan-Canning catchment (Figure 10) (Morgan *et al*. 1998, Smith *et al*. 2002a), with McLure and Horwitz (2009) recording the species in Lake Chandala; this was recently verified genetically by David Galleoti (Edith Cowan University). Although we sampled Lake Chandala (February 2010) it was extremely dry at the time and it is likely that the individuals had aestivated, although the densities of the predatory introduced Eastern Mosquitofish were high at the time. The next nearest population is in the Kemerton area north of Bunbury, and then it is found in locally abundant populations in ephemeral coastal water bodies between Augusta and Denmark (Pen *et al*. 1993, Morgan *et al*. 1998). The conservation of the outlying population(s) of the species is a priority.

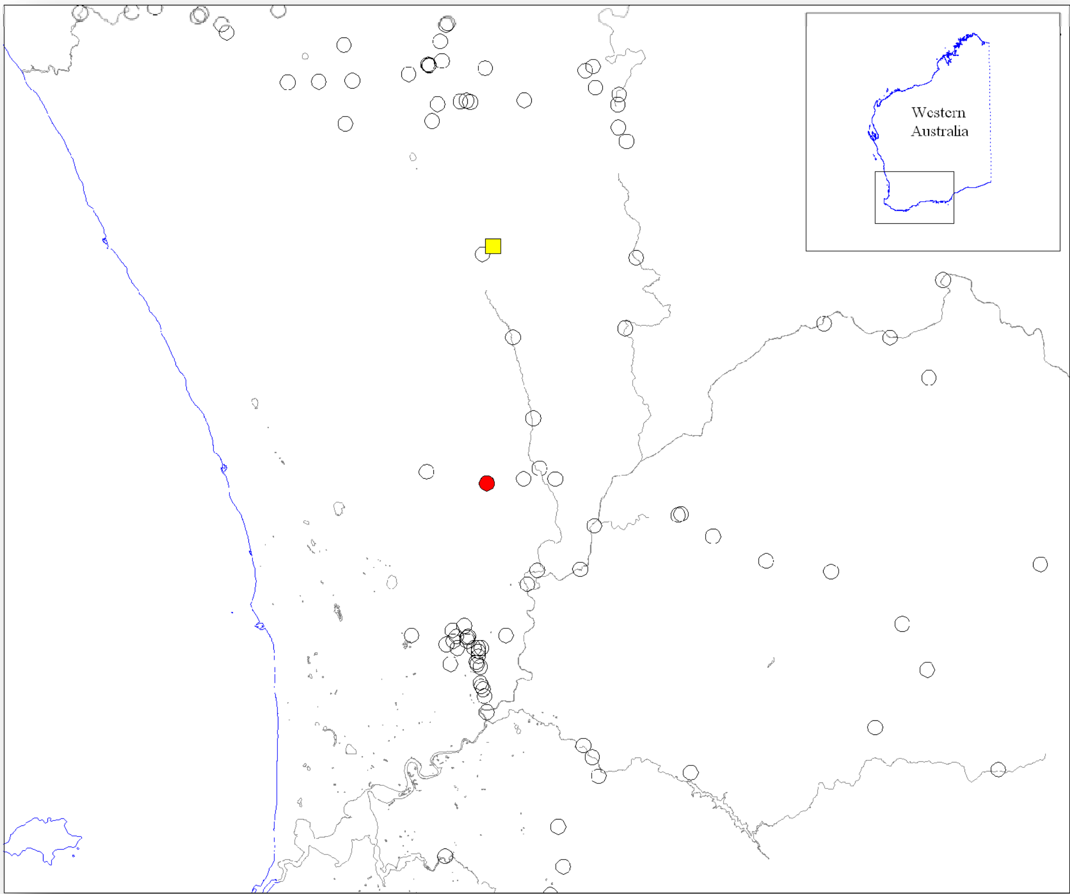


Figure 10 Distribution of the Black-stripe Minnow in the Swan-Canning catchment. N.B. The yellow box is a recent record from McLure and Horwitz (2009) and the red circle is from historical capture sites (Melaleuca Swamp) (Smith *et al*. 2002a, CFFR Database) and open circles non-capture sites from the Freshwater Fish Group (CFFR, Murdoch University) database.

Western Pygmy Perch (*Edelia vittata*)

The Western Pygmy Perch is one of two formally recognised nannopercids in south-western Australia. A third species was, however, recently discovered in the Denmark region (Morgan and Beatty, unpublished data). Within the Swan-Canning catchment the Western Pygmy Perch is restricted to fresh habitats and is found in only one (groundwater-fed) site east of the Darling Scarp (Figure 11), which suggests that it has been lost from much of the greater catchment. It was recorded in four sites in both the Brockman River and Ellen Brook (Tables 1 and 2). The Western Pygmy Perch is a relatively widespread species in the freshwater systems of south-western Australia. Although the acute salinity tolerance of the species has recently been found to be similar to Western Minnows, it is generally found only in remnant freshwater habitats (<~5ppt), suggesting that it is more susceptible to changes in salinity during some of its life-history stages. For example, sperm viability may be reduced in saline systems, larvae may be less salt-tolerant than adults, or salinisation may have led to a decline in prey specific to larval development stages (see Morgan *et al*. 2003).

The major spawning period of the Western Pygmy Perch is spring (Pen and Potter 1990). Thus, some of the current sampling (i.e. November 2009) coincided with this period. During the breeding period, the males of the species become brightly coloured. The species is known to undertake spawning migrations from the main channel of systems into tributaries (Beatty *et al*. 2006). The species was captured in similar numbers moving upstream and downstream within each system (Figure 12).

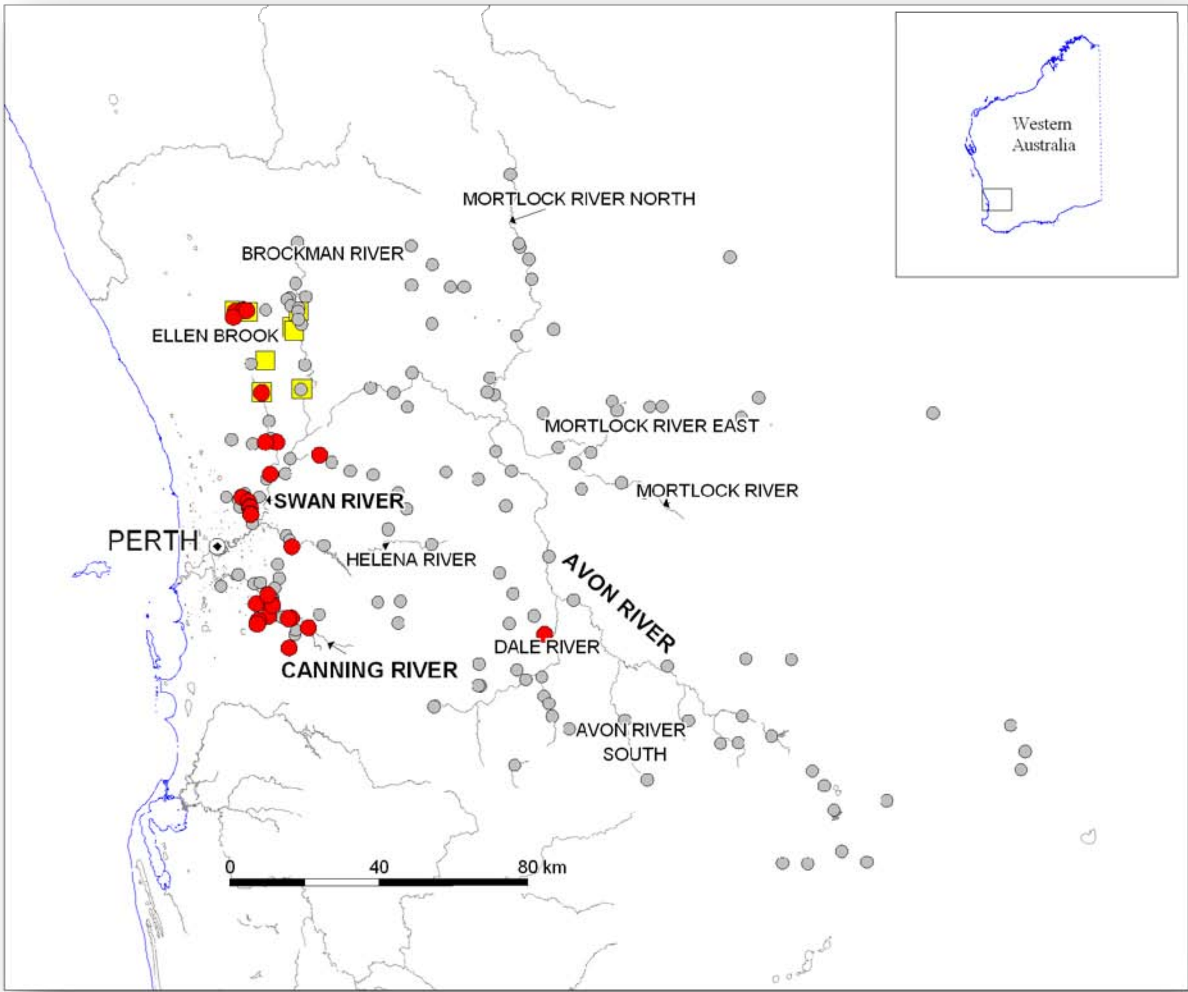


Figure 11 Distribution of the Western Pygmy Perch in the Swan-Canning catchment. N.B. boxes are capture sites in the current survey, red circles are historical capture sites and grey circles non-capture sites from the Freshwater Fish Group (CFFR) database.

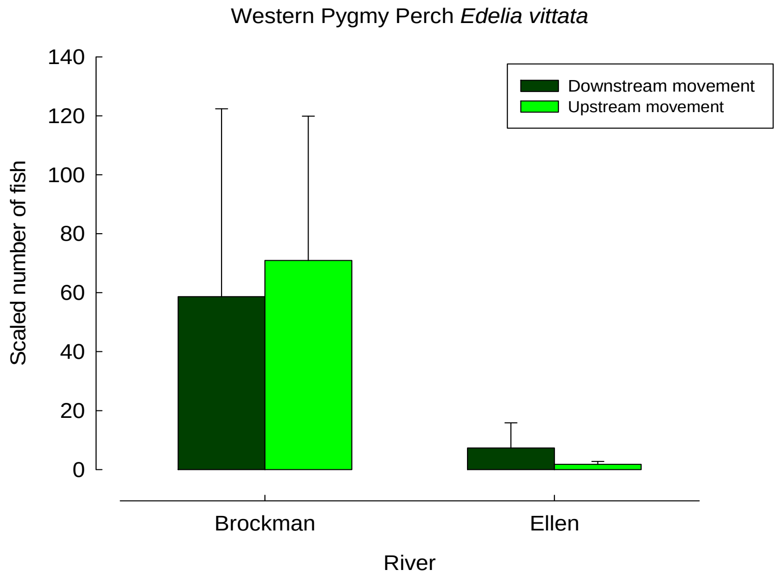


Figure 12 Upstream and downstream movement of the Western Pygmy Perch within Brockman River and Ellen Brook.

From the length-frequency distribution, the population of Western Pygmy Perch within Brockman River was dominated by 0+ individuals (modal length 25-29 mm TL) whereas greater numbers of larger, older cohorts were recorded from Ellen Brook (mode 45-49 mm TL). Similar to the Western Minnow, the majority of Western Pygmy Perch were captured from the perennially flowing Lennard Brook in February 2010 which may have accounted for the larger modal size (i.e. allowing ~3 months of additional growth) in the Ellen Brook length-frequency distribution. The greater numbers of cohorts >0+ in the latter system may also reflect more suitable habitat availability in Lennard Brook when compared to the Brockman River (Figure 13). Regardless, the fresh tributaries of the Swan-Canning system, such as Ellen Brook and the Brockman River are important refuges for the species. The importance of these refuges is further highlighted when considering that there are distinct genetic differences between populations of the species throughout it range (Unmack, Adams, Hammer, Morgan and Beatty unpublished data).

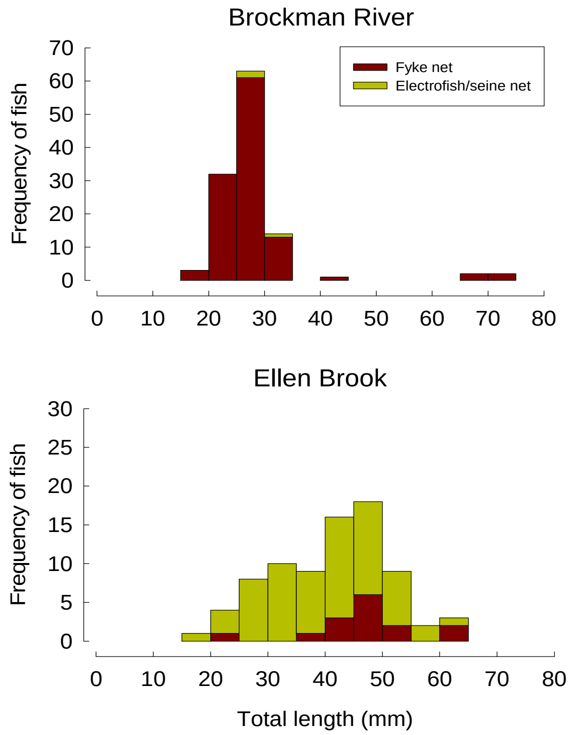


Figure 13 Length-frequency distributions of the Western Pygmy Perch captured in the Brockman River and Ellen Brook.

Nightfish (*Bostockia porosa*)

The Nightfish was almost entirely restricted to freshwater habitats within the Swan-Canning catchment (Figure 14). Within the current survey, it was captured in five and four sites in the Brockman River and Ellen Brook, respectively (Tables 1 and 2, Figure 14). Although the acute salinity tolerance is unknown, based on the Freshwater Group (CFFR) database, it is likely to be similar to the Western Pygmy Perch. The capture of large numbers of 0+ individuals at the Cook Rd site in the Brockman River (8.24 mS/cm: the most saline site in the study) suggests that it can tolerate, and possibly breed in, at least that level of salinity (Table 1).

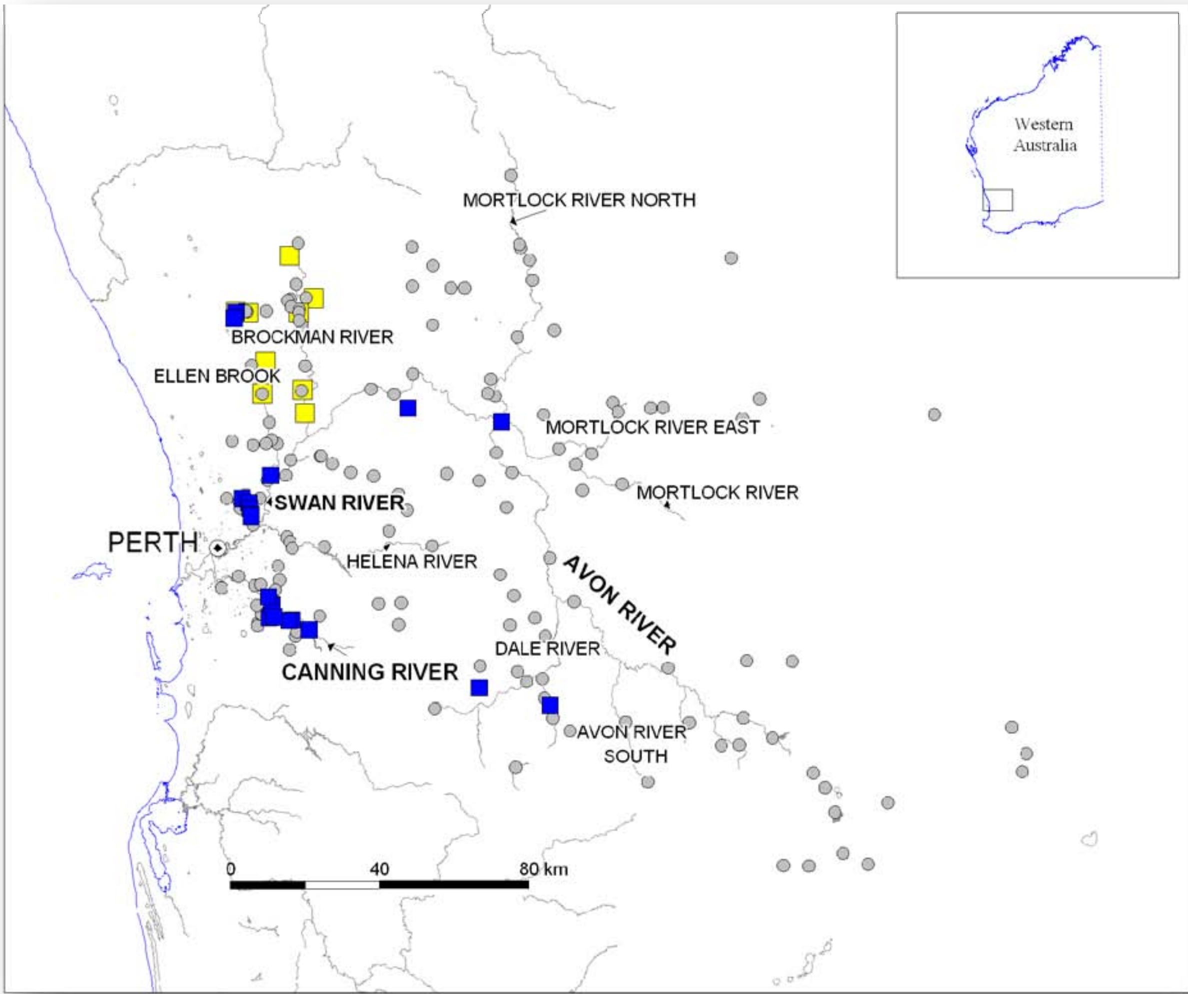


Figure 14 Distribution of Nightfish in the Swan-Canning catchment. N.B. Yellow boxes are capture sites in the current survey, blue boxes are historical capture sites and grey circles non-capture sites from the Freshwater Fish Group (CFFR) database.

Similar to the Western Pygmy Perch, the species is known to have a peak spawning period in spring (Pen and Potter 1991c). Furthermore, it has recently been shown to undergo upstream spawning migrations into tributaries from the main channel of the Blackwood River with subsequent downstream movement of juveniles occurring in November/December (Beatty *et al*. 2006). Interestingly, the fyke captures in Brockman River were a reverse of this trend with large numbers of 0+ individuals (mode 40-44 mm TL) recorded moving upstream at the Cook Rd site (Figures 15 and 16). Regardless, the upper Brockman River appears to be a major breeding and nursery area for this species. The length-frequency distributions also demonstrated that viable populations, with a wide range of size and age cohorts, were present in both the Brockman River and Ellen Brook (Figure 16), and these are important refugia for the species.

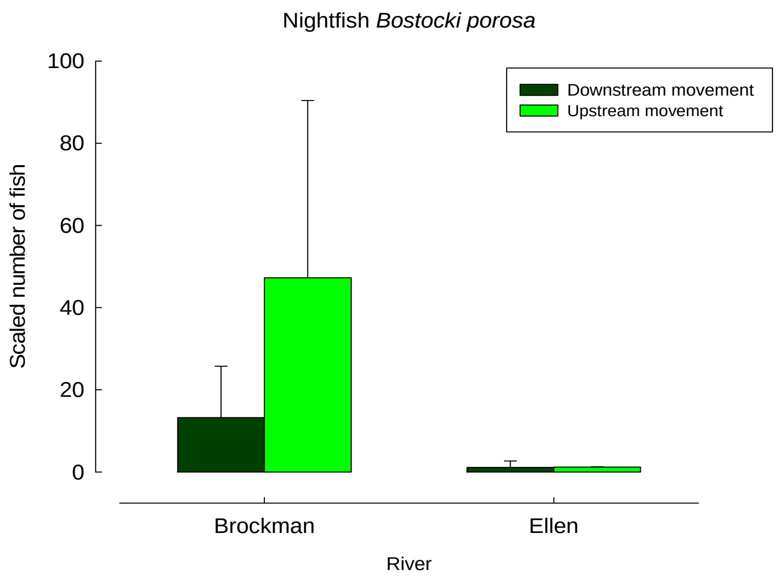


Figure 15 Upstream and downstream movement of the Nightfish within Brockman River and Ellen Brook.

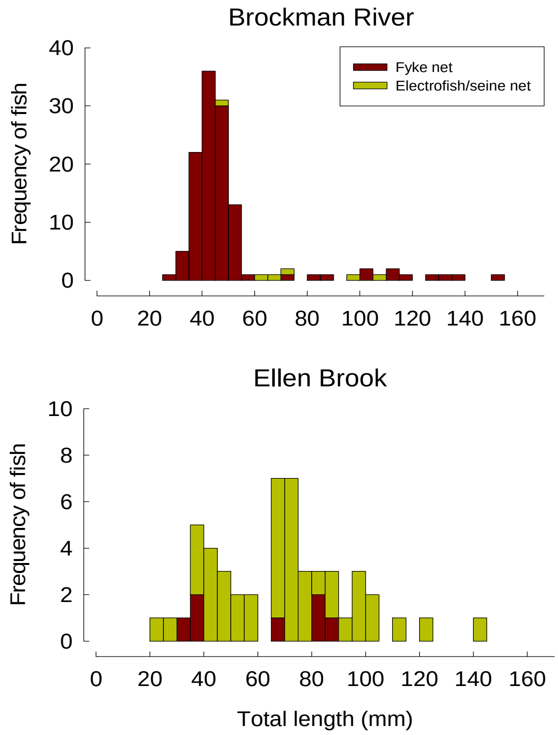


Figure 16 Length-frequency histograms of Nightfish captured in the Brockman River and Ellen Brook.

Freshwater Cobbler (*Tandanus bostocki*)

Photo: M. Allen

Growing to ~50 cm TL, the Freshwater Cobbler is south-western Australia's largest native freshwater fish. It generally prefers the main channel of rivers and is occasionally encountered in downstream sections of small tributaries (Beatty and Morgan, unpubl data). In the current survey, reasonable numbers were recorded within the Brockman River at Julimar Bridge, Clune Park and Marbling Brook (adjacent to the main channel) (Table 1, Figure 17). The Freshwater Cobbler is known to undertake large localised migrations over riffle zones during spring and summer, probably for feeding rather than spawning purposes, and therefore baseflow connectivity of riffle zones can be important to enable access through those zones (Beatty *et al*. 2006). Its major spawning period is late spring/early summer and females reach maturity at ~170 mm TL in the Blackwood River (McAleer, Beatty and Morgan unpublished data). In the Brockman River, large numbers were recorded moving both upstream and downstream in November 2009 (Figure 15).

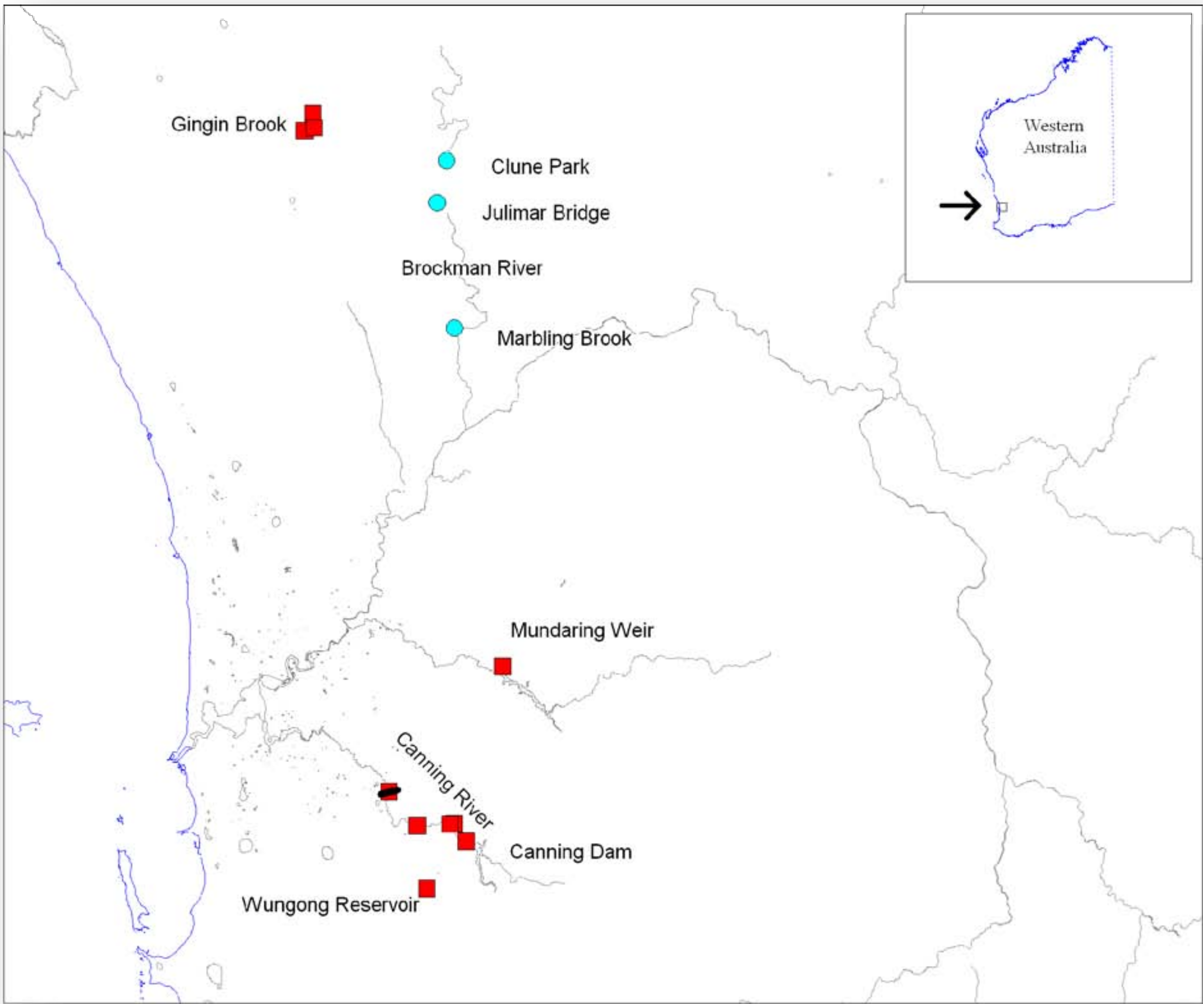


Figure 17 Distribution of Freshwater Cobbler in the Swan-Canning catchment. N.B. Blue circles are capture sites in the current survey, red boxes are historical capture sites from the Freshwater Fish Group (CFFR) database.

The population of Freshwater Cobbler in the Brockman River appears to be recruiting successfully as suggested by a wide size range of individuals being captured (size range 32 mm-399 mm TL); including the 0+ cohort <~100 mm TL (Figure 18). The species is also the major known host of glochidia of the Freshwater Mussel (*W. carteri*) (see Freshwater Mussel section below). Given its large size and the fact that it is the only recreationally fished native freshwater fish in south-western Australia, the species has the potential to be a flag-ship for river restoration and conservation programs.

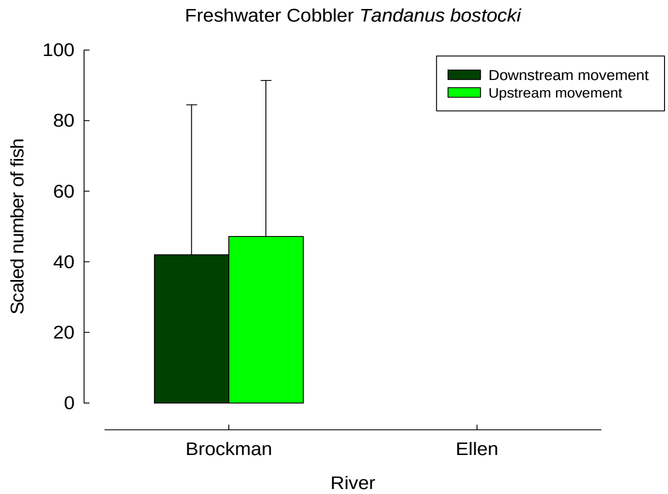


Figure 18 Upstream and downstream movement of the Freshwater Cobbler within Brockman River.

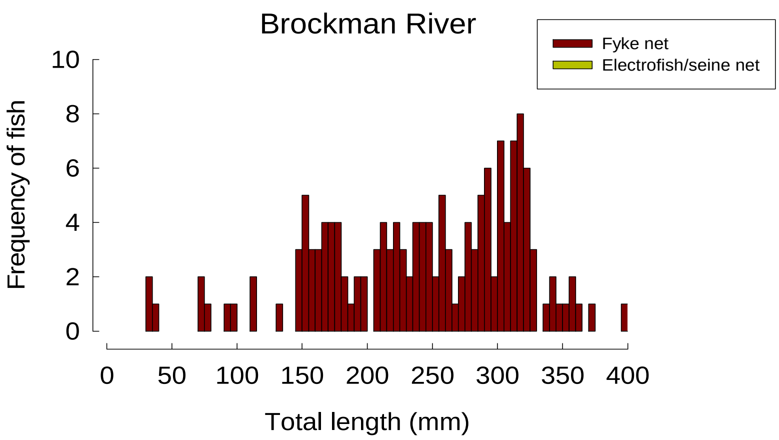


Figure 19 Length-frequency distributions of the Freshwater Cobbler captured in the Brockman River.

Native Estuarine Fishes

Western Hardyhead (*Leptatherina wallacei*)

The typically estuarine Western Hardyhead has penetrated inland in the Swan catchment, perhaps as a result of secondary salinisation (see Morgan *et al*. 2003) and was recorded at numerous sites in inland salinised tributaries including the Avon, Mortlock and Dale rivers (Figure 20). The Western Hardyhead is one of two estuarine species recorded in the freshwaters of the Brockman River and Ellen Brook catchments in the current study. It was captured at two sites in the Brockman River and was only recorded in the Bambun Lakes in the Ellen Brook catchment (Tables 1 and 2, Figure 20).

Along with the Swan River Goby and the South-west Goby (*Afurcogobius suppositus*), the inland colonisation of this species into many of the major rivers in south-western Australia has been facilitated by secondary salinisation of those systems (see Morgan *et al*. 1998, 2003, Beatty *et al*. 2006). This saline environment has created conditions in these rivers that favour those species with a broad salinity tolerance (i.e. euryhaline) such as these typically estuarine species at the expense of the salt-intolerant freshwater (i.e. stenohaline) native fishes that have largely contracted into fresher, downstream tributaries; such as has occurred in the Brockman River and Ellen Brook (see Western Pygmy Perch and Nightfish).

Figure 21 illustrates that the vast majority of Western Hardyheads were moving upstream in the Brockman River. From the length-frequency histogram (Figure 22), the population was dominated by new recruits with a modal length of 15-19 mm TL. This upstream movement of this cohort was unlikely to be a spawning migration but rather to colonise upstream habitats.

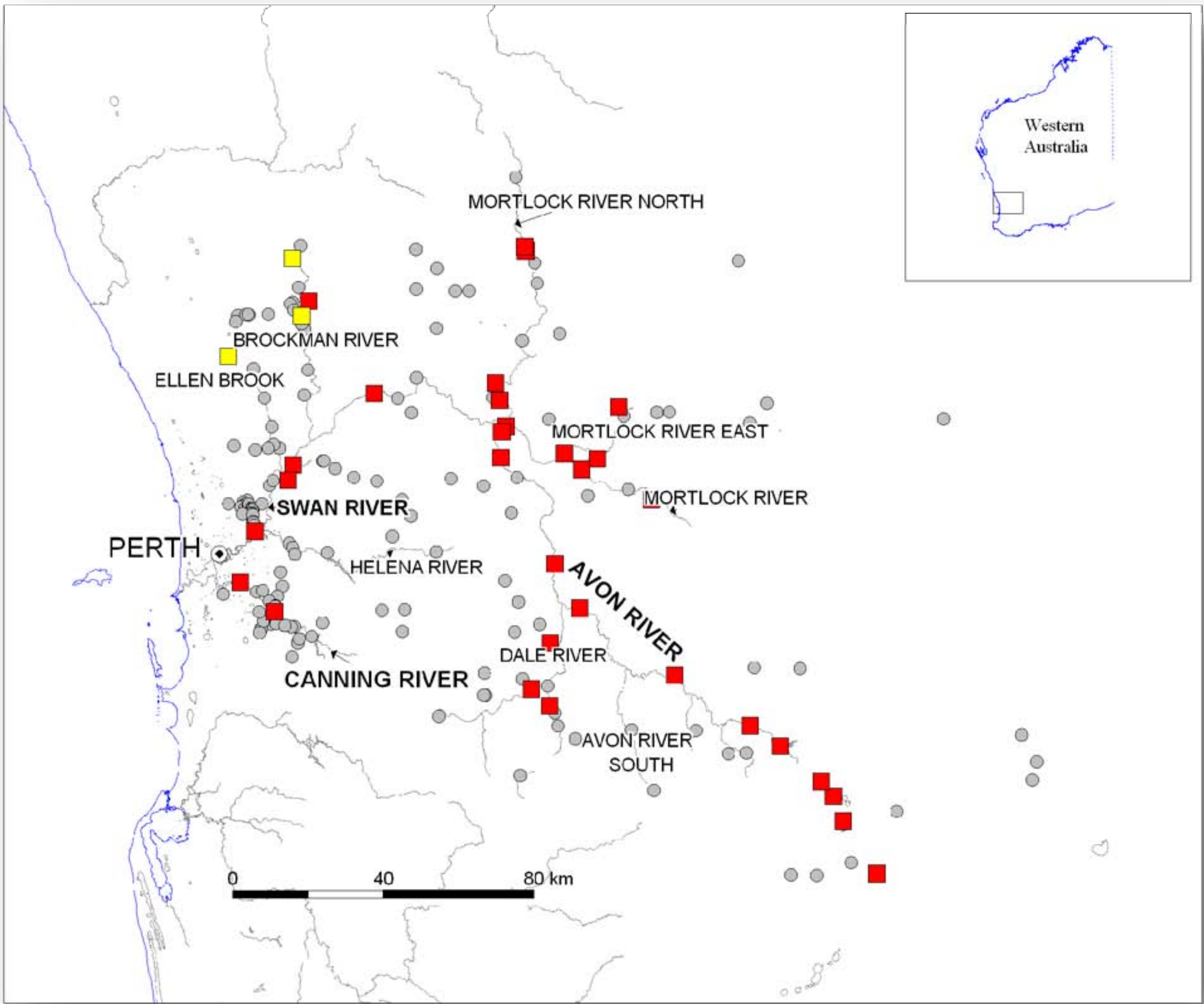


Figure 20 Distribution of the Western Hardyhead in the Swan-Canning catchment. N.B. Yellow boxes are capture sites in the current survey, red boxes are historical capture sites and grey circles non-capture sites from the Freshwater Fish Group (CFFR) database.

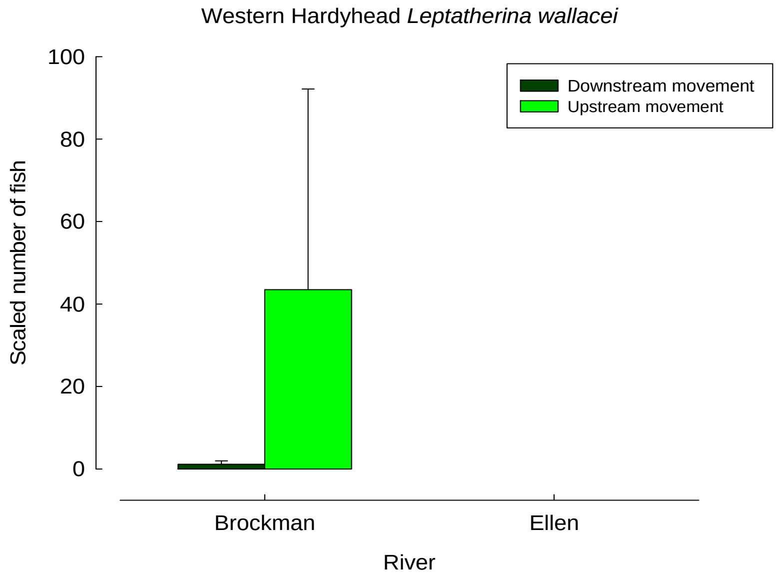


Figure 21 Upstream and downstream movement of the Western Hardyhead within the Brockman River.

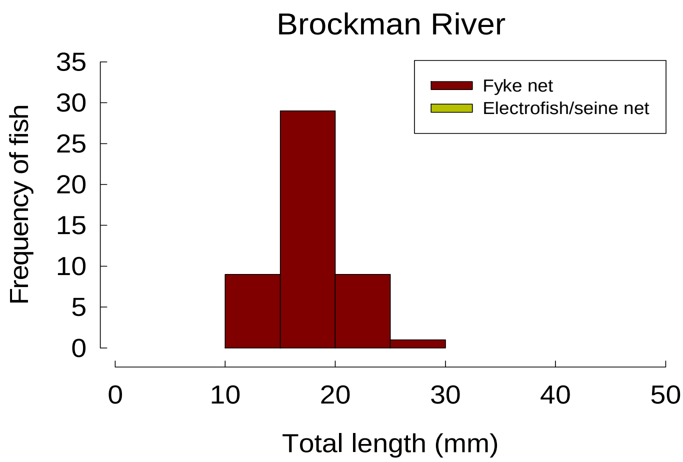


Figure 22 Length-frequency distributions of the Western Hardyhead captured in the Brockman River.

Swan River Goby (*Pseudogobius olorum*)

The Swan River Goby (also known as Blue-spot Goby) is found throughout the Swan-Canning catchment including major tributaries such as the Mortlock, Dale and Avon (Figure 23). During the survey of the Brockman River and Ellen Brook, it was recorded at two sites in the Brockman River (i.e. Clune Park and Cook Rd) and in Bambun Lake in the Ellen Brook Catchment (Tables 1 and 2) and it has previously been recorded elsewhere in these systems (Figure 23) (Morgan *et al*. 2000). This typically estuarine species has penetrated inland in the Swan-Canning and other secondarily salinised systems such as the Blackwood River (Morgan *et al*. 2003). Although not recorded in the current survey, a number of species, such as the South-west Goby (*A. suppositus*), Black Bream (*Acanthopagrus butcheri*) and Sea Mullet (*Mugil cephalus*) may also, at least seasonally, utilise the lower reaches of these two systems.

The majority of the Swan River Gobies were captured moving downstream in the Brockman River and there were clearly two size cohorts present (modes of 25-29 mm and 45-49 mm TL) that are likely to correspond to two age classes (Figures 24 and 25). Similar to other small estuarine species that penetrate into salinised rivers, the Swan River Goby appears to breed within the Brockman River and is not reliant on the Swan River estuary for recruitment. Furthermore, the very large numbers recorded from Bambun Lakes (12.2 per m^2) also suggests that there is also a self-maintaining population within that site (Tables 1 and 2).

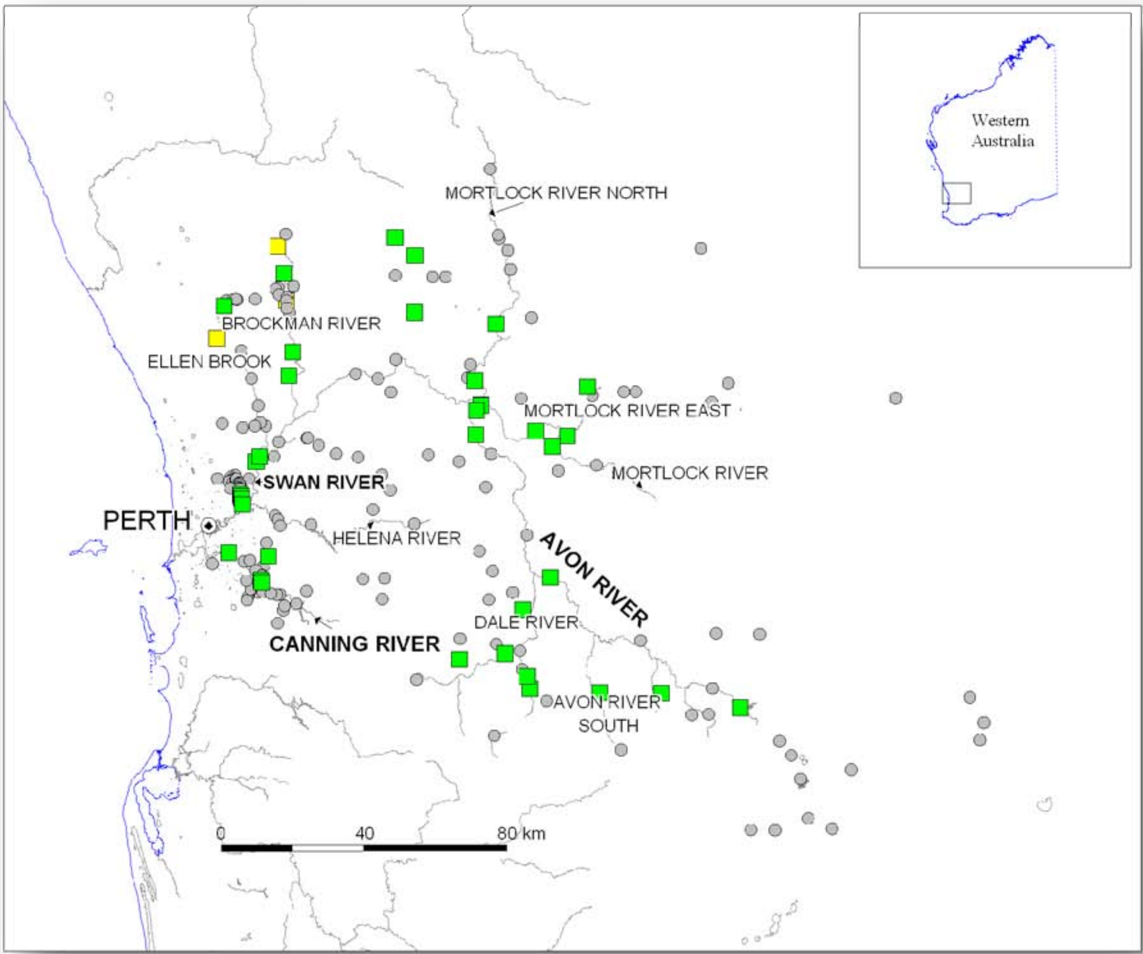


Figure 23 Distribution of the Swan River Goby in the Swan-Canning catchment. N.B. yellow boxes are capture sites in the current survey, green boxes are capture sites and grey circles non-capture sites from the Freshwater Fish Group (CFFR) database.

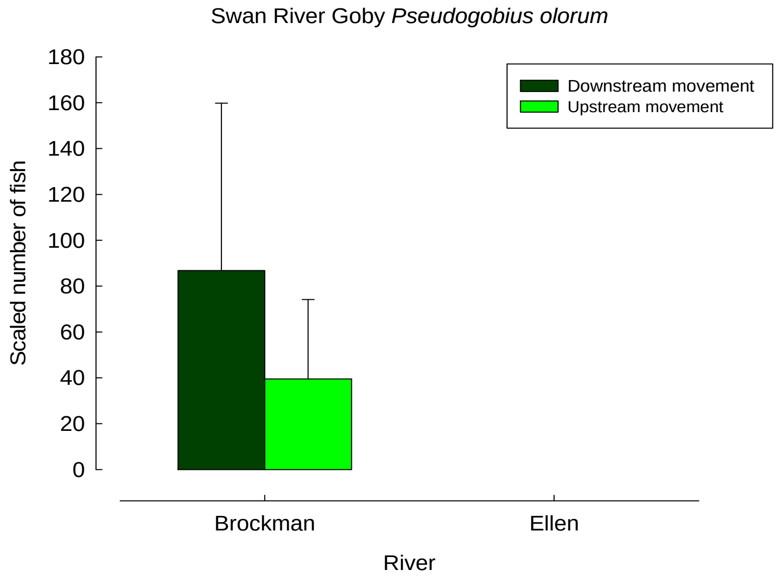


Figure 24 Upstream and downstream movement of the Swan River Goby within the Brockman River.

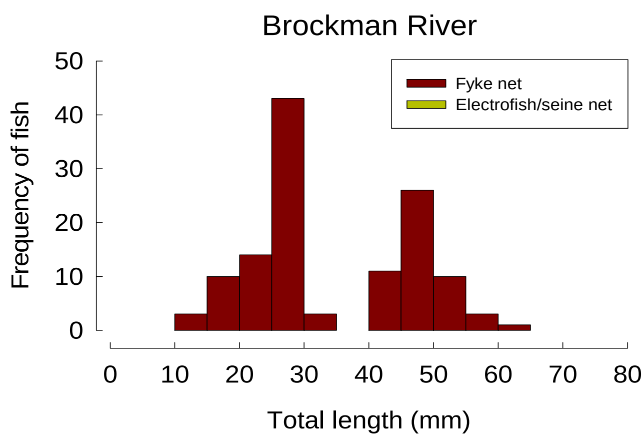


Figure 25 Length-frequency histogram of the Swan River Goby within the Brockman River.

Freshwater Decapods

Gilgie (*Cherax quinquecarinatus*)

All 11 native freshwater species of south-western Australia are endemic to the region (Austin and Knott 1996, Horwitz and Adams 2000) and freshwater crayfish are known to play important roles in the structure and function of aquatic ecosystems and can thereby be keystone species. The Gilgie is one of the most widespread of these species, being found in almost all freshwater habitats including ephemeral wetlands, streams and major rivers (Austin and Knott 1996; Beatty *et al*. 2005a). The Gilgie was very widespread in both the Brockman River (seven of nine sites) and Ellen Brook (six of the eight sites) (Tables 1 and 2). Most individuals were recorded moving in a downstream direction (Figure 26). The movement pattern of this species has not previously been examined in detail. Both systems housed self-sustaining populations of this species as indicated by their widespread distribution, high abundances, and the relatively wide size range including juvenile individuals and older age classes (Figure 27) (see Beatty *et al*. 2005a).

The ability of the Gilgie to burrow into the water table during the summer dry periods has facilitated the use of seasonally inundated habitats. The species is also known to have a life-history strategy that allows it to rapidly re-colonise habitats, such as potentially breeding multiple times a year (Beatty *et al*. 2005a).

The Gilgie and another widespread species, the Koonac (*Cherax preissii*), are often mistakenly identified as the eastern Australian Yabbie (*Cherax destructor*) (see Yabbie section), however, both can be easily differentiated by the presence of setae on the merus ('arm') and carpus ('wrist') on Yabbies that are absent from any south-western freshwater crayfish (Figure 28).

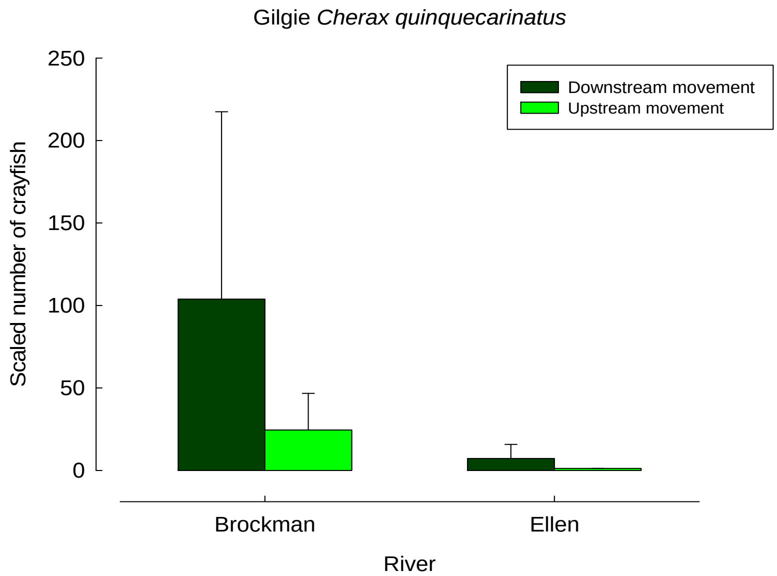


Figure 26 Upstream and downstream movement of the Gilgie within the Brockman River and Ellen Brook.

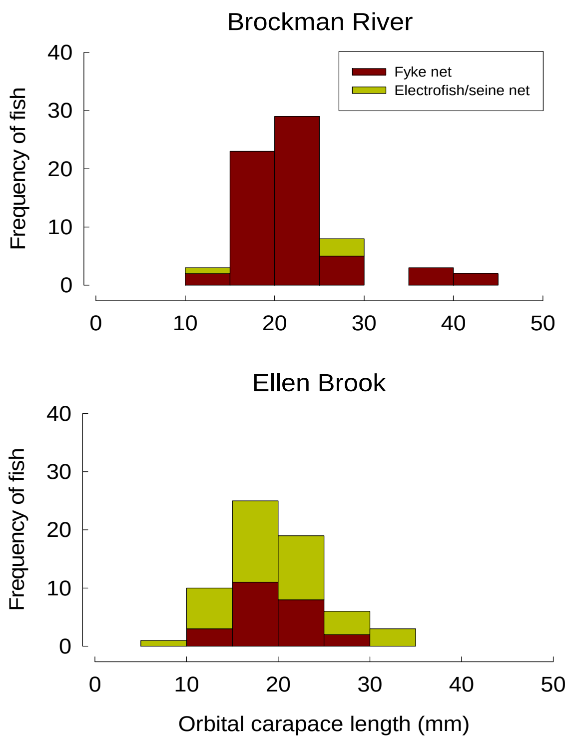


Figure 27 Length-frequency distributions of the Gilgie within the Brockman River and Ellen Brook.

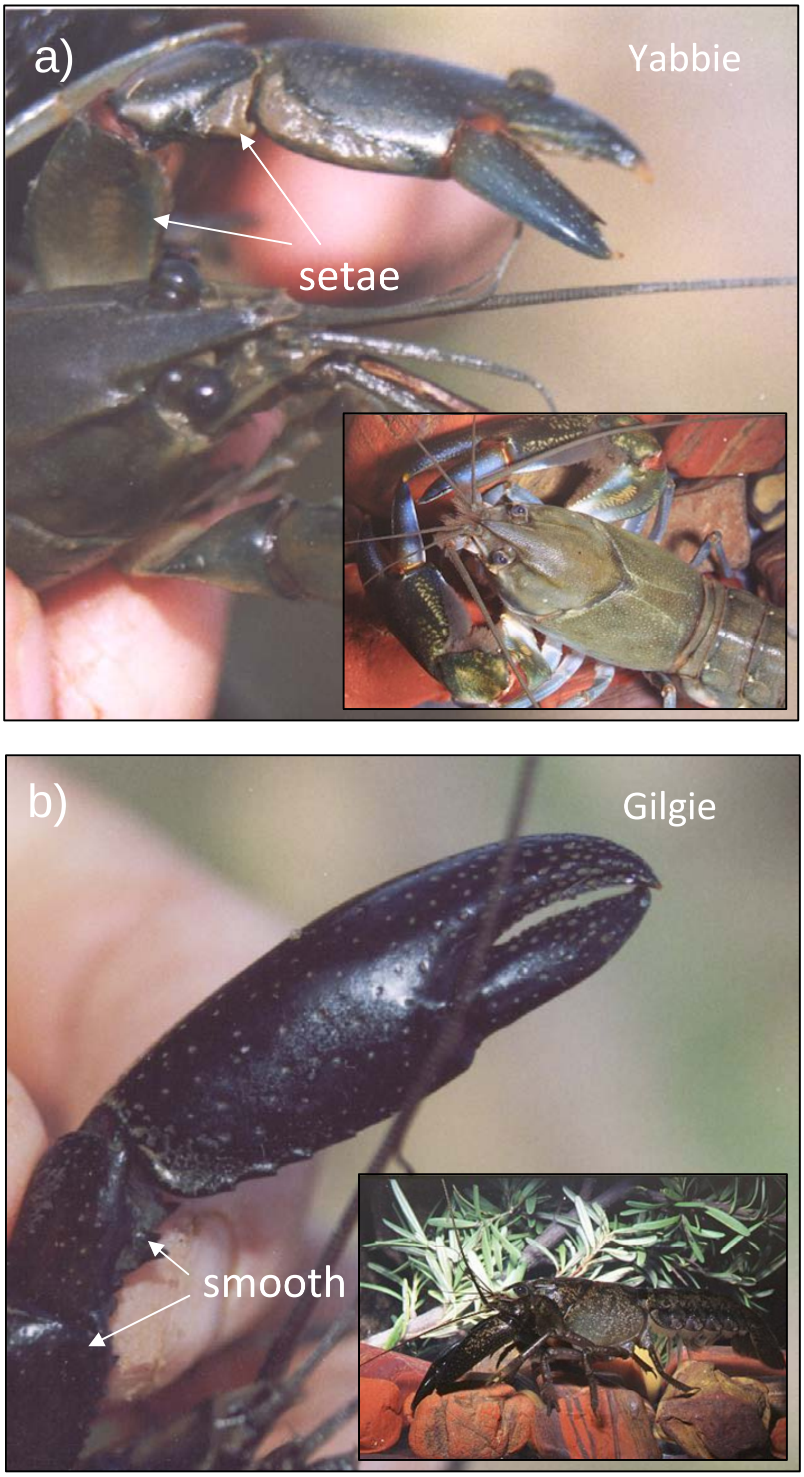


Figure 28 Differences between the native Gilgie (*Cherax quinquecarinatus*) and the eastern Australian Yabbie (*Cherax destructor*). Note the setae on the carpus ('wrist') and merus ('arm') of the Yabbie that is absent from endemic freshwater crayfish of WA.

One individual Gilgie from Yalyal Brook appeared to be infected by a microsporidian due to the white streaky appearance of muscle tissue (infection is known as 'porcelain' disease) (Figure 29). Two species of microsporidian are known from Western Australia: *Thelohania parastaci* and *Vavraia parastacida* that are both similar in appearance (Beatty 2005). The former genus includes species that have been documented to cause serious impacts on freshwater crayfishes; including Yabbies in Western Australian farm dams (Moodie 2003). Transmission of the spores of these microsporidians (see Figure 30) is generally by consumption of infected tissue. Given that both Yabbies and Gilgies were present in Yalyal Brook, the observed infection may have been either *T. parastaci* or *V. parastacida*; this requires genetic determination.

Figure 29 Microsporidian infection on a Gilgie from Yalyal Brook, Ellen Brook. Note the white, streaky muscle tissue in the abdomen.

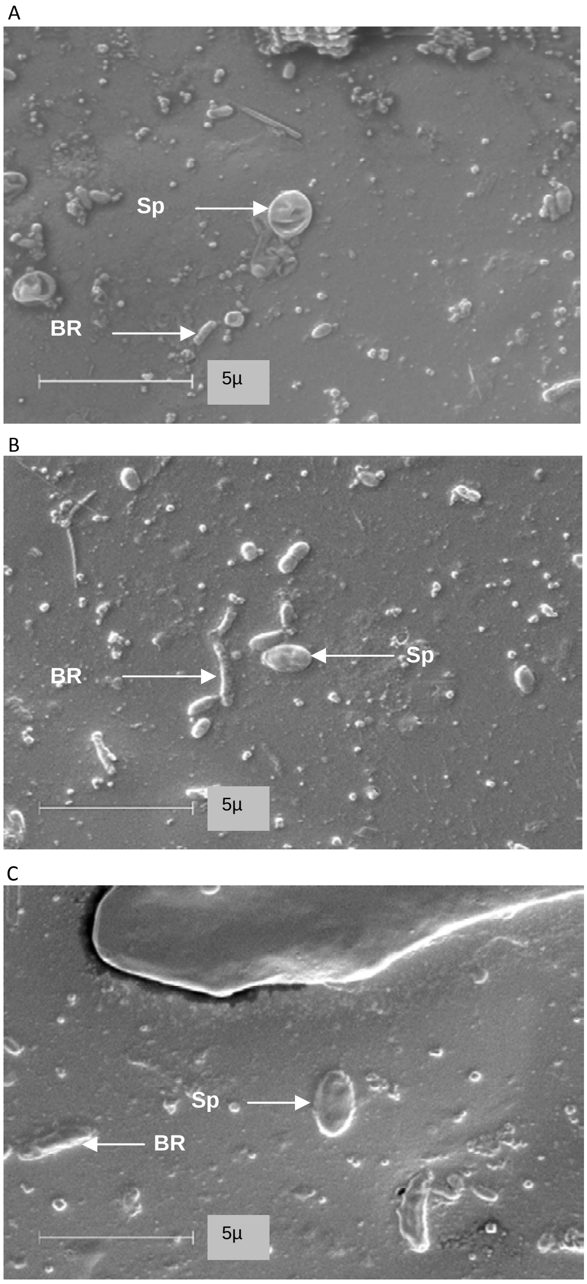


Figure 30 Scanning electron microscope images of mature spores (Sp) of *Thelohania parastaci* from *Cherax destructor* in the Hutt River WA. N.B. Bacterial rods are shown (BR), magnification = 3600x. From Beatty (2005).

Smooth Marron (*Cherax cainii*)

The Marron was recorded at two sites in the Brockman River (Marbling Brook and Moondyne) and one in the Ellen Brook catchment (Lennard Brook) (Tables 1 and 2). The species relies on permanent habitat for survival and does not utilise the seasonally inundated habitats that Gilgies and Yabbies occupy. Therefore, those sites in which the species was recorded in the current survey must provide such permanent aquatic habitat (such as the groundwater-maintained Lennard Brook). From the length-frequency of Marron in Lennard Brook, the population there probably consisted of two age classes (see growth rates in Beatty *et al*. 2005b) and therefore it appears to be breeding in that system (Figure 31). Additional survey effort would be required to confirm the sustainability of the population in that system and the other sites where it was recorded in the study.

The Marron supports an iconic inland recreational fishery and is the world's third largest freshwater crayfish species. Its geographical range has changed substantially since European settlement; previously believed to be distributed between Harvey and west of Albany, it has been translocated north to the Hutt River (north of Geraldton) and east to the Esperance region, whilst its inland range has been reduced due to secondary salinisation and eutrophication of inland reaches of major rivers (Morrissy 1978; Austin and Knott 1996). Unlike smaller crayfish species, the Marron generally reproduces annually, matures at the end of its second year of life, and has a fast growth rate (Beatty *et al*. 2003, 2005b). Like most freshwater crayfishes, its diet consists largely of detritus; however, it has recently been shown to also be an opportunistic omnivore assimilating considerable amounts of animal material (Beatty 2006).

Therefore, as with other crayfishes, the species has the potential to be a keystone aquatic species important in structuring ecosystems.

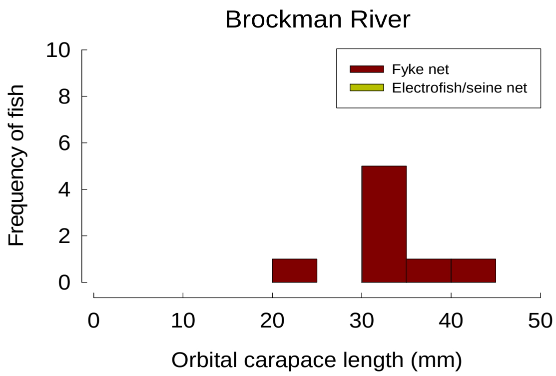


Figure 31 Length-frequency histogram of Marron within the Brockman River.

Yabbie (*Cherax destructor*) FERAL

The Yabbie is the only feral freshwater crayfish species currently known from south-western Australia. In the current study, it was recorded in the Ellen Brook catchment (Yalyal Brook, Brand Hwy and Chandala Brook) (Table 2). The length-frequency histogram of these individuals illustrates that there were at least two and possibly three age classes present (see biology of the species in Beatty *et al*. 2005c). Originally introduced into south-western Australia in the 1930's for aquaculture, this species has escaped into numerous wild aquatic systems in this region (Beatty *et al*. 2005c). Its life-history traits allow it to rapidly colonise new systems and these include: maturing in its first year of life, breeding multiple times during warmer months; burrowing to escape drought; tolerance of extreme temperatures and low dissolved oxygen; and omnivorous diet (e.g. Beatty *et al*. 2005c, Beatty 2006). It has been shown to compete for assimilated food sources with Marron (also having a similar growth rate in its first year of life) and undoubtedly competes with other endemic species when present (Beatty 2006). As discussed in the section on the Gilgie, the species also has the potential to introduce disease. Once established in a wild aquatic system, its eradication is extremely unlikely.

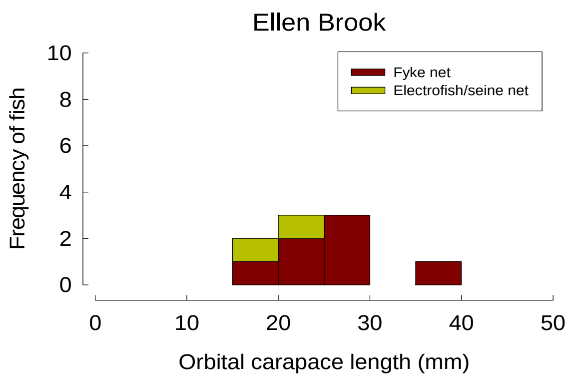


Figure 32 Length-frequency histogram of Yabbies within Ellen Brook.

Freshwater Shrimp (*Palaemonetes australis*)

The Freshwater Shrimp (also known as South-west Shrimp) was recorded at three sites each on the Brockman River and Ellen Brook (Tables 1 and 2). The species is endemic to south-western Australia and is found in a wide range of waterbodies including freshwater and salinised lakes and rivers. Little is known about its biology or ecology. The species is believed to breed during spring and summer (Beatty and Morgan, unpubl. data) and is an important dietary component of larger endemic freshwater fishes such as Freshwater Cobbler, Nightfish and Western Minnows (Morgan *et al*. 1998). Most individuals captured in fyke nets in the Brockman River were moving upstream (Figure 33).

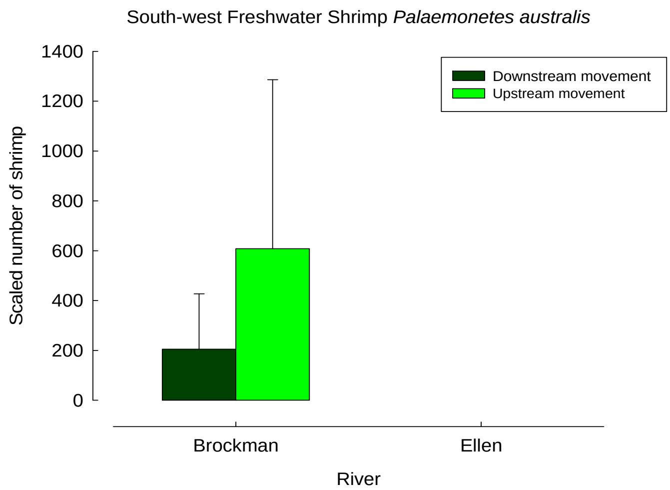


Figure 33 Upstream and downstream movement of the Freshwater Shrimp within the Brockman River and Ellen Brook.

Feral freshwater fishes

Eastern Mosquitofish (*Gambusia holbrooki*)

The Eastern Mosquitofish was recorded at two sites in the Brockman River and four in Ellen Brook with a maximum density of 40 fish/m^2 being recorded (at the Cook Rd site) (Figure 34, Tables 1 and 2). The Eastern Mosquitofish was captured moving in similar numbers upstream and downstream in the Brockman River (Figure 35). The species is not known to be a migratory fish and therefore this movement was probably related to localised feeding activity. The species has invaded the majority of the Swan-Canning catchment (Figure 34) and in particularly disturbed habitats it dominates the fish fauna. It is likely that the species has been found in this system since it was first introduced in the 1930s into WA for mosquito control. However, it is generally less abundant in habitats that experience perennial flows due to groundwater discharge, such as Lennard Brook. There are very few instances where this species co-exists with the small threatened galaxiid fauna of south-western Australia (such as Western Mud Minnow and Black-stripe Minnow) (Morgan and Beatty unpublished data). The reasons for this are probably species specific and may be a consequence of the habitat associations of these rare fishes. For example, throughout their range Western Mud Minnows are almost exclusively found in headwater streams or areas with groundwater discharge, whereas Black-stripe Minnows are usually associated with ephemeral wetlands. However, it may also be that as they are all small surface feeding fishes that have a high reliance on terrestrial fauna (insects) in their diets, the mosquitofish may out-compete the native fishes through aggression and abundance. Also, the mosquitofish is a well known fin-nipper of south-western Australia freshwater fishes (Gill *et al*. 1999).

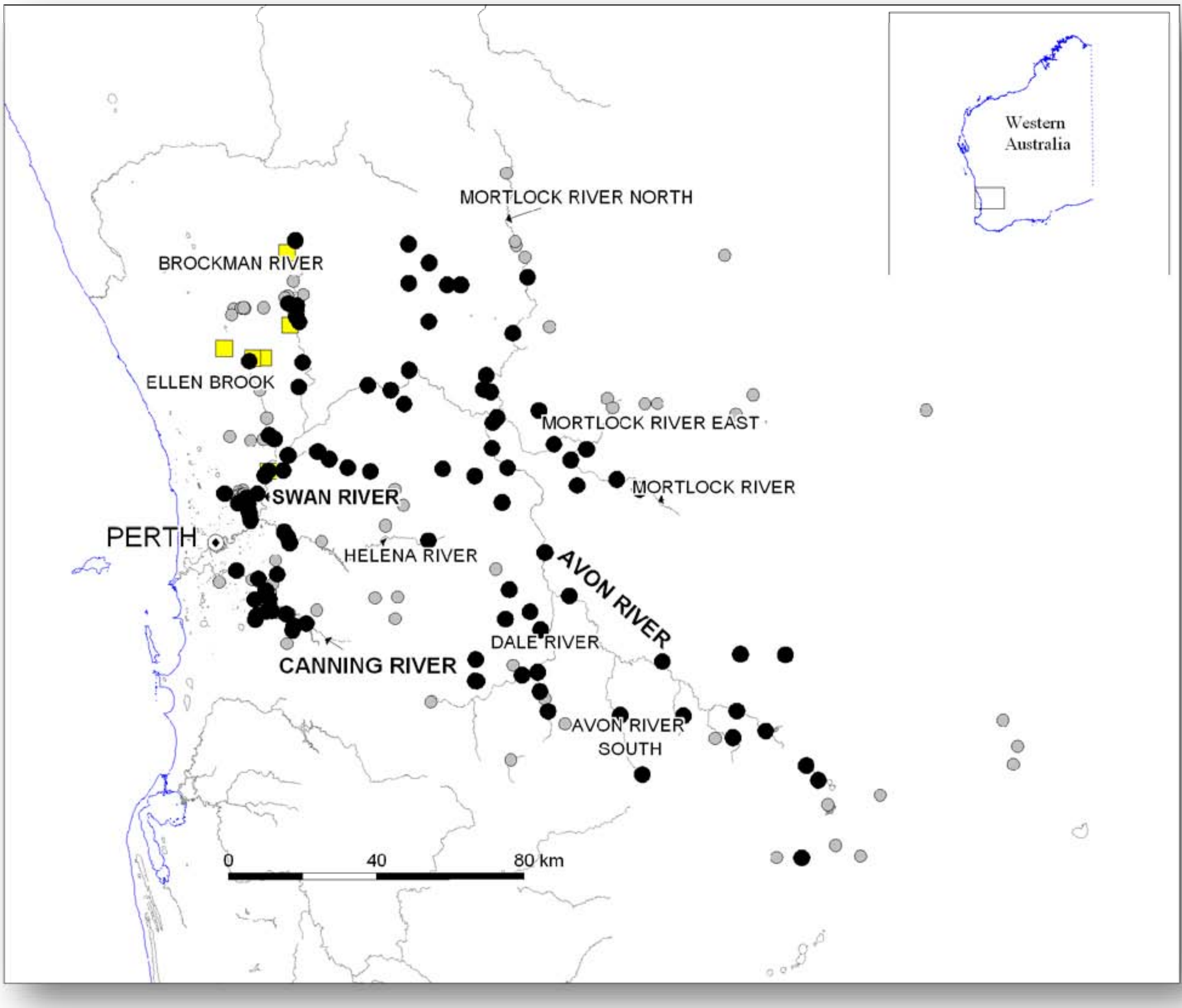


Figure 34 Distribution of the introduced Eastern Mosquitofish in the Swan-Canning catchment. N.B. Yellow boxes are capture sites in the current survey, black boxes are historical capture sites and grey circles non-capture sites from the Freshwater Fish Group (CFFR) database.

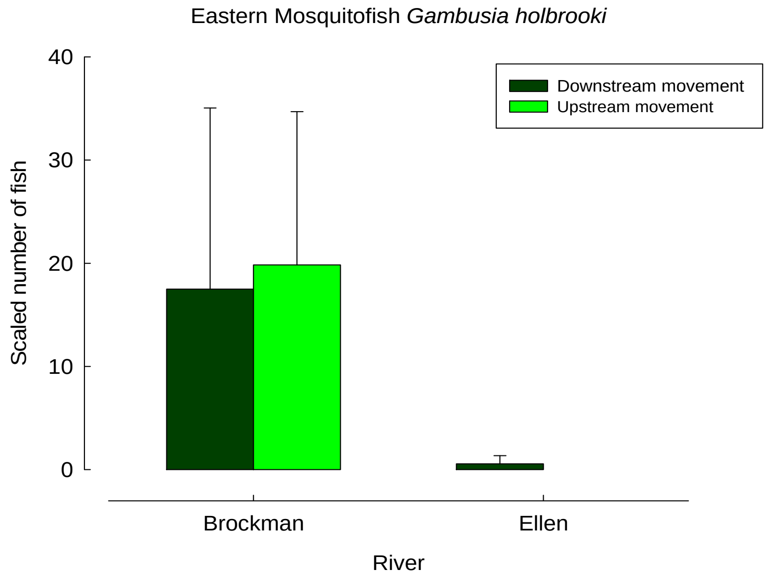


Figure 35 Upstream and downstream movement of the Eastern Gambusia within the Brockman River and Ellen Brook.

Goldfish (*Carrasius auratus*)

As a result of illegal releases, Goldfish, which are arguably the most popular of all aquarium fishes, are now found in wild aquatic systems of most Australian states and throughout much of the world (McKay 1984, Fuller *et al*. 1999, Gido and Brown 1999, Skelton 2001, Koehn and McKenzie 2004, Morgan *et al*. 2004). The species, which is native to eastern Asia, is now found in many artificial wetlands as well as a number of lakes and rivers of south-western Australia.

Their distribution in Western Australia is summarised in Morgan *et al*. (2004) and their ecological impacts and biology (diet, age and growth) were recently examined in the Vasse River (Morgan and Beatty 2006, 2007). Goldfish were captured in Ellen Brook between 1996 and 1998 (Morgan *et al*. 2000) and again during this study, but appear to be confined to the lower reaches of the brook. Anecdotal reports of Goldfish in the Brockman River were provided by T. Wallace via the Swan River Trust in 2009. While they are extremely successful and dominate specific aquatic ecosystems in south-western Australia, such as eutrophic waters where growth is rapid and the omnivorous diet is dominated by cyanobacteria (blue-green algae) (Morgan and Beatty 2006, 2007), in non-eutrophic waters of the south-west they are not nearly as successful and growth rates are subdued. Goldfish impact ecosystems through: (1) the introduction of disease and parasites (such as the ectoparasitic crustacean *Lernea cyprinacea* which was only recently discovered in south-western Australia (Figure 35) (Marina *et al*. 2008), (2) competition for food and habitat, (3) predation on native fishes and their eggs and, (4) the potential to fuel algal blooms through re-suspension of nutrients during feeding and re-activation of cyanobacteria on passage through their intestines (Kolmakov and Gladyshev 2003). They are also tolerant of a range of environmental variables such as high temperatures and relatively high salinities and low oxygen levels. The tolerance to adverse and fluctuating environmental conditions is partly why they are a favoured aquarium species, but also implies that if introduced into the wild they are likely to survive.

Figure 35 The introduced copepod parasite *Lernea cyprinacea* on the dorsal fin of a Freshwater Cobbler (*Tandanus bostocki*) from the Murray River, WA.

Native Reptiles

Oblong Turtle (*Chelodina oblonga*)

The Oblong Turtle, which was incidentally captured during fish surveys, was recorded at four sites in the Brockman River (Table 1). Most individuals were recorded moving upstream, however, many of these were from the dams in Spoonbill Reserve and therefore not indicative of migration movement (Table 1, Figure 36). The species is endemic to south-western Australia and occupies a wide range of permanent and temporary aquatic habitats including lakes and rivers (Cogger 1996). The species is known to have two nesting periods in spring (September-November) and summer (December-January) (Clay 1981). The length-frequency histogram demonstrates a wide size range indicative of multiple age classes (Figure 37) and the population appears self-maintaining in the Brockman River. Recent research has demonstrated that Marron, Koonacs and introduced Yabbies can be aggressive and predatory towards hatchlings of the Oblong Turtle (which has implications for the critically endangered Western Swamp Turtle in Ellen Brook Nature Reserve) (Bradsell *et al.* 2002).

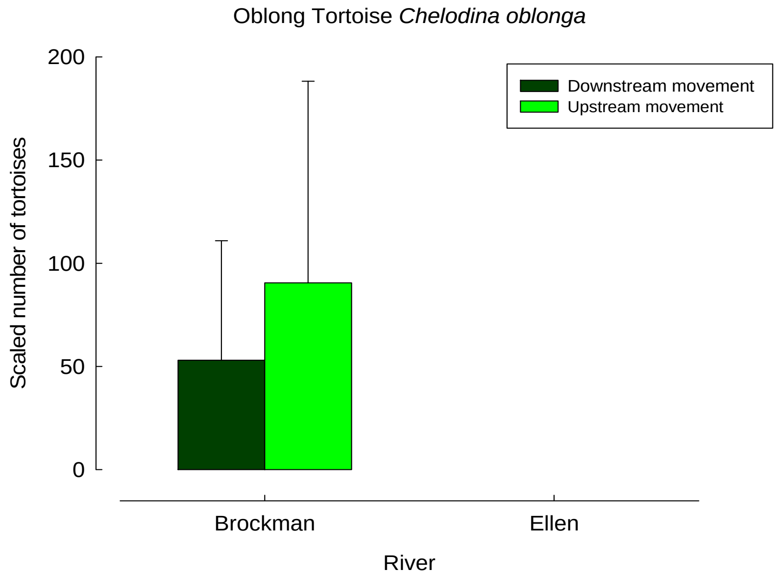


Figure 36 Upstream and downstream movement of the Oblong Turtle within the Brockman River.

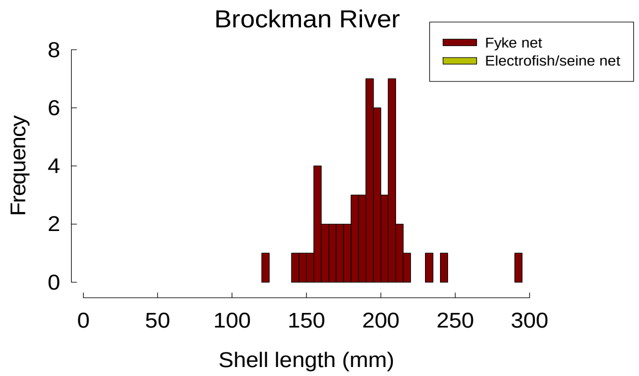


Figure 37 Length-frequency histogram of the Oblong Turtle within the Brockman River.

Freshwater Bivalves

Carter's Freshwater Mussel (*Westralunio carteri*)

Distribution and abundance

Table 4 summarises Carter's Freshwater Mussel (*W. carteri*) density for four sites where they were found (Yalyal Brook– Reserve Road, Marbling Brook – Chittering Valley Road, Lennard Brook - Cockram Road and Lennard Brook - Westralia Fruits); no mussels were found in any of the remaining 15 sites. More mussels dominated Ellen Brook sites, with mean densities of: 9.8 m^{-2} at Yalyal Brook – Reserve Road, 3.3 m^{-2} at Lennard Brook (Cockram Road) and 1.5 m^{-2} at Lennard Brook (Westralia Fruits), compared to the Brockman River site (Marbling Brook) with only 0.5 m^{-2}. The greatest mussel density recorded was in the Yalyal Brook site, with 40 m^{-2} along the stream bank in a mixed substrate of coarse sand and fine soils, detritus and overhanging vegetation. Mussels were found exclusively in freshwater (NaCl <1.0 ppt) and occurred in greatest numbers in spring-fed sites with salt concentrations less than 0.53 ppt. Fewer mussels were found in areas influenced by agriculture, with the lowest densities occurring in areas frequented by cattle (Marbling Brook). Deep, dense detritus blanketed much of the Lennard Brook (Westralia Fruits site), where mussel densities were also lower.

Glochidial-host fish relationships

During this study, Freshwater Cobbler (*T. bostocki*) was the only species of fish captured found to host glochidia (Table 5, Figure 39). Glochidia prevalence on Freshwater Cobbler at the various sites ranged from 0 to 19% (mean = 5%), and mean intensity (number of glochidia per infected host) overall was 3 (Table 5).

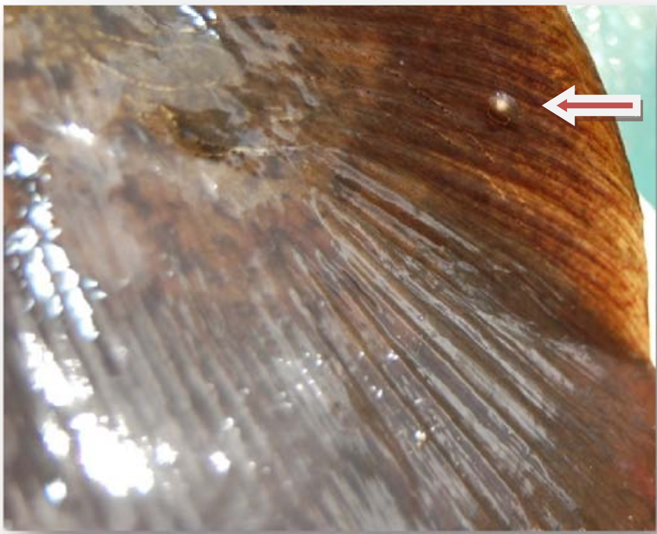
Table 4 Mean density (± standard error) of Carter's Freshwater Mussel (*Westralunio carteri*) at three sites in Ellen Brook and one site in the Brockman River.

Site	River System	Density (number/m^2)
Yalyal Brook	Ellen Brook	9.8 (±3.5 SE)
Lennard Brook - Cockram Rd	Ellen Brook	3.3 (±1.7 SE)
Lennard Brook – Westralia Fruits	Ellen Brook	1.5 (±0.8 SE)
Marbling Brook – Chittering Valley Rd	Brockman River	0.5 (±0.3 SE)

Table 5 Glochidia prevalence and intensity on Freshwater Cobbler at the various sites (see also Figure 40). N.B. Subsamples of each other species captured during this study were also examined at site of capture and then promptly released; none showed evidence of hosting glochidia.

Species	Number	Glochidia Prevalence (%)	Mean Intensity (number of glochidia)
Freshwater Cobbler: *Tandanus bostocki*[1]	153	5	3
Freshwater Cobbler: *Tandanus bostocki*[2]	26	19	4
Freshwater Cobbler: *Tandanus bostocki*[3]	122	3	2
Freshwater Cobbler: *Tandanus bostocki*[4]	5	0	0

[1]All sites, [2]Marbling Brook – Chittering Valley Road, [3]Julimar Bridge, [4]Clune Park



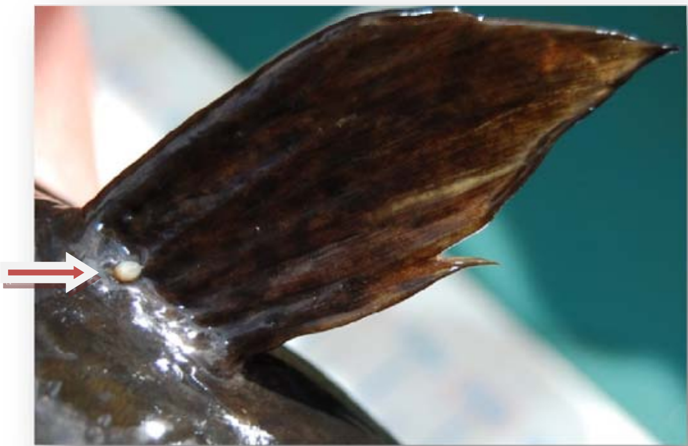


Figure 39 Glochidia (larval stage of Carter's Freshwater Mussel (*Westralunio carteri*)) attached to the caudal fin (top) and the base of the dorsal fin (below) of Freshwater Cobbler (*Tandanus bostocki*).

Mussel population structure

Mean MHI was 61.3%, which is within the range reported for *W. carteri* (60-70%; McMichael and Hiscock 1958). Although species keys describe two other shell measurements, beak height (BH) and beak length (BL) need to be measured on the internal sides of the shell and they were not used as it was impractical to measure them in the field. All other taxonomic characters matched keys for *W. carteri* (McMichael and Hiscock, 1958, Walker, 2004). Mussels in the Yalyal Brook site were the largest, dominated by individuals in the 62-83 mm shell length range (Figure 40) followed by Marbling Brook, with all mussels >60 mm shell length, Lennard Brook (Westralia Fruits) 32-69 mm shell length and Lennard Brook (Cockram Road) having the smallest mussels with the majority of shell lengths in the 38-65 mm size classes. Only two small mussels (<30 mm shell length) were recorded in all of the sites (Figure 40). The lack of small individuals (<40 mm shell length) in Yalyal Brook and Marbling Brook (and potentially all sites) suggests that recruitment and/or offspring survival is low. The absence of very large mussels (>71 mm shell length) suggests reduced longevity of mussels in Lennard Brook, compared to the other sites. Although a host for the larval stage of *W. carteri* was found within the Brockman River, i.e. Freshwater Cobbler, the host for this species in Ellen Brook is unknown. It is important to identify hosts for this species to guarantee their survival.

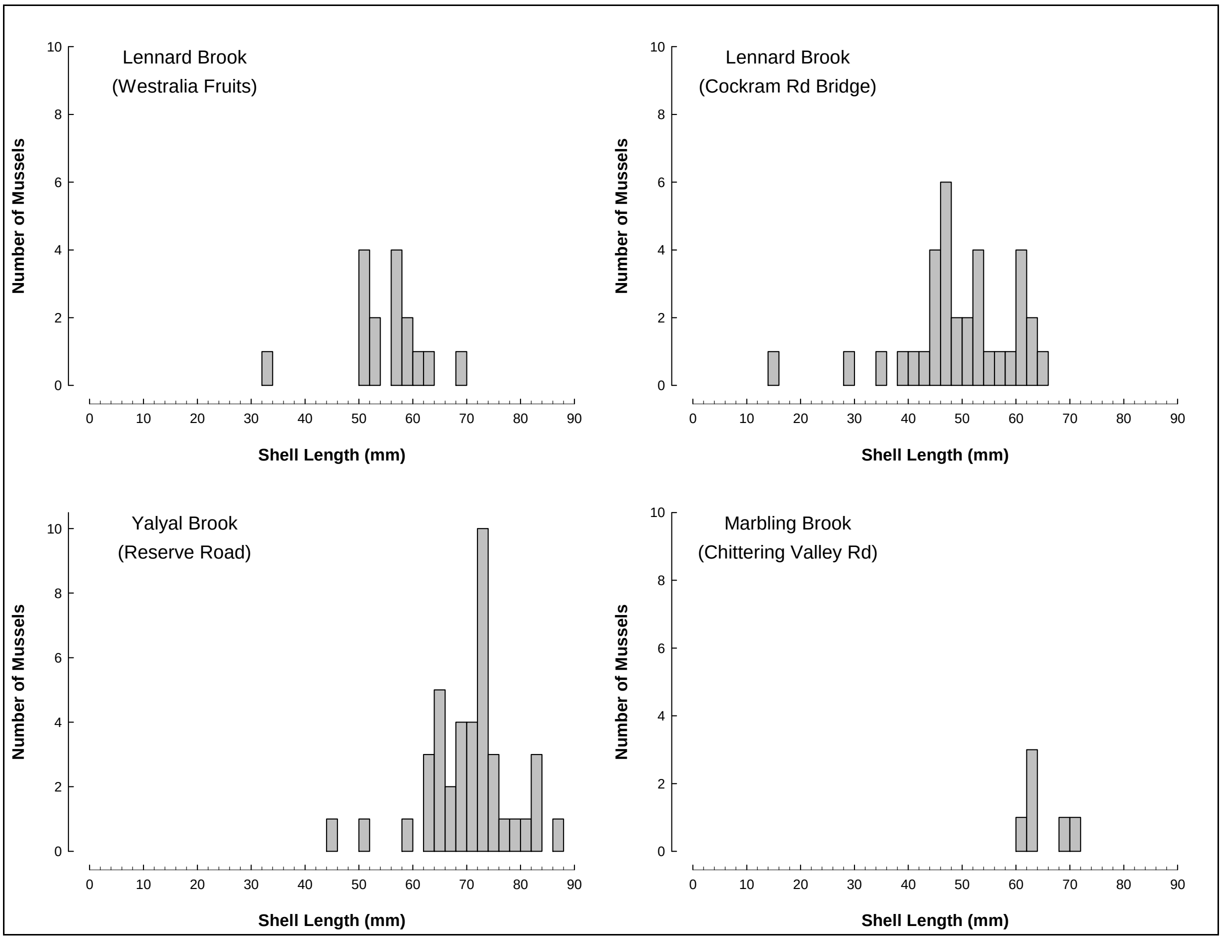


Figure 39 Length-frequency histograms of freshwater mussels (*Westralunio carteri*) in Ellen Brook and the Brockman River.

Conservation significance and recommendations

An examination into the artificial barriers of these systems is required and this is particularly relevant in acknowledging the impacts of barriers on the migration patterns of the various species. The impacts of feral species should also be assessed. Overall, the results of the current study suggest that groundwater resources may be vital in ensuring the longevity of populations of a number of endangered aquatic macrofauna in Ellen Brook. In particular, groundwater inputs may maintain remnant populations of Western Mud Minnows in Lennard Brook and Carter's Freshwater Mussel in Lennard Brook and Yalyal Brook. Furthermore, ephemeral systems such as Melaleuca Park and Chandala Lakes are significant refuges for the Black-stripe Minnow. These two fish species have been lost from elsewhere in the Swan-Canning catchment, which is the largest in south-western Australia. These species have also declined throughout much of their range. Groundwater accounts for between 30 and 70% of the world's total freshwater, with surface waters such as rivers containing <0.01% (Freeze & Cherry 1979, Petts *et al*. 1999). Groundwater-dependent ecosystems are complex, often support a relatively diverse fauna and may provide refugia for relictual species, however they vary in their degree of dependency on groundwater to maintain their composition and function (Hattons & Evans 1998, Power *et al.* 1999, Murray *et al*. 2003, Humphreys 2006). Localised areas of groundwater water discharge into streams create a unique environment known as the hyporheic zone. Characteristics of this region are important in maintaining populations of aquatic species, including fish. For example, the hyporheic zone often provides a thermal refuge for aquatic species by buffering against extreme upper and lower lethal temperatures (Power *et al*. 1999, Hayashi & Rosenberry 2002). The hyporheic zone influences water quality by maintaining flows independent of surface runoff, supplying dissolved oxygen, maintaining stream productivity, and providing habitat and maintaining migratory routes. There are a number of specific examples that document the importance of groundwater to particular species in particular systems, however, Sear *et al*. (1999) considered that the nature of the importance of groundwater is difficult to determine at a regional scale, but should be assessed at a local or catchment level. It is important that the current remnant populations of these rare and threatened species are maintained, and this will only be possible if the habitats in which they reside are conserved.

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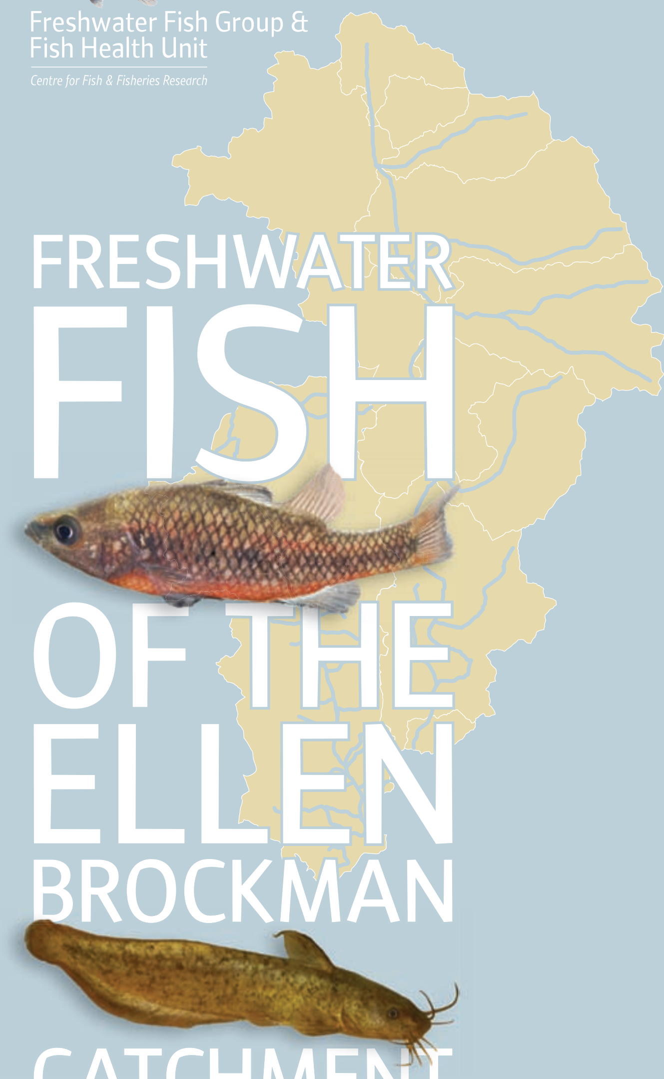
APPENDIX I

Educational brochure of the freshwater fishes of Ellen Brook and the Brockman River

Freshwater Fish Group &
Fish Health Unit
Centre for Fish & Fisheries Research

FRESHWATER FISH OF THE ELLEN BROCKMAN CATCHMENT



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The freshwater fish fauna of Western Australia is separated into three major Drainage Divisions: the Kimberley, Pilbara and South-west. The south-west region shares no native freshwater fish species with the northern two Divisions and has the highest percentage of endemic fishes (80%) of any Australian Drainage Division. The south-west region also houses 11 species of freshwater crayfishes and all are native to this region. Therefore, the region is unique in terms of its freshwater fish and crayfish fauna.

Freshwater Cobbler *(Tandanus bostocki)*

Western Minnow *(Galaxias occidentalis)*

Nightfish *(Bostockia porosa)*

Western Pygmy Perch *(Edelia vittata)*

Western Mud Minnow *(Galaxiella munda)*

Black-stripe Minnow *(Galaxiella nigrostriata)*

Freshwater Species

Six of the eight species of freshwater fish endemic to south-western Australia are found within Ellen Brook and the Brockman River. Ellen Brook is home to two extremely rare fishes, the Western Mud Minnow and the Black-stripe Minnow; species which have largely disappeared from the Swan Coastal Plain and represent therefore outlying populations. The next nearest population of Western Mud Minnows is in the Vasse River near Busselton, while the Black-stripe Minnow is found in ephemeral wetlands near Bunbury and also on the south-coast between Augusta and Denmark. The Freshwater Cobbler was not found in Ellen Brook, but is quite common in parts of the Brockman River, while the Western Pygmy Perch, Nightfish and Western Minnow are found in both catchments.

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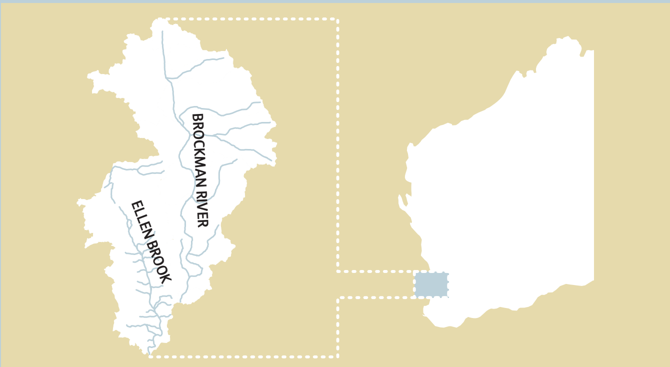

For more information see: **www.cffr.murdoch.edu.au**
or email: **fish@murdoch.edu.au**

Or contact your local Landcare Centre
Chittering Landcare Centre
175 Old Gingin Road, Muchea
T: **9571 0400** E: **chitteringlandcare@iinet.net.au**
www.chitteringlandcare.org.au

Estuarine Species

A number of estuarine fishes commonly enter freshwaters in south-western Australia. Recent research has shown that some of these species have moved up the main channel of our major rivers as a result of salinisation of our freshwater ecosystems. Salinisation has also led to a number of freshwater fishes now being restricted to fresh tributaries as they are unable to tolerate the higher salinities now found in many of our rivers. The Swan River (or Blue-spot) Goby and the Western Hardyhead are found within Ellen Brook and the Brockman River.

Swan River (or Blue-spot) Goby *(Pseudogobius olorum)*

Western Hardyhead *(Leptatherina wallacei)*

Photographs: David Morgan, Stephen Beatty, Mark Allen, Gerry Allen
Text: David Morgan, Stephen Beatty, Michael Klunzinger, Alan Lymbery

Feral Species

There are currently two feral fish species (Eastern Mosquitofish and Goldfish) in the Ellen Brook and Brockman River, while a number of other species are in adjacent tributaries (e.g. Pearl Cichlids in Bennett Brook, Redfin Perch and trout in many water storage dams, One-spot Livebearers in Bull Creek and Lesmurdie Brook). There is the potential for the Pearl Cichlid to invade these tributaries via the Swan River. The Yabbie (*Cherax destructor*) has recently also been found in Ellen Brook (Yal Yal) and is now widespread throughout south-western Australia and competes with the native crayfishes – including Marron (*Cherax cainii*) and Gilgies (*Cherax quinquecarinatus*) which are found in Ellen Brook and the Brockman River. Feral species impact native species and their ecosystems and also have the potential to spread disease and parasites.

Eastern Mosquitofish *(Gambusia holbrooki)*

Goldfish *(Carassius auratus)*

Pearl Cichlid *(Geophagus brasiliensis)*

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