

Ecological Values of Seven South-West Rivers

Desktop review



prepared for

Environmental Water Planning Section
Department of Water

by

Wetland Research & Management

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Report

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Frontispiece: (left to right): hairy marron *Cherax tenuimanus*, endemic to the Margaret River (photo unknown); Balston's pygmy perch, *Nannatherina balstoni* (photo by D. Morgan); Wilyabrup Brook (photo by Katherine Bennett/DoW).

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1 BACKGROUND

The Department of Water (DoW) is the primary water resource management agency in Western Australia. The DoW administers the Rights in Water and Irrigation Act 1914 (RIWI), which provides for the sustainable use and development of the State's water resources, the protection of natural ecosystems and the control of activities that may be detrimental to ecosystem condition. The DoW collects and analyses water resource information, prepares policies and management plans and issues licences to take water. In providing water for consumptive use, the DoW must also consider the maintenance of environmental and social values.

Water dependant environmental values and non-consumptive social values are maintained through the setting of an Environmental Water Provision (EWP) and an allocation limit that guides licence decisions. EWPs are the water regimes provided as a result of the water allocation decision-making process, which takes into account ecological, social and economic impacts. A key step in the determination of EWP's is the assessment of ecological water requirements (EWRs). An EWR is defined as the water regime required to maintain key ecological values (existing, historical or proposed for restoration) of water dependent ecosystems at a low level of risk. The EWP may meet in full or in part the ecological and social water requirements depending on the economic benefits of water use to the region and State.

The concept of EWRs and EWPs is consistent with National Principles for the Provision of Water for Ecosystems (ANZECC/ARMCANZ 2000). The need to recognise the ecological impacts of flow regulation and diversion has also occurred through a number of Commonwealth Government policies:

- Principles of Ecologically Sustainable Development (1992);
- Intergovernmental Agreement on the Environment (1992);
- COAG recommended fundamental water reforms, including the need to provide water for the environment as part of the introduction of comprehensive systems of water allocations;
- Draft National Water Quality Management Strategy (1994).

The Commonwealth and State agreements on water allocation issues reflect the emerging importance of EWRs in the overall management of river systems. Allocation of water to meet EWRs is based on the premise that the environment has a right to water and, therefore, is regarded as a legitimate user.

The DoW is currently in the process of developing water resource management plans for a number of systems in southwest Western Australia. In line with protecting ecologically important downstream ecosystems, the DoW have commissioned ***Wetland Research & Management*** to determine the Ecological Water Requirements (EWRs) of the Margaret River, Brunswick River, Capel River, Wilyabrup Brook and Chapman Brook over the next two years. The DoW will determine the EWRs of Lefroy Brook and Cowaramup Brook. The location of these systems within the southwest is presented in Figure 1.

Identification of water-dependent ecological values for which flows are to be determined is a critical first step of the EWR process. This is usually achieved through a literature review to identify what is known, followed by targeted sampling to fill knowledge gaps.

This report presents the literature reviews which aim to document the current known ecological values for each system, and by doing so, highlight the values which have not been sufficiently studied. These water-dependent ecological values will then be targeted in specific field studies aimed at rivers or parts of rivers which have not been sufficiently surveyed. Field surveys will then be conducted in autumn and spring 2007. This approach, consisting of a combination of detailed review and targeted sampling, avoids duplication of effort as a result of resurveying the same area for values already well documented in the literature.



Figure 1. Location of the seven river systems, as well as the major Blackwood and Collie Rivers, within the southwest of Western Australia (map compiled by Lisa Chandler / WRM)

2 MARGARET RIVER

2.1 Study Area

The Margaret River (Plate 1) is a relatively small river system in the southwest of the state. It is approximately 60 km in length, has a catchment area of 470 km² and runs through the Margaret River township and out into the Indian Ocean just north of Prevelly (Pen 1997). Morgan *et al.* (2003) describe the Margaret River as “one of the few river systems in south-western Australia that has not become salinised as a result of large-scale land clearing”. However, the river has a number of weirs and road crossings along its length that would act as barriers to fish passage at certain times of the year.



Plate 1. The Margaret River at EWR survey Reach 1; the (photo Katherine Bennett / DoW)

The Margaret River traverses three distinct geomorphologic units. In its headwaters, the river flows across the Blackwood Plateau, then through the Margaret River Plateau and into the Leeuwin-Naturaliste Coast. The Blackwood Plateau has a gently undulating surface of moderately raised land (between 80 to 180 m above sea level) that is formed on laterised sedimentary rocks. The Margaret

River Plateau is between 5 and 15 km wide and has formed on granitic and gneissic basement rock of the Leeuwin Block. It contains fertile valleys and is characterised by deep gravely sandy loam soils. The Leeuwin-Naturaliste Coast is a discontinuous ridge of Tamala Limestone between Cape Naturaliste and Cape Leeuwin. It is a narrow strip of land between 0.2 and 6 km wide. In some places along its length, the underlying Leeuwin Block granite is exposed (Hanran-Smith 2003).

Groundwater resources within the Margaret River area include the Leederville Formation, the Yarragadee Aquifer and superficial formations (CSIRO 2005). According to CSIRO (2005), natural values reliant on groundwater in the region include maintenance of cave ecosystems, wetland processes, riverine processes, hydrological balance and support for inland remnant vegetation communities. In the mid-reaches of the Margaret River, characterised by extensive, permanent pool systems, the Yarragadee is overlain directly by superficial formations. Therefore, drawdown of the Yarragadee Aquifer in this area may result in overlying aquifers percolating down, which would likely result in the drying of permanent riverine pools (Richard Pickett, DoW, pers. comm.).

Landuse within the catchment includes beef and dairy cattle grazing, sheep grazing, potatoes, orchards, vineyards, olives and bluegums in the middle and lower reaches, while most of upper catchment remains uncleared (being within State Forest) or are under pine plantations (Hanran-Smith 2003). There is also some residential subdivision throughout the area (Hanran-Smith 2003).

2.2 Riparian vegetation

Hopkins *et al.* (2001) reported that approximately 66% of the Cape to Cape region is covered with native vegetation. Following a detailed foreshore condition survey, Hanran-Smith (2003) regarded the riparian (fringing) vegetation of the Margaret River to be very narrow and degraded in places. In general, the region is known for its high levels of species diversity and endemism (Beard 1990).

The flora of this system is contained within the Menzies and Warren subdistricts of the South-west Botanical Province (Beard 1990). Woodland and forest of jarrah (*Eucalyptus marginata*) or jarrah-marri (*E. marginata-Corymbia calophylla*) dominate the Menzies subdistrict, with blackbutt (*E. patens*), flooded gum (*E. rudis*) and bullich (*E. megacarpa*) also common to some areas. Within the Warren subdistrict, vegetation associations depend largely on soil type; with karri forest (*E. diversicolor*) being found on deep loams and jarrah-marri forest on the leached sands (Beard 1990). Sedge swamps and extensive paperbarks (*Melaleuca*; Plate 2) occur within valleys.

Broad vegetation communities along the river were reported by Hanran-Smith (2003) in the Margaret River Action Plan, and are as follows:

- “jarrah-marri forest with blackbutt, bullich and *Hakea lasianthoides* - east of town
- karri forest - within town
- marri-jarrah forest with peppermint (*Agonis flexuosa*) - between town and Caves Rd
- Heathlands on shallow rocky soils and granite outcrops with *Kunzea* spp., *Darwinia citriodora* and *Hakea trifurcata* - mainly between Bussell Highway and the coast
- *Melaleuca* woodland- towards the coast.”



Plate 2. *Melaleuca* stand with sedges in foreground (photo by Jess Lynas / WRM).

Foreshore condition assessments have been conducted as part of the Margaret River Action Plan (Hanran-Smith 2003). The downstream EWR survey reach corresponded with the foreshore assessment site 7 (Hanran-Smith 2003). The river in this area has retained a diverse and reasonably wide band of riparian vegetation dominated by jarrah-marri forest, with some peppermint (Hanran-Smith 2003). The Environmental Rating in the vicinity of the EWR survey reach ranged from C1 (erosion prone) to B3 (understorey dominated by weeds). Upstream of this site, the next EWR reach was foreshore assessment site 5. The Margaret River flows through National Park in this reach and has a healthy and diverse riparian vegetation, with minimal weed infestation. Dominant native vegetation includes marri, blackbutt, tea trees (*Agonis linearifolia* and *Astartea fascicularis*), bullich (*Eucalyptus megacarpa*) and numerous species of rushes and sedges. The river in this section was given an Environmental Rating of A3 (slightly disturbed) to A2 (near pristine). The most upstream EWR reach was not included in foreshore assessments by Hanran-Smith (2003), but is situated in State Forest.

2.3 Freshwater macroinvertebrates

No scientific reports detailing the aquatic macroinvertebrate fauna of the Margaret River were found even though an extensive literature review was undertaken. However, GeoCatch, Ribbons of Blue and Southwest Rivercare have undertaken some sampling with community and school groups in association with foreshore condition assessments (Drew McKenzie, pers. comm.). Macroinvertebrate sampling was conducted in the middle reaches, where the river was classified as B2-B3 (degraded: weed infested). Whilst specific information was not available on the types and abundance of species collected, one reference to this work on the internet suggested the number and diversity of aquatic macroinvertebrates was very low. Ribbons of Blue generally identify taxa to family level. The aim of these sampling exercises is generally for training/education purposes, rather than for data collection. Macroinvertebrate fauna of wetland areas and tributaries of the Margaret River have also been studied by community groups, with identification to family-level (Drew McKenzie, Cape to Cape Catchments, pers. comm.).

2.4 Freshwater crayfish

Four species of crayfish native to the southwest of Western Australia are known to occur in the Margaret River. These include the smooth marron (*Cherax cainii*), the hairy marron (*Cherax tenuimanus*, endemic to the Margaret River), and two species of gilgie, *Cherax quinquecarinatus* (Plate 3) and *Cherax crassimanus*. In a study by Morgan and Beatty (2003), eight sites along the Margaret River were sampled using a variety of methods including electrofishing and seine netting (see section 1.5 and Figure 2 for locations of sampling sites and the approximate position of survey reaches from the

current EWRs project). Hairy marron were collected from all eight sites and gilgies (*Cherax quinquecarinatus*) were recorded from three sites. In addition, a study assessing the effectiveness of the fishway at Apex Weir recorded smooth marron (*C. cainii*) and two species of gilgie (*C. quinquecarinatus* and *C. crassimanus*) from the fishway (Morgan and Beatty 2004).

Gilgies (*C. quinquecarinatus*) have a range from the Moore River in the north to Bunbury in the south (Shipway 1951). *Cherax crassimanus* have a more restricted distribution, between Margaret River and Denmark. This species can be distinguished by the presence of a small, sharply curving, anteriorly directed spine on the mesial margin of their carpus ('wrist' on chelae).



Plate 3. The gilgie, *Cherax quinquecarinatus* (photo by Andrew Storey).

Gilgies are known to exploit almost the full range of freshwater environments, and can be found in habitats that range from semi-permanent swamps to deep rivers (Austin & Knott 1996). These crayfish have a well developed burrowing ability, digging short burrows under stones on the stream bed or in the banks along the margins (Shipway 1951). In this way, gilgies are able to withstand periods of low water level by retreating into burrows until flows return. A study on the microhabitat characteristics of *C. cainii*, *C. quinquecarinatus*, and the introduced *Cherax destructor* (yabby) within the Canning River system near Perth, determined that gilgies are more commonly found in areas with higher flow velocity and dissolved oxygen concentrations than marron, *Cherax cainii* (Lynas *et al.* 2006).

Little is known of the physiological tolerances of gilgies. However, Shipway (1951) suggests that *C. quinquecarinatus* are able to tolerate more extreme environmental conditions than marron, and may survive longer periods out of water. Beatty *et al.* (2005) suggested the reproductive biology of *C. quinquecarinatus* may help explain their apparent success throughout the range of aquatic habitats found in southwest Western Australia. That is, they show traits of both r- and K-strategists (Beatty *et al.* 2005). Beatty *et al.* (2005) studied the population biology of gilgies from a permanent urban stream, Bull Creek, in the southwest of the State. Populations within this waterway have been under considerable pressure from overfishing. Traits found to be associated with r-strategists were early maturation (they breed at the end of their second year), an extended late winter-summer spawning period (with multiple spawning events), and high mortality rates (Beatty *et al.* 2005). Qualities typical of K-strategists included relatively slow growth rates, low fecundity, and moderately sized eggs (Beatty *et al.* 2005).

Nicholl and Horwitz (2000) have recognised marron as a flagship species for river conservation within WA. Marron were originally identified as a single species by Smith (1912) but Austin and Ryan (2002) recognised and described two distinct species; *Cherax tenuimanus* (Smith), the 'hairy'

marron (Plate 4), was described on specimens from Margaret River, and the other species, the smooth marron (Plate 5), was given the species name *Cherax cainii* (Austin and Ryan 2002). The more ubiquitous *C. cainii*, has a wide distribution across the southwest, with an extended distribution between the Hutt River in the north (near Geraldton) and Esperance in the southeast (Lawrence and Morrissy 2000, Beatty *et al.* 2003). Prior to European settlement, its distribution was thought to extend only from Harvey to Albany (Morrissy 1978). The hairy marron, however, is restricted to the Margaret River and is found almost exclusively in the upper reaches in an area less than 50 km in length. The river in the upper reaches is within State Forest and has better water quality, abundant riparian vegetation and is generally less modified than downstream reaches. It also has a series of large, deep, permanent pools that would provide summer refuge areas. Whilst this species does still occur at sites downstream, having been collected from all eight sample sites by Morgan and Beatty (2003) (Figure 2), competition with the smooth marron is considered to pose a considerable threat (Bunn 2004, CALM 2005). There is the potential for species replacement of hairy marron given competitive advantage and reproductive interference (hybridisation) by smooth marron (Molony *et al.* 2004). However, such mechanisms have not yet been fully studied. The hairy marron is now formally gazetted under the WA Wildlife Conservation Act 1950, following IUCN Red List Categories and Criteria version 3.1, as critically endangered (Bunn 2004; CALM 2005).



Plate 4. Hairy marron, *Cherax tenuimanus* (photo by John Bunn / Edith Cowan University).

Marron are a riverine crayfish and require permanent water. They are characteristically “K-selected species” and inhabit the deeper and broader water of permanent river systems (Riek 1967). They typically belong to large, stable populations which inhabit low nutrient waters. Marron are highly sensitive to environmental fluctuations (Morrissy 1983; Morrissy *et al.* 1984; Holdich and Lowery 1988). They have a long annual period of ovarian development with a single springtime breeding season. There is a tendency for breeding failure in highly eutrophic waters (Morrissy 1983). Unlike

gilgias, the burrowing habit in marron is not strongly developed. Riek (1967) suggested this is a consequence of the relatively poor development of chelae muscles in marron, thus restricting their ability to construct burrows. Shipway (1951) noted marron were more content to seek shelter under logs or stones in the bed of streams than to burrow. It is generally accepted that marron do not burrow to escape drought (Maguire *et al.* 1999; Lawrence and Jones 2002).

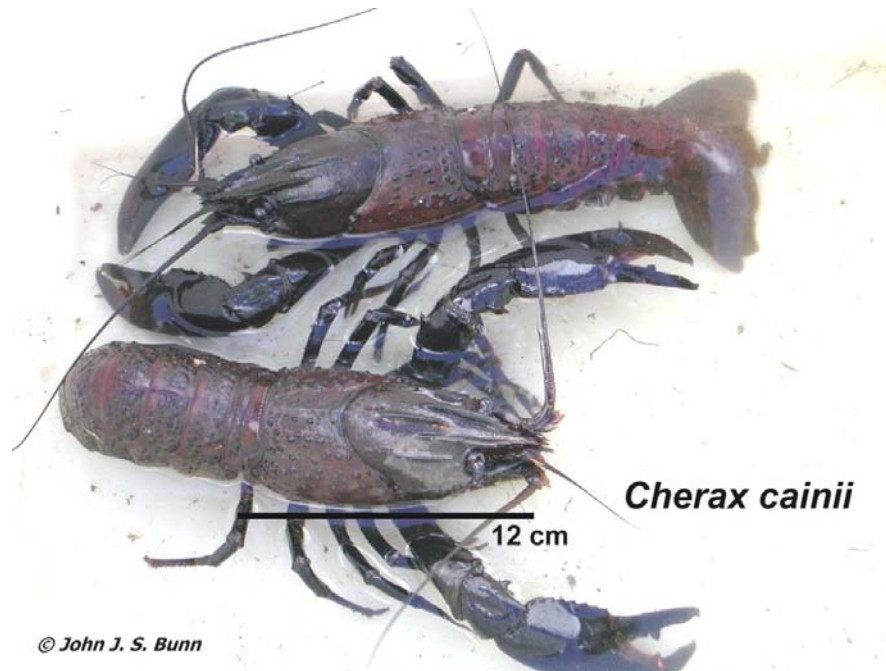


Plate 5. Smooth marron, *Cherax cainii* (photo by John Bunn / Edith Cowan University).

2.5 Fish fauna

A total of nine freshwater fish species (including six species native to the south-west) and two predominantly estuarine species are known from the Margaret River. The fish fauna of the Margaret River was surveyed by Morgan and Beatty in 2003 and again in 2004. The aim of these surveys was firstly to examine the impact of the weirs on upstream movement of native fishes (Morgan and Beatty 2003), and then to assess the effectiveness of a rock ramp fishway (Plate 6) constructed at the Apex Weir (Morgan and Beatty 2004). A variety of sampling techniques were used including mask and snorkel visual survey, electrofishing (Plate 7), seine nets and gill nets. A list of the species collected during these surveys is presented in Table 1. The native species collected (in order of decreasing abundance) were the western minnow *Galaxias occidentalis*, western pygmy perch *Edelia vittata*, mud minnow *Galaxiella munda*, Balston's pygmy perch *Nannatherina balstoni*, nightfish *Bostockia porosa*, and pouched lamprey ammocoetes *Geotria australis* (Morgan and Beatty 2003). Prior to these studies the only data on the fish fauna of the Margaret River was that obtained by Morgan *et al.* (1998) and a few records in the Western Australian Museum.



Plate 6. Fishway on the Margaret River weir (photo provided by Antonietta Torre / DoW)

The location of Morgan and Beatty's (2003) fish and crayfish study sites is provided in Figure 2, together with the relative position of the reaches surveyed for the current EWRs project. The most downstream reach appears to correspond with a site sampled by Morgan and Beatty (2003) for fish and crayfish fauna (Kevill Rd waterpoint). Whilst the middle EWR survey reach was not specifically sampled, it lies in close proximity to a number of Museum Record and Morgan and Beatty (2003) sampling sites. Similarly, the upstream reach, whilst not included specifically in their surveys, was close to two study sites. It is likely that the crayfish and fish fauna of this reach are similar to that reported by Morgan and Beatty (2003) for their two uppermost sites (Canebreak Pool and Rapids Pool).



Plate 7. An example of fish sampling using an electrofisher (photo David Lynas).

Table 1. Fish collected from the Margaret River by Morgan and Beatty (2003) and (2004). ✓ = was captured by Morgan and Beatty (2003), and # = captured by Morgan and Beatty (2004).

	Lamprey	Western minnow	Mud minnow	Nightfish	Western pygmy perch	Balston's pygmy perch	Mosquitofish
Kevill Rd water point	✓	✓		✓	✓		✓
Town Weir	✓	✓	#	✓	✓		✓
Below large weir	#	✓	#	#	✓		✓
Upstream v-notch weir	✓	✓		✓	✓		✓
Railway bridge xing	✓	✓		✓	✓		✓
Jindong Treeton Rd		✓		✓	✓		✓
Canebreak Pool		✓	✓	✓	✓	✓	
Rapids pool		✓	✓	✓	✓	✓	✓

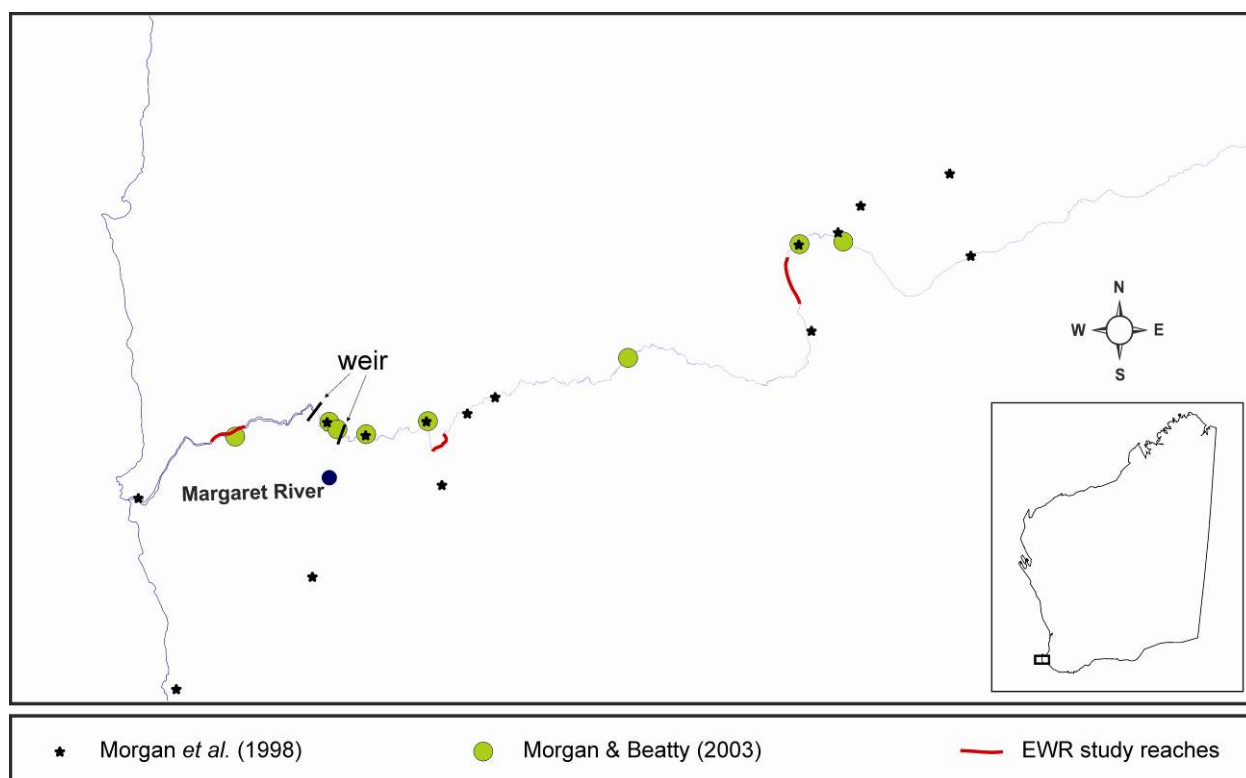


Figure 2. Morgan and Beatty (2003) sample sites, together with Museum records (Morgan *et al.* 1998) and EWR survey reaches as part of the current study (after Morgan and Beatty 2003).



Plate 8. Balston's pygmy perch, *Nannatherina balstoni* (photo by D. Morgan)

Of the six native freshwater fishes, three have considerable conservation significance, including Balston's pygmy perch, the mud minnow and pouched lamprey. Balston's pygmy perch (Plate 8) is the rarest of all southwest endemic freshwater fishes (Morgan *et al.* 1998). It is listed under the IUCN Redlist of Threatened Species as 'Data Deficient' (World Conservation Centre 1996). In 1999 it was listed as 'Vulnerable' with the Australian Society for Fish Biology, however, this was amended to 'Data Deficient' in 2001. More recently, it was

nominated in February 2005 for inclusion as 'Vulnerable' under the Environment Protection and Biodiversity Act 1999. Their nomination was primarily based on their restricted distribution and considerable contraction of range over the past century. CALM (2005) have also listed *N. balstoni* on their List of Priority Fauna as 'Priority 1'. The criterion for inclusion in this Priority category is that they are "taxa with few, poorly known populations on threatened lands" (CALM 2005). This listing has recently been revised, with their previous nomination as 'Vulnerable' being accepted in 2007. *Nannatherina balstoni* are currently listed as 'Vulnerable' under the Department of Environment and Conservation's (previously the Department of CALM) list of Declared Threatened Fauna under the *EPBC ACT 1999*. This listing suggests that while the species is not endangered or critically endangered, it still faces a high risk of extinction or destruction in the medium-term.

Historically, *N. balstoni* had a distribution extending from the Moore River (Gingin Brook) in the north to Two Peoples Bay (Goodga River, near Albany) in the southwest (Museum Records, Morgan *et al.* 1998). However, due to anthropogenic disturbance and habitat degradation (salinisation, damming, eutrophication and dewatering), their range now consists of highly fragmented populations in the extreme southwest of the State, between Margaret River and Two Peoples Bay. It has been suggested that they have been lost from freshwater systems in the northern half of their original range (Anon. 2005a) and recent surveys failed to record them in the Moore River (Morgan *et al.* 2000, Strategen 2006) or Collie River (Morgan *et al.* 1998). It is also likely that this species has been lost from rivers and lakes on the Swan Coastal Plain south of Perth (Anon 2005a). In the Margaret River, Balston's pygmy perch are only known to occur above Canebreak Pool (Morgan and Beatty 2003).

The mud minnow (Plate 9) is listed as 'Restricted' by the Australian Society for Fish Biology (2001) and 'Lower Risk – Near Threatened' on the IUCN Redlist of Threatened Species (Wager 1996). The latter listing means that the mud minnow is considered a species which does not qualify for 'Conservation Dependent', but is close to qualifying for 'Vulnerable' (Wager 1996). Furthermore, in February 2005, *G. munda* was also nominated for inclusion as 'Vulnerable' under the *EPBC Act 1999*. Its nomination was based on the substantial reduction in numbers over the past century, coupled with its restricted distribution (Anon. 2005b). According to its nomination form, the mud minnow has undergone a loss of populations from all rivers between Moore River and Margaret River (Anon. 2005b). Populations have also become severely fragmented or lost from many of the rivers within its current distribution (i.e. Blackwood and Margaret rivers) due to loss of habitat (salinisation, damming, eutrophication and dewatering) and introduced species (Anon. 2005b). A

number of rivers in which it is currently found also support species of introduced fishes known to predate on *G. munda*. This species was also listed as Priority 4 on CALM's List of Priority Fauna, suggesting it is a taxon in need of monitoring (CALM 2005). This listing, however, has been recently revised and its nomination as 'Vulnerable' under the *EPBC Act 1999* was accepted in 2007. This indicates that the mud minnow has now been adequately surveyed and is deemed to face a high risk of extinction.

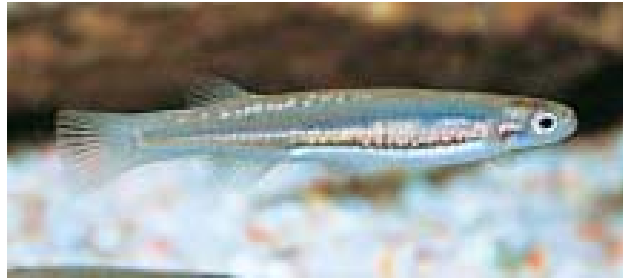


Plate 9. Mud minnow, *Galaxiella munda* (photo taken from Department of Fisheries website 2005).

The mud minnow has undergone a considerable reduction in range (Anon. 2005b, Morgan & Beatty 2005). Currently, *G. munda* is essentially restricted to the extreme south-west corner of the State, between the Goodga and Margaret rivers, with an isolated population at Gingin, approximately 100 km north of Perth (Morgan *et al.* 1998, Allen *et al.* 2002). However, this population consists of very few individuals which are restricted to a small spring in Gingin Brook. Its centre of distribution is in the small lakes and streams around Windy Harbour in the D'Entrecasteaux National Park (Morgan *et al.* 1998). Within the Margaret River mud minnows are essentially restricted to a few pools in the upper reaches, habitats that were previously free from introduced fishes (Morgan & Beatty 2003). Morgan and Beatty (2004) reported the first record of mud minnows in the lower Margaret River, downstream of Canebreak Pool.

The major threats to the status of both Balston's pygmy perch and mud minnows are from habitat alteration and the introduction of exotic species (Morgan *et al.* 1998). In south-western Australia, habitat degradation is likely to occur through alterations to flow regimes (regulation and abstraction), increased salinisation, siltation and eutrophication, which occur through dam construction, groundwater extraction and agricultural/forestry practices in the uppermost catchment (Morgan *et al.* 1998). The vulnerability of Balston's pygmy perch is compounded by their short life-cycle, low fecundities, single breeding event, low population sizes (approx. <1000 mature per river system), predation by introduced fish (evidenced by lack of co-occurrence) and an inability to tolerate marginally saline or eutrophic waters (characteristic of the larger rivers and wetlands of southwestern Australia).

The other species of conservation importance known to occur in the Margaret River is the pouched lamprey (Plate 10; Morgan *et al.* 1998, Morgan and Beatty 2003, 2004). This species belongs to an ancient lineage of jawless fishes whose morphology has remained largely unchanged for approximately 280 million years. *Geotria australis* is the only surviving species of Geotriidae in Australia, and one of four extant lamprey species found in the Southern Hemisphere (Potter 1996)

(Allen *et al.* 2002). Although most abundant in river systems south of Margaret River, museum records indicate they have been found as far north as the Swan River (Morgan *et al.* 1998). Lamprey ammocoetes have been recorded in quite high numbers from the Margaret River. Morgan and Beatty (2003) collected ammocoetes from four sites; one below the first weir, one above the first weir, and two sites above the second weir (see Table 1 and Figure 2).



Plate 10. Pouched lamprey, *Geotria australis*, showing the ammocoete (top; photo by David Morgan), adult (bottom left), and adult oral disc (photo by David Morgan).

Habitat alteration (including the construction of dams, extraction of groundwater and agricultural practices) and salinisation are believed to have led to the loss of pouched lamprey from many areas. In particular, agriculture in the southwest has reduced the abundance of suitable ammocoete beds due to increased run-off adversely affecting the composition of the substrate. Pouched lamprey ammocoetes burrow into soft substrate beds where they feed on diatoms, detritus and micro-organisms (Potter 1996). Ammocoetes spend 4-5 years in freshwaters, before metamorphosing and migrating to the sea. Adults remain in the open ocean for at least two years before returning to the rivers to spawn. Spawning is believed to take place in November.

The two predominantly estuarine species in the Margaret River, the Swan River goby (*Pseudogobius olorum*) and western hardyhead (*Leptatherina wallacei*), are restricted to the estuary (Morgan and Beatty 2003). This is in contrast to the many river systems of the southwest undergoing salinisation, in which predominantly estuarine fish species have been recorded hundreds of kilometres upstream (Morgan *et al.* 1998, 2003).

Three species of introduced freshwater fish are known from the Margaret River (Morgan *et al.* 1998, Morgan and Beatty 2003, 2004). The introduced mosquitofish *Gambusia holbrooki* was the most abundant of all species collected by Morgan and Beatty (2003) and accounted for over 90% of all fish captured. While both the introduced carp (goldfish) *Carassius auratus* and redbfin perch *Perca fluviatilis* were not captured by Morgan and Beatty (2003, 2004), they are known to occur in the Margaret River (Morgan *et al.* 1998).

None of the freshwater fish in the Margaret River have adaptations to withstand desiccation and therefore have a requirement for permanent water¹. Components of the biology of native species most likely to be affected by altered flow regimes are fish migration and reproduction. In fact, migration and reproduction in native fish species is stimulated by changes in flow patterns, water levels, temperature and photoperiod (Morgan *et al.* 1998). Western minnows, western pygmy perch and nightfish migrate up tributaries to spawn during winter months. Cues for migration by these species include breaking late autumn/early winter flood pulses and higher water levels, increased flow and currents, as well as increased turbidity, lower temperatures and diminishing daylight.

Sufficient water is also required to inundate trailing riparian vegetation, a favoured spawning habitat of the western minnow during winter. If water levels fall too soon, or fluctuate greatly, eggs may be left dry and desiccate. Flooded vegetation and shallow, flooded off-river areas also provide sheltered, low velocity nursery areas for growing juveniles.

2.6 Amphibian fauna

Frog species known to occur in the Margaret River catchment include common species of the southwest, such as the western green tree frog or motorbike frog (*Litoria moorei*) (Clare Foreword, DEC, pers. comm.).

Litoria moorei is closely associated with water and is common in the reeds and grasses of swamp regions (Bamford and Watkins 1983). Their distribution is from the lower Murchison River in the north to Pallinup River in the southwest. This species is found in areas of permanent water, where it hides beneath bark, rocks or logs (Tyler *et al.* 2000). Eggs are laid in spring to mid-summer, with the spawn clump being attached to vegetation (Tyler *et al.* 2000).

Frogs play an important role in functional ecosystems and have a requirement for water during their life cycle. They spend much of their lives in moist environments, such as marshes, swamps and along the riparian zone of rivers, due to their permeable skin which makes them susceptible to desiccation. Frogs also need water during certain stages of their life cycle in which to lay eggs and for tadpoles to survive and metamorphose.

2.7 Reptilian fauna

One aquatic reptile species, the long-necked turtle *Chelodina oblonga* (Plate 11), is known to occur in the Margaret River (Hanran-Smith 2003). This species is restricted to the south-west of Western Australia, with a distribution extending from the Hill River in the north to the Fitzgerald River National Park in the south-west. Long-necked turtles inhabit both permanent and seasonal waterbodies throughout their range. They can migrate relatively long distances overland if local conditions deteriorate (Gerald Kuchling, The University of Western Australia, pers. comm.) or they can burrow into the sediment and aestivate. Since their diet includes tadpoles, fish, and aquatic

¹ *Lepidogalaxias salamandroides* is the only species in the southwest known to burrow to avoid desiccation in times of drought. The black-stripe minnow (*Galaxiella nigrostriata*) inhabits ephemeral wetland systems and is thought to inhabit the moist area below the substrate when pools dry (Morgan *et al.* 1998).

invertebrates, tortoises only eat when open water is present. In permanent waters, this species has two nesting periods (September-October and December-January) but in seasonal systems, nesting will only occur in spring. Tortoises generally nest in sandy soils and eggs take up to two hundred days to hatch.



Plate 11. Long-necked tortoise (*Chelodina oblonga*) (photo by Andrew Storey / WRM).

In addition, a number of species of reptile likely to inhabit the riparian zone of the Margaret River can perhaps be regarded as semi-aquatic since they are reliant upon riparian vegetation for survival and tend to be limited to areas of damp soil (Mike Bamford, Bamford Consulting pers. comm.). Such species include the tiger snake *Notechis scutatus* (Plate 12), the mourning skink or western glossy swamp skink (*Egernia luctuosa*) and the western three-lined or southwestern cool skink (*Acritoscincus trilineatum*); all of which are largely restricted to the margins of waterways (Bamford Consulting 2003).



Plate 12. Tiger snake *Notechis scutatus* (grey-banded form) (photo by Peter Robertson / Wildlife Profiles Pty. Ltd).

2.8 Waterbirds

Waterbird species observed on the Margaret River include the dusky moorhen *Gallinula tenebrosa* (Plate 13), grey teal duck *Anas gracilis* (Plate 14), pacific black duck *Anas superciliosa*, white-faced heron *Egretta novaehollandiae*, and cormorant *Phalacrocorax* spp. (Hanran-Smith 2003).



Plate 13. Dusky moorhen *Gallinula tenebrosa* (photo K Vang and W Dabrowka / Bird Explorers ©)

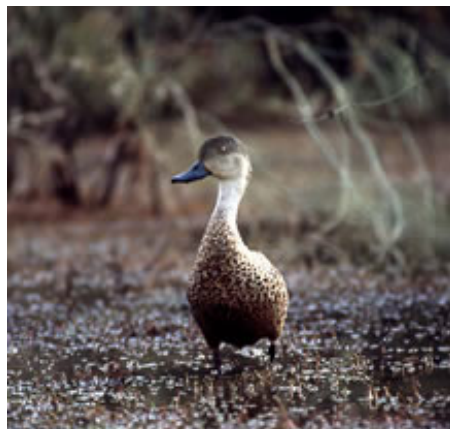


Plate 14. Grey teal duck *Anas gracilis* (photo M. Seyfort / Nature Focus © Australian Museum).

[http://photos.rnr.id.au/birds/Dusky Moorhen Birdsland3140918.jpg](http://photos.rnr.id.au/birds/Dusky_Moorhen_Birdsland3140918.jpg)

Whilst waterbirds are more likely to frequent wetland systems, the perennial Margaret River may be important as a drought refuge in summer. Waterbirds are dependent on aquatic systems as they provide habitat for feeding (they forage on a range of aquatic organisms, including plants, macroinvertebrates and fish), moulting, breeding and nesting. In a study of the waterbird usage from aquatic systems of the Swan Coastal Plain between Lancelin and Bunbury, the amount of submerged macrophyte, area, extent of wetland buffer and area of emergent vegetation were found to strongly influence waterbird fauna (Storey *et al.* 1993). Generally, rivers and water courses on the Swan Coastal Plain did not comprise important waterbird habitat, supporting low numbers of a small suite of species (Storey *et al.* 1993). Waterbirds tend to be found in greatest abundance where there is permanent water (Balla 1994).

2.9 Other riparian fauna

Landholders have observed a number of different types of fauna using the riparian zone of the Margaret River, including the water rat *Hydromys chrysogaster*, brushtail possum *Trichosurus vulpecula*, western grey kangaroo *Macropus fuliginosus*, and the southern brown bandicoot or quenda *Isodon obesulus* (Hanran-Smith 2003).

Of these animals, water rats (Plate 15) are likely to be the most dependent on the river system since they are known to suffer from heat stress if access to permanent water is lost (Watts and Aslin 1981). Water rats are adapted to an aquatic life and have distinctive broad partially-webbed hind-feet, water-repellent fur, and a thick tail. Water rats are common around coastal Australia and New Guinea, occurring in a wide range of coastal, brackish and freshwater environments (Watts & Aslin 1981). However, the isolated population in southwestern Australia has suffered a substantial decline due to a loss of habitat through salinisation and clearance of riparian vegetation (Lee 1995). They are classified by CALM as a Priority 4 species, indicating they are in need of monitoring (CALM 2005). Within their known range, water rats can be found in rivers, swamps, lakes and drainage

channels (Flannery 1995) where they build nests into banks near tree roots or in hollow logs. Therefore, there is a requirement for stable banks, tree roots and large woody debris.



Plate 15. A water rat, *Hydromys chrysogaster* (photo by Bert and Bab Wells).

Water rats are largely carnivorous, feeding on crayfish, mussels, fish, plants, water beetles, water bugs, dragonfly nymphs and smaller mammals and birds. Plants are more commonly consumed in winter or during periods of limited resources (Woollard *et al.* 1978; Harris 1978). Given the predominance of aquatic prey items, their feeding is closely linked with the river system, where they typically forage along the shoreline (Watts and Aslin 1981). They tend to restrict their movements to shallower waters of less than

20 metres depth. Water rat activity is generally obvious since they often take prey to a favourite feeding platform, such as a log, rock, or stump, located close to the water, where remains of its food may be seen.

In addition, quenda (Plate 16) are closely associated with the river system. They only occur in areas with dense covering vegetation, such as the margins of wetlands and Banksia woodland/Jarrah forest. Their distribution includes the southwest of Western Australia, Victoria, South Australia, New South Wales, Tasmania and Queensland. Quenda are listed as a Priority 4 species with CALM (2005) and were classified under Schedule 1 of the Endangered Species List. They have since been removed from the latter list due to population increases in the southern forests as a result of fox baiting programs. Despite this, metropolitan populations of quenda are declining, with local extinctions due to clearing for housing developments. Current threats include fragmentation and loss of habitat, and increased predation by introduced predators such as foxes, cats and dogs (Maxwell *et al.* 1996).



Plate 16. A southern brown bandicoot, or quenda, *Isodon obesulus* (photo by Mandy Bamford).

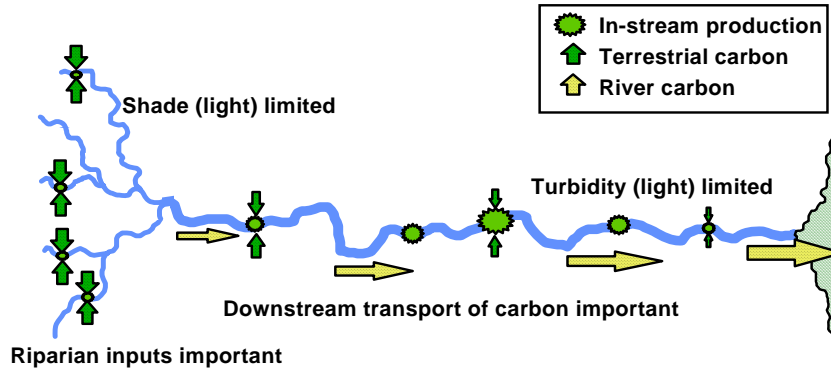
2.10 Carbon sources/processing

Of importance to the protection of current ecological values through setting EWRs, is the maintenance of carbon sources which drive the river's food web and thus ecosystem processes (Bott *et al.* 1978). Carbon is the principal building block of all living tissue (Welker and Streamtec 2000). Therefore, successful river management requires an understanding of the flux of organic carbon through the ecosystem, and in particular, the source and fate of carbon. A number of factors can influence the production of carbon in rivers, including light penetration, nutrient levels and flows (WRC 2003). In addition, human activities can substantially alter the carbon cycle (Bunn 1997).

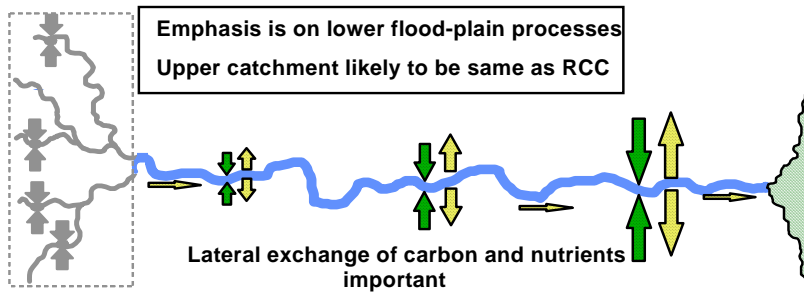
Food webs in rivers are generally considered to be reliant on energy inputs (organic carbon) from the surrounding catchment and immediate riparian zone (WRC 2003). There are currently three models which describe ecosystem function in relation to carbon movement through freshwater systems. These are the River Continuum Concept (Vannote *et al.* 1980), the Flood-Pulse Concept (Junk *et al.* 1989), and the Riverine Productivity Model (Thorp and Delong 1995) (see Figure 3).

Under the River Continuum Concept (RCC; Vannote *et al.* 1980), lower river reaches rely on fine particulate organic matter derived from upstream terrestrial vegetation. This model emphasises the longitudinal connection of upstream/downstream river reaches, and the importance of transport of upstream carbon to the function of lower river reaches. In contrast, the Flood-Pulse Concept (FPC; Junk *et al.* 1989) highlights the significance of lateral terrestrial sources of organic matter, and therefore the river-floodplain connection, to the aquatic ecosystem. This model has often been applied to large floodplain rivers. The RCC and FPC may underestimate the role of non-filamentous aquatic algae, and local riparian and in-stream sources of organic carbon. The Riverine Productivity Model (RPM; Thorp and Delong 1995) emphasises the importance of local primary production (phytoplankton and benthic algae), and direct inputs from the adjacent riparian zone.

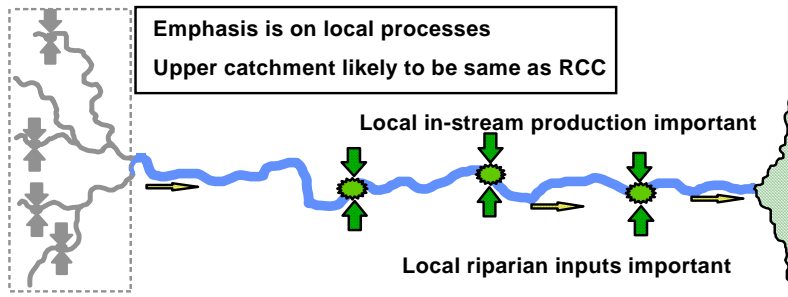
The Margaret River is perhaps best defined by the River Continuum Concept owing to the extensive riparian vegetation and forest present along the banks in its headwaters. Downstream carbon is likely derived from these upstream terrestrial sources, making the upstream/downstream connection highly important to ecosystem function. The RPM likely plays a greater role in the more open, lower reaches of this system.



(a) River Continuum Concept (RCC)



(b) Flood-Pulse Concept (FPC)



(c) Riverine Productivity Model (RPM)

Figure 3. Schematic showing the three models of riverine function (after Bunn 1997).

3 BRUNSWICK RIVER

3.1 Study Area

The Brunswick River (Plate 17) has a catchment area of approximately 228 km². Originating in State Forest on the Darling Scarp, east of the Brunswick Junction townsite, the river flows into the Leschenault estuary via the Collie River (McLaughlin and Jeevaraj 1994, Beckwith Environmental Planning 2006). The confluence with the lower Collie River is at Point Latour (McLaughlin and Jeevaraj 1994), approximately 10 km from the estuary.



Plate 17. The Brunswick River (photo by Katherine Bennet / DoW)

With respect to geomorphology, the Lowden formation predominates in the upper catchment, with its steep slopes and lateritic soils (Taylor 2006). The Murray landform dominates the Swan Coastal Plain, with some outcrops of Lowden formation near the scarp. Primarily composed of deep fluvial deposits, the Murray landform contains clays and some sand in coastal areas (Rose 2004). Numerous perched water tables in winter are a result of the impermeable clays under gravel (Stokes 1985).

Approximately 25% of the upper Brunswick River catchment has been cleared (McLaughlin and Jeevaraj 1994). Dominant land uses in this area are State Forest and the Worsley Alumina Refinery (Beckwith Environmental Planning 2006). The Brunswick Plantation forms part of the State Forest, where silviculture operations are also conducted (Taylor 2006). In contrast, extensive clearing has occurred in the lower portion of the catchment on the Swan Coastal Plain (downstream of Brunswick Junction), with 75% of the land being cleared, predominately for agriculture (Beckwith Environmental Planning 2006, Taylor 2006). The dominant land uses in this area are horticulture and agriculture, including beef and dairy farming. Residential development has resulted in the land around Australind and Bunbury being largely cleared (Taylor 2006). The lower section of the Brunswick River has undergone substantial modification, with engineering projects altering the course of the river in this area (Beckwith Environmental Planning 2006). A loss of riparian vegetation results in increased nutrient, and sediment loads downstream coupled with increased surface runoff, resulting in flooding and channel erosion. In the lower reaches, the Brunswick River is characterised by “relatively deep, incised, often eroded and slumping stream banks, erodable steep banks and unstable sand-gravel beds” (Rose 2004). Sand slugs are present moving downstream which result in highly turbid conditions when river flow is established or during flood pulses (Rose 2004). Historically, riparian zones would have been wide and densely vegetated with winter-wet depressions and swamps on floodplains during winter.

3.2 Riparian vegetation

Vegetation complexes of the Brunswick River catchment vary depending on soil type and landform. According to Matiske and Havel (1998), the catchment can be divided into four regions based on their vegetation complexes, including the Darling Scarp, Lowdon landform, Murray landform, and lower catchment. Generally, open forest of jarrah-marri woodland predominates throughout the headwater catchment, with *Eucalyptus rudis* (flooded gum; Plate 18) – *Melaleuca rhabdophylla* (swamp paperbark; Plate 19) complexes in the valley floors on the floodplain, in wet depressions and along the river bank (Waterways Commission 1993a, Matiske and Havel 1998). Some admixtures of *Eucalyptus laeliae* (Darling Range ghost gum) are also found on the Darling Scarp in the north (subhumid zone), and low woodland of *Allocasuarina huegeliana* (rock sheoak) and closed heath of *Myrtaceae-Proteaceae* species are present on or near granite outcrops. Some *Agonis flexuosa* (peppermint) and *Eucalyptus wandoo* (wandoo) are found within the Lowdon landform, and blackbutt is present over the Murray landform. On the Swan Coastal Plain near the inlet, vegetation comprises salt-marsh of *Sarcocornia quinqueflora* (bearded samphire), *Halosarcia indica* (shrubby glasswort), *Juncus Kraussii* (shorerush), *Casuarina obesa* (saltwater sheoak), *Bolboschoenus caldwellii* (club rush). Swamp paperbark and flooded gum are also present in this area (Matiske and Havel 1998).



Plate 18. Flooded gum *Eucalyptus rudis* (taken from florabase.calm.wa.gov.au).



Plate 19. Swamp paperbark *Melaleuca raphiophylla* (taken from florabase.calm.wa.gov.au)

Along the length of the lower Brunswick River the native understorey has been almost completely replaced with introduced weed species and pasture (Waterways Commission 1993a). Remaining native understorey comprises a number of sedge and rush species, including coastal saw sedge

(*Gabnia trifida*), pale rush (*Juncus pallidus*), twig rush (*Baumea junca*) and common sword sedge (*Lepidosperma longitudinale*). Also present, but less common, are the coast sword sedge (*Lepidosperma gladiatum*) and angle sword sedge (*Lepidosperma tetraquetrum*; Plate 20), with the twig rushes *Baumea articulata* and *Baumea riparia* in waterlogged sites. Between the Clifton Road Bridge and Bunbury Bypass Bridge, the Brunswick River has a narrow band of closed sedgeland comprising club-rush (*Bolboschoenus caldwellii*; Plate 20) (Waterways Commission 1993a). Mat grass (*Hemarthria uncinata*) and small pennywort (*Centella cordifolia*) make up the native ground cover (Waterways Commission 1993a).



Plate 20. Angle sword sedge *Lepidosperma tetraquetrum* (left) and club-rush *Bolboschoenus caldwellii* (right) (taken from florabase.calm.wa.gov.au).

The main weeds within the understorey of the Brunswick include watsonia (*Watsonia bulbilifera*), swans down (*Asclepias* sp.), kikuyu (*Pennisetum clandestinum*), couch (*Cynodon dactylon*), buffalo grass (*Stenotaphrum secundatum*), pampas grass (*Cortaderia selloana*), rye grass (*Lolium* spp.), paspalum (*Paspalum dilatatum*), clubnut rush (*Cyperus* sp.), blackberry (*Rubus* spp.), dock (*Rumex crispus*), wild aster (*Aster subulatus*), and arum lily (*Zantedeschia aethiopica*). Along the riverbank upstream of the confluence with the Collie River, persicaria (*Polygonum minus*) and watercouch (*Paspalum distichum*) are common. The introduced bulrush (*Typha orientalis*) is also present along the river (Waterways Commission 1993a).

Foreshore condition assessments have been undertaken along the length of the Brunswick River as part of the River Action Plan (Taylor 2006). The downstream EWR survey reach (see Figure 4; section 2.4) was in the vicinity of the foreshore assessment reach 1. This reach supports a paperbark, rivergum and peppermint overstorey with an understorey predominantly comprising weeds with some sparse natives (Taylor 2006). Upstream of Paris Road (which also corresponds to the EWR survey reach) there is extensive erosion due to a lack of vegetation to stabilise the bank. Downstream of this point, however, rushes and sedges are present and stabilise riverbanks (Taylor 2006). The foreshore along this reach was classified B3-C1, suggesting it was weed dominated and erosion prone. The uppermost EWR survey reach (see Figure 4; section 2.4) is in roughly the same area as the RAP foreshore reach 3. This reach is on agricultural land and as such has very little native understorey, with pasture and weeds dominating the riparian zone (Taylor 2006). The

overstorey is sparse and covers only a narrow band, typically of one row of flooded gums and/or peppermints. The channel is affected by erosion, bank slumping and undercutting. This poses a threat to the native riparian vegetation as the riverbank is eroding beneath their root system (Taylor 2006).

3.3 Freshwater macroinvertebrates

The macroinvertebrate fauna of the Brunswick and Wellesley Rivers was studied during spring 1996 and autumn 1997 to provide baseline information on the ecological status of these systems (Papas *et al.* 1997). Four sites along the Brunswick were sampled (Wellesley Road, Whistlers Gully, Walford Road and Paris Road) using a 250 µm mesh sweep net. Habitats sampled included riffles, emergent macrophytes and channel. Samples were processed using live sorting over a 30 minute period, with specimens identified to family-level (Papas *et al.* 1997). During these surveys, 43 families were recorded in the Brunswick (Papas *et al.* 1997). SIGNAL values based on the macroinvertebrate composition were calculated and ranged from 3 to 5. This suggests the Brunswick is moderately to severely degraded (Papas *et al.* 1997). The invertebrate assemblage of the upstream environment was found to be representative of an undisturbed river, while in the lower reaches it was more typical of nutrient enriched systems (Papas *et al.* 1997). Since AusRivAS models were still under development at the time, banding scores were not provided.

In addition, as part of Worsley Alumina Refinery monitoring programs, sampling of the macroinvertebrate fauna in the Augustus, Ernest and Brunswick rivers was undertaken on four occasions during 1999 (Hale *et al.* 2000). Sampling was conducted at one site on the Brunswick River using the rapid assessment techniques of the National River Health Program. This technique involves live picking to family level only (Davies 1994, Smith *et al.* 1999).

A total of 27 families were recorded from channel and macrophyte habitats at site S4, located downstream of the confluence with the Augustus River, near Mornington Road (Hale *et al.* 2000). Taxa included Oligochaeta, Hydridae (freshwater mussels), Ancyliidae (freshwater limpets), Cyprididae, Parastacidae (freshwater crayfish), Unionicolidae (water mites), Oxidae (water mites), Aturidae, Gripopterygidae (stone fly), Caenidae (may fly), Baetidae (may fly; Plate 21), Leptophlebiidae (may fly), Aeshnidae (dragonfly larvae; Plate 21), Cordulidae (dragonfly larvae), Gomphidae (dragonfly larvae), Veliidae, (water bug) Chironominae (non-biting midge larvae), Orthocladinae (non-biting midge larvae), Tanypodinae (non-biting midge larvae), Ceratopogonidae (biting midge larvae), Simuliidae, (black fly), Tipulidae (crane fly), Ephydriidae, Leptoceridae (caddis fly larvae; Plate 21), Ecnomidae (caddis fly), Hydropsychidae (caddis fly) and Hydrobiosidae (caddis fly).

Freshwater mussels (*Westralunio carteri*) were collected from the Brunswick River. This species is restricted within the south-west and is currently listed as a Priority 4 species under CALM's Wildlife Conservation (Specially Protected Fauna) Notice 2005 and as 'vulnerable' under the IUCN Red List of Threatened Species (2004). These listings indicate that whilst not currently threatened, mussel populations are fragmented and in need of monitoring. Population decline has been reported in many areas throughout the south-west and is likely related to secondary salinisation and heavy sedimentation/siltation of river beds and pools.



Plate 21. Leptoceridae (left), Aeshnidae (top right), and a Baetidae (bottom right).

It is suggested that neither study adequately documents the water-dependent macroinvertebrate values of the Brunswick River because both studies only made family-level identifications. We suggest that such taxonomic resolution is not sufficient since the ecologies and life histories of macroinvertebrate fauna tend to be species-specific (Edward *et al.* 2000, Lenat and Resh 2001, King and Richardson 2002). This means that water-dependence may in fact vary between species of the same family. For example, whilst most Glossiphonidae (freshwater leeches) require permanent water, some species are able to aestivate during periods of drought by burrowing into the mud. Furthermore, at least one species of Simuliidae (black fly larvae) has an egg-stage which is resistant to desiccation.

Tolerances to environmental disturbance also tend to be species-specific. For example, under the AUSRIVAS Guidelines (Australian River Assessment System) of the National River Health Program, Leptophlebiidae are considered a highly sensitive family (Davies, 1994), yet members of the genus *Atalophlebia* are known to be exceptionally tolerant of pollution (Gooderham and Tsyrlin 2002). Even within the same genus, species of Chironomidae have a range of environmental tolerances (i.e. within *Dicrotendipes* and *Tanytarsus*) (Armitage *et al.* 1995, King and Richardson 2002). Within other families common to rivers of the southwest, such as Dytiscidae, genera and species exhibit a wide range of environmental tolerances. Changes in water quality may result from alterations to flow regimes associated with impoundment and/or abstraction.

3.4 Freshwater crayfish

Freshwater crayfish from two sites on the Brunswick River (S3 and S4) were sampled as part of the monitoring surveys conducted by Hale *et al.* (2000). Two species were collected using electrofishing techniques, including marron presumed to be *Cherax cainii* (previously known as *C. tenuimanus*) and

gilgies (*Cherax quinquecarinatus*). Both species were recorded from both upstream and downstream sites, with gilgies being recorded in higher abundances (Hale *et al.* 2000).

The crayfish fauna of the Brunswick River was again sampled in February 2006 by Morgan and Beatty (2006). Seven sites along the length of the river were surveyed (Figure 4) using an electrofisher over a range of in-stream habitats. Again, two species were collected (gilgies and marron). Gilgies were more widespread, being recorded from four of the seven sample sites, and were often found in high densities (Morgan and Beatty 2006). Marron were less abundant and somewhat restricted in the Brunswick River. They were collected from two sites in the upper reaches, upstream of the confluence with the Augustus River (Morgan and Beatty 2006).

For a detailed description of the ecologies of these species and their possible dependence on the Brunswick River refer to section 1.4.

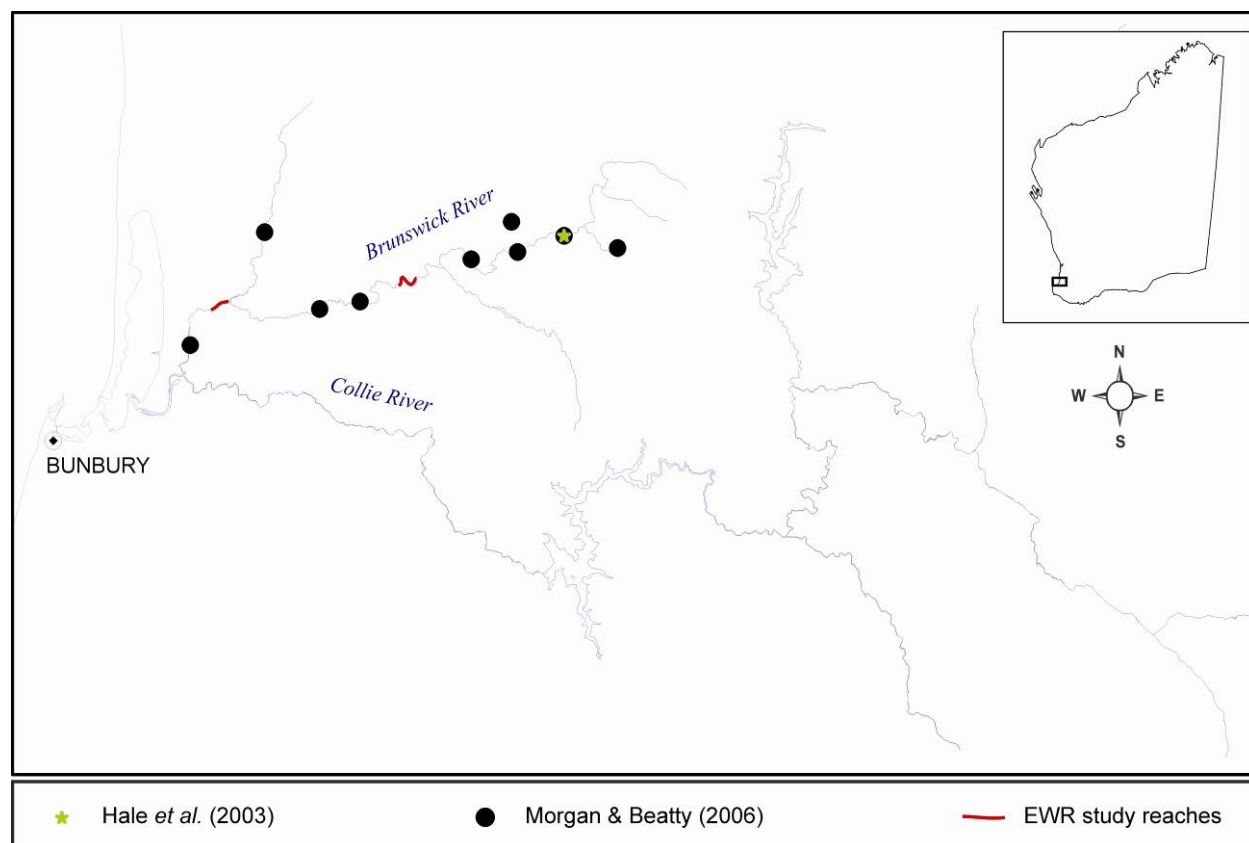


Figure 4. Sites sampled by Morgan and Beatty (2006) and Hale *et al.* (2003), with study reaches for the current EWRs project also indicated (after Morgan and Beatty 2006).

3.5 Fish fauna

Five species of freshwater fish native to the southwest are known to occur in the Brunswick River (Morgan *et al.* 1998, Hale *et al.* 2000, Morgan and Beatty 2006). These include the western pygmy perch (*Edelia vittata*), western minnow (*Galaxias occidentalis*), nightfish (*Bostockia porosa*), freshwater

catfish (*Tandanus bostocki*) and pouched lamprey ammocoetes (*Geotria australis*). A number of marine/estuarine species are also known from the limit of tidal influence, but do not penetrate into the freshwaters of the Brunswick River. These include yellow-eye mullet (*Aldrichetta forsteri*), whitebait (*Hyperlophus vittatus*), blue sprat (*Spratelloides robustus*), western hardyhead (*Leptatherina wallacei*), the Swan River goby (*Pseudogobius olorum*) and the southwestern goby (*Afurcagobius suppositus*) (Morgan and Beatty 2006). Morgan and Beatty (2006) suggested that the lower channelised sections of the Brunswick River may not be conducive to estuarine species and/or the weir may restrict movement upstream. Introduced species of the Brunswick include the mosquitofish (*Gambusia holbrooki*), rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) (Hale *et al.* 2000, Morgan and Beatty 2006). Between 1999 and 2004 some 90 000 fry were stocked in to the Brunswick River by the Western Australian Department of Fisheries.

The fish fauna of the Brunswick River was surveyed in 1999 as part of monitoring programs for Worsley Alumina (Hale *et al.* 2000). The same two sites (S3 and S4) were sampled using an electrofisher. Four native fish were collected, including the western pygmy perch, nightfish (Plate 22), freshwater catfish and pouched lamprey (Table 2). All three introduced fish known to occur in the Brunswick River were also collected.



Plate 22. Nightfish, *Bostockia porosa* (photo taken by Glenn Shiell / WRM).

Morgan and Beatty (2006) reported the perennial flows of the Brunswick to support good populations of a number of southwestern Australia's endemic freshwater fishes. From the seven sites sampled, four native species were recorded. These were the freshwater cobbler, western minnow (Plate 23), western pygmy perch and nightfish. The latter species was found to be restricted to the headwaters, while the remaining three species were widespread throughout the Brunswick River (Morgan and Beatty 2006). Sampling was undertaken primarily with an electrofisher, however a variety of seine nets were also deployed at sites with suitable habitat, i.e. in wide, shallow reaches. See Figure 4 for the locations of sample sites relative to EWR survey reaches.

Table 2. Fish species recorded by Hale *et al.* (2000) from two sites on the Brunswick River.

	Brunswick upstream S3	Brunswick downstream S4
NATIVE		
Western pygmy perch	✓	✓
Nightfish	✓	✓
Freshwater cobbler		
Pouched lamprey		✓
INTRODUCED		
Mosquitofish		✓
Rainbow trout		✓
Brown trout		✓

For information on the water-dependence of native freshwater fish species see section 2.5.



Plate 23. Western minnow, *Galaxias occidentalis* (photo taken by Glenn Shiell / WRM).

3.6 Amphibian fauna

No studies of the Brunswick River frog fauna were found during an extensive literature review. However, a study of the nearby Kemerton region (to the north of the Brunswick River and ~3 km east of the Lechenault Inlet) identified a number of frog species, including Glauert's froglet *Crinia glauerti*, squelching froglet *Crinia insignifera*, Lea's frog *Geocrinia leai*, Gunther's toadlet *Pseudophryne guentheri*, the slender tree frog *Litoria adelaidensis*, and the western green tree frog *Litoria moorei* (see section 2.6) (Bamford and Watkins 1983).

The Sign-bearing or squelching froglet, *Crinia insignifera* (Plate 24), is found in coastal plain habitats near temporary swamps and marshes between Gingin and Busselton. Female squelching froglets lay between 66 and 268 eggs in small clumps in shallow water (Tyler *et al.* 2000). The tadpoles take approximately three to five months to develop.



Plate 24. *Crinia insignifera* (photo taken by JD Roberts Australian Frog Database 2005).

Glauert's froglet, *Crinia glauerti*, is found in coastal plains with marshy areas, seeps and shallow bogs, from the Moore River in the north to the Pallingup River in the south east. Females lay approximately 70 eggs individually within shallow waters. This species will breed following any rain (Tyler *et al.* 2000). Tadpoles take four months to develop. There are no known declines in numbers of *Crinia glauerti* and they occur over a large area. However, continuing development along the coastal plain in the southwest is reducing their habitat.



Plate 25. The slender tree frog, *Litoria adelaidensis* (Rob Davis 2001).

The slender tree frog, *Litoria adelaidensis* (Plate 25), is widespread and abundant throughout the southwest of the State between Port Gregory and Cape Arid. It is commonly found within the dense cover of reeds and rushes, such as *Typha*, along the edge of static or slowly moving waterbodies. Breeding occurs during spring with eggs being deposited in the water and attached to emergent aquatic vegetation (Tyler *et al.* 2000). Although this species is common, there has been recent concern over local mortalities from a chytrid fungus which has been killing frogs in the southwest. Habitat loss through clearing is also a considerable threat.

Of the remaining species known from the Brunswick River, *Geocrinia leai* and *Litoria moorei* are both closely associated with streams and swamps. Both species lay their spawn attached to vegetation (Tyler *et al.* 2000).

3.7 Reptilian fauna

Although the literature review found no published surveys of reptiles for the Brunswick River, similar types would be expected to inhabit the riparian zone of the Brunswick River as those found along the Margaret River (Mike Bamford, Bamford Consulting pers. comm.). The tiger snake *Notechis*

scutatus, the mourning skink or western glossy swamp skink (*Egernia luctuosa*), and the western three-lined or southwestern cool skink (*Acritoscincus trilineatum*) can perhaps be regarded as semi-aquatic since they are reliant upon riparian vegetation for survival and tend to be limited to areas of damp soil. These three species are largely restricted to the margins of waterways.

3.8 Waterbirds

Bamford and Watkins (1983) considered the *Melaleuca* and *Eucalyptus* lined banks of the Brunswick, Collie and Wellesley Rivers to provide important breeding habitat for a limited variety of waterbirds including tree nesting ducks and herons. The *Melaleuca* swamps adjacent to the Brunswick River also provide roosting sites for Australian white ibis (*Threskiornis aethiopicus*) and straw-necked ibis (*Threskiornis aethiopicus*; Plate 26) (Bamford and Watkins 1983). These species feed in floodplains and moist grasslands. Given *Threskiornis* species nest in a limited number of colonies, they are highly susceptible to land use changes (Waterways Commission 1993b).



Plate 26. Straw-necked ibis (*Threskiornis aethiopicus*) (photo taken from fotohead.com.au 2003)

3.9 Other riparian fauna

Of the fauna known to inhabit the riparian zone of the Brunswick River, a number are reliant on the aquatic system, either directly or indirectly as habitat (riparian vegetation) and/or a food source. Such fauna include the brush-tailed phascogale (*Phascogale tapoatafa*), quenda (*Isodon obesulus*), western ringtail possum (*Pseudocheirus occidentalis*), and brushtail possums (*Trichosurus vulpecular*) (Taylor 2006). Quenda only occur in areas with dense covering vegetation, such as the margins of wetlands and Banksia woodland/Jarrah forest (see section 1.8). In addition, three of the species are reliant upon dense vegetation and the availability of hollow-bearing trees such as which occurs close to rivers and wetlands, including brushtail possums, ringtail possums and the brush-tailed phascogale.

The brush-tailed phascogale (Plate 27) is classified as 'Vulnerable' on Schedule 2 of the *Threatened Species Conservation Act, 1995*. Its listing as Priority 3 by CALM (2005) has recently been revised and is currently classed as 'Vulnerable' under the EPBC Act 1999. The brush-tailed phascogale has a patchy distribution around the coast of Australia (Soderquist 1995). The phascogale of south-western Australia represents an isolated population of the southern-subspecies which is found from Rockhampton in Queensland to the Mt Lofty Ranges in South Australia (Soderquist 1995). They are found in jarrah, marri and karri forests of the southwest region. The main threats to their survival are from habitat loss/alteration, decline in the availability of hollow-bearing trees and predation by cats and foxes (Maxwell *et al.* 1996).



Plate 27. The brush-tailed phascogale *Phascogale tapoatafa* (photo L Broome / NPWS)



Plate 28. Western ringtail possum *Pseudocheirus occidentalis*.

The western ringtail possum (Plate 28) is listed as a Schedule 1 species under the *Western Australia Conservation Act 1950*, 'Vulnerable' under the *Environmental Protection and Biodiversity Conservation Act 1999*, and 'Vulnerable' under the IUCN Red List of Threatened Species. This species satisfies the criteria for inclusion as 'Vulnerable' in the IUCN Red List because it is in continuing decline and has a severely fragmented distribution (Australasian Marsupial & Monotreme Specialist Group 1996). Populations of western ringtail possums are scattered over an area in the southwest between Collie River and Two Peoples Bay. Their current range typically includes forests of Peppermint *Agonis flexuosa*. They are found in greatest abundance in habitats with dense vegetation often associated with drainage lines. Their main threats are considered to be predation from introduced foxes and habitat loss.

A number of bat species are also likely to inhabit the riparian zone where they would roost in trees and forage over water (Kyle Armstrong, Molhar Pty. Ltd., pers. comm.). However, the size of the riparian patch and stream width to a certain extent determines the species present (Kyle Armstrong, Molhar Pty. Ltd., pers. comm.). In a study of the vertebrate fauna of the Kemerton region to the north of the Brunswick River, Bamford and Watkins (1983) recorded five bat species which shelter in tree hollows of *Melaleuca* and *Eucalyptus rudis*. Species captured included Gould's wattled bat (*Chalinolobus gouldii*), southern cave bat (*Eptesicus regulus*) (now known as *Vespadelus regulus*), lesser long-eared bat (*Nyctophilus geoffroyi*; Plate 29), western greater long-eared bat (*Nyctophilus major*) (now known as *Nyctophilus timoriensis major*), and the western false pipistrelle (*Pipistrellis tasmaniensis*) (now known as *Falsistrellus mackenziei*). Given that vegetation suitable as their habitat is common along the riparian zone of the Brunswick River, Waterways Commission (1993b) suggested that populations of these bat species are likely present.



Plate 29. Lesser long-eared bat *Nyctophilus geoffroyi* (photo from the Australian Museum 1999, www.amonline.net.au).

3.10 Carbon sources/processing

The source and flux of carbon in the Brunswick River would be best described by the River Continuum Concept. The Brunswick retains relatively healthy remnant terrestrial vegetation in its upper reaches, with the majority being state forest. Therefore, terrestrial organic matter entering the river in these upper reaches is likely the main source of carbon to the upper system, and will provide carbon to lower reaches. However, impoundment of rivers is known to disrupts the flow of carbon downstream, and this may affect the Brunswick with the Beela Dam in the mid reaches likely acts as a carbon sink. Therefore, with increasing distance downstream, the Riverine Productivity Model likely plays a greater role, with in-stream algal carbon likely a significant contributor since much of the riparian zone in the lower Brunswick has been cleared.

For information on the importance of carbon to aquatic ecosystems and a description on the three models of ecosystem function see section 2.10.

4 WILYABRUP BROOK

4.1 Study Area

Wilyabrup Brook (Plate 30) has a catchment area of 90 km² and total length of approximately 100 km (Jury 2006). Its mean annual flow is the second largest in the Cape to Cape region, after the Margaret River. However, the flow regime has been substantially modified by large dams, mostly associated with viticulture. The impact of the significant number of dams on the water balance of the catchment, whilst considered to be significant, is yet to be quantified (Coppolina 2006), but is currently the focus of a detailed study by the DoW (R. Donohue, DOW, pers com.). The brook is located approximately midway between Cape Naturaliste and Cape Leeuwin in the southwest and originates west of the Dunsborough Fault.



Plate 30. EWR survey Reach 1 on Wilyabrup Brook (photo by Katherine Bennett / DoW)

The Wilyabrup Brook flows across two physiographic regions, the Leeuwin Naturalist Coast and the Margaret River Plateau (Coppolina 2006). The former is a narrow strip of land between 0.2 and 6 km wide which extends between Cape Naturaliste and Cape Leeuwin. It is primarily composed of a

gently undulating laterite plateau, with loamy gravels and grey deep sandy duplex soils (Jury 2006). Loamy soils are found in the valleys, yellow sands overlay the limestone ridge, and calcareous sands dominate the coastal dunes (Jury 2006). A series of valley systems dissect the Margaret River Plateau which is between 5 and 15 km wide (Tille and Lantzke 1990).

In its upper catchment, the Wilyabrup Brook flows for the most part through agricultural land, with the downstream reaches traversing national park. Across the catchment, agriculture constitutes the main land use (84%), and includes viticulture (40%), grazing and pasture (29%), dairies (10%) and other agricultural operations (5%). Residential development comprises only 4%, with native vegetation covering the remaining 12% of the catchment (Jury 2006). Coppolina (2006) suggested that 81% of the catchment had been cleared by 1996.

4.2 Riparian vegetation

The majority of the vegetation within the Wilyabrup catchment has been cleared or degraded as a result of agricultural practices, including stock access and grazing (Jury 2006). Weed invasion is also a major issue in the catchment. Along the brook itself, very little of the remaining riparian vegetation has a healthy and complete structure (Jury 2006). There is a mature overstorey of peppermint and marri along the main channel, but little else and with little recruitment (Jury 2006).

According to Beard (1990), the flora of the Wilyabrup Brook comes under the Menzies and Warren subdistricts of the Darling District within the Southwest Botanical Province. Jury (2006) detailed the main vegetation communities found along the brook in the River Action Plan, and were as follows:

- “marri (Plate 31)-jarrah-blackbutt-peppermint forest or woodland on well drained loamy gravels
- Marri-peppermint-tea tree woodland on poorly drained flats and depressions
- Karri forest over peppermint on loamy gravels near Cowaramup
- Jarrah-marri-banksia woodland on sandy soils near Caves Rd and Fifty One Rd
- Heathland with *Kunzea* spp. and *Darwinia citriodora* on rocky soils and rock outcrops primarily west of Caves Rd
- *Melaleuca* woodland and coastal heath near the mouth”.



Plate 31. Marri *Corymbia calophylla* (taken from florabase.calm.wa.gov.au).

Foreshore condition assessments have been undertaken along the length of Wilyabrup Brook as part of the River Action Plan (RAP) (July 2006). The downstream EWR survey reach (see Figure 5; section 3.5) was in the vicinity of the RAP foreshore assessment reach 5 (July 2006). This reach was in near pristine condition (classified as A2) and comprised a healthy overstorey of marri-jarraah, peppermint and heartleaf poison (*Gastrolobium bilobum*). A range of rushes and sedges were also present along the riverbank, including *Lepidosperma* spp., and *Baumea* spp. (July 2006). Weeds of concern in this area were arum lily, wavy gladiolus, fig trees, pittosporum and non-local acacias. The upstream EWR survey reach was in the vicinity of the RAP foreshore assessment site 8. The brook flows through viticulture and agricultural land in this reach. As a result, the channel is considerably more degraded than the downstream reach; erosion is evident where there is stock access, there is little native vegetation and the understorey is dominated by weeds and pasture (July 2006). The remaining native overstorey comprises marri, blackbutt (Plate 32) and peppermint, with patches of tea tree (July 2006). The Environmental Rating for this reach was C1 (erosion prone) to B3 (degraded – understorey dominated by weeds) (July 2006). Weeds of concern in this section of Wilyabrup Brook include blackberry, apple of sodom, arum lily, fig trees, bridal creeper, agapanthus and annual and perennial grasses (July 2006).



Plate 32. Blackbutt *Eucalyptus patens* (taken from florabase.calm.wa.gov.au).

4.3 Freshwater macroinvertebrates

No studies on the aquatic macroinvertebrate fauna of Wilyabrup Brook were found during the extensive literature review.

4.4 Freshwater crayfish

Two species of freshwater crayfish endemic to the southwest region are known from Wilyabrup Brook. These are the marron *Cherax cainii* and the ubiquitous gilgie *Cherax quinquecarinatus* (refer to section 2.4 for a detailed description of the ecology of these species and their possible dependence on Wilyabrup Brook). In addition, the introduced yabby *Cherax destructor* has also been recorded from this system.

A study by Beatty *et al.* (2006) was undertaken to ascertain the fish and freshwater crayfish communities of streams in the Cape Naturaliste region. A number of sites were sampled during September 2005 across five systems, including Wilyabrup Brook, Jingarmup Brook, Dugulup Creek, Dandatup Brook and Meelup Brook (Beatty *et al.* 2006). The gilgie was the most widespread and abundant species, being found at four of the six Wilyabrup sites. Marron were recorded from two sites; Howard Park/Madfish and Brookland Valley Winery. The introduced yabby was also captured from the Howard Park/Madfish site (Beatty *et al.* 2006). See Figure 5 (section 3.5) for the site locations relative to EWR survey reaches.

The introduced yabby (Plate 33) is native to eastern Australia, and was first introduced to Nareembeen in the Western Australian Wheatbelt District in 1932 (Morrissy and Cassels 1992). It has since proven to be a highly successful invasive species and has since spread throughout much of the southwest of the state (Lynas *et al.* 2004, 2006, in press).



Plate 33. The yabby, *Cherax destructor* (Photo by Jess Lynas / WRM).

This species poses a considerable threat to the native freshwater crayfish of Wilyabrup Brook. It has a highly aggressive nature and the potential for it to out-compete native species has been previously detailed (Lynas *et al.* 2004, 2006, in press, Beatty *et al.* 2005). Yabbies are also tolerant of a wide range of environmental conditions, have the ability to exploit a wide variety of different aquatic habitats, including semi-permanent swamps, billabongs, irrigation channels, and deeper, permanent streams and rivers (Austin 1985), and produce a large number of offspring. Yabbies are burrowing crayfish adapted to long-term population survival in the fluctuating environments of impermanent waters.

4.5 Fish fauna

Five fish species have been recorded from the Wilyabrup Brook (Beatty *et al.* 2006; Table 3). Of these, only two are truly freshwater species, the western pygmy perch (*Edelia vittata*; Plate 34) and the

western minnow (*Galaxias occidentalis*). Estuarine species collected from the Wilyabrup Brook mouth included the Swan River goby (*Pseudogobius olorum*), western hardyhead (*Leptoatherina wallacei*), and the big-headed goby (*Afurcagobius suppositus*). Whilst two of these estuarine species were only collected from the mouth, the Swan River goby was found to penetrate into the freshwater environments further upstream (Beatty *et al.* 2006; Table 3).



Plate 34. Western pygmy perch, *Edelia vittata*, in breeding colours (photo by Jess Lynas / WRM).

Beatty *et al.* (2006) sampled six sites along the brook using electrofishing and seine netting techniques. Whilst they only collected two species of native freshwater fish during their surveys, landholders reported that ‘restricted’ mud minnows (*Galaxiella munda*) had previously been sighted from the system. Beatty *et al.* (2006) also considered it unusual that nightfish (*Bostockia porosa*) were not captured from Wilyabrup Brook since they are found within systems nearby. Of the five systems sampled in the Cape to Cape region during this study, native freshwater fish were only captured in Wilyabrup Brook. Beatty *et al.*'s (2006) study was the first survey of freshwater fish from the Wilyabrup Brook.

Table 3. Fish fauna recorded from Wilyabrup Brook by Beatty *et al.* (2006).

	Western minnow	Western pygmy perch	Swan River goby	Western hardyhead	Big-headed goby
Wil 1 Puzey Road					
Wil 2					
Wil 3 Howard Park/Madfish	✓	✓	✓		
Wil 4 Juniper Winery	✓	✓	✓		
Wil 5 Brookland Valley					
Wil 6 mouth			✓	✓	✓

Figure 5 shows the locations of the sites sampled by Beatty *et al.* (2006), along with the approximate position of the two EWR survey reaches. The most upstream survey reach appears to be in close proximity to Beatty *et al.* (2006) site 4 (near Juniper Winery). However, there seems to be a large area between Beatty *et al.* (2006) sites 5 and 6 which was not sampled for fish or crayfish fauna. This section of the river is in the vicinity of the downstream EWR survey reach and therefore requires

further survey to ascertain species present. According to Jury (2006), this is also the best condition reach on the river system in terms of vegetation and channel stability.

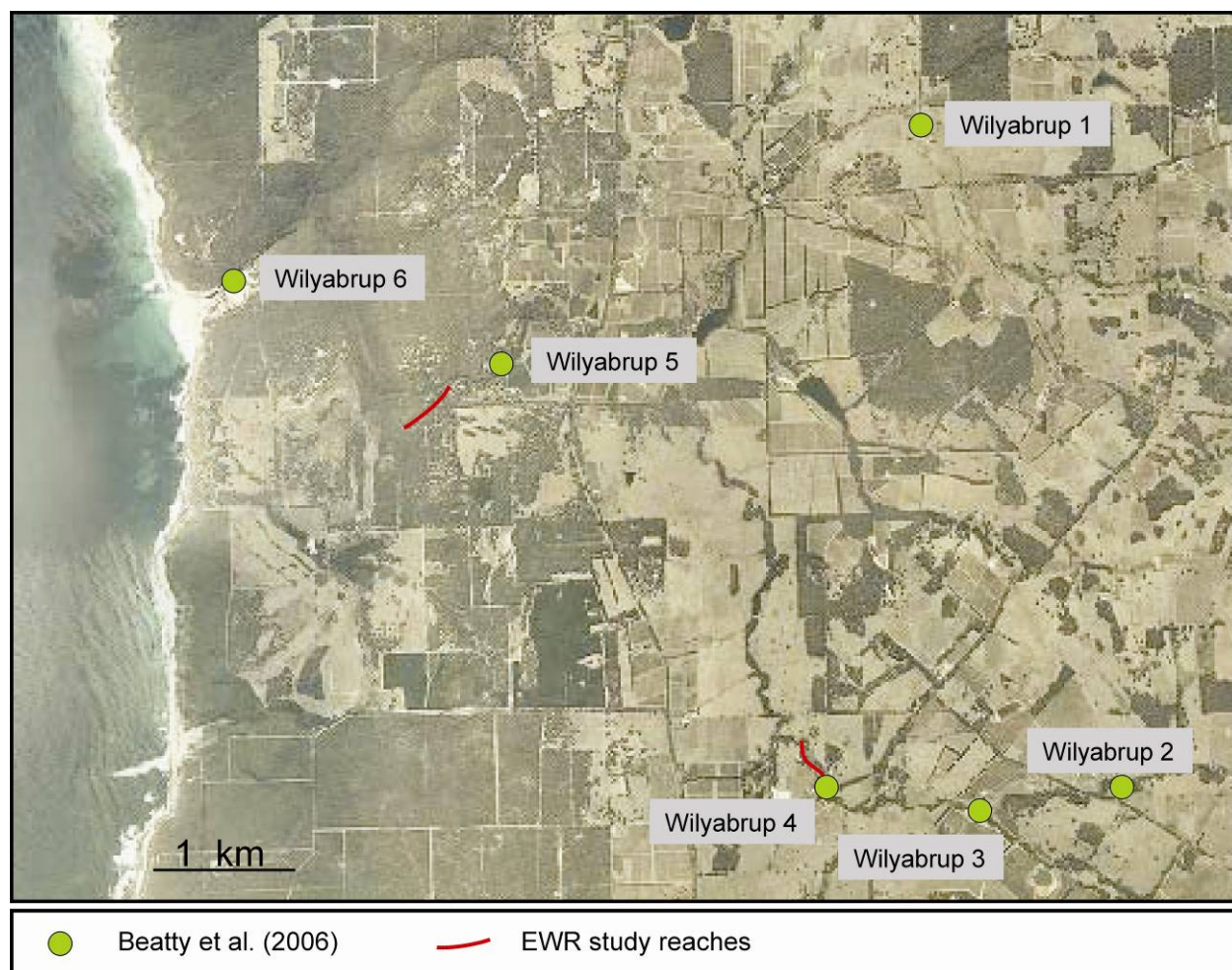


Figure 5. Sites sampled by Beatty *et al.* (2006) on Wilyabrup Brook, with reaches surveyed as part of the current EWRs project also indicated (after Beatty *et al.* 2006).

4.6 Amphibian fauna

Jury (2006) reported that a large number of frogs and reptiles inhabit the Wilyabrup catchment, but no information on the species present was given. For an explanation regarding the importance of flows to frogs see section 2.6.

4.7 Reptilian fauna

The literature review found no published surveys of reptiles for the Wilyabrup Brook, however, in areas of good riparian condition, similar species may be found as those which inhabit the riparian zone of the Margaret River (Mike Bamford, Bamford Consulting pers. comm.). The tiger snake

Notechis scutatus, the mourning skink or western glossy swamp skink (*Egernia luctuosa*), and the western three-lined or southwestern cool skink (*Acritoscincus trilineatum*) can perhaps be regarded as semi-aquatic since they are reliant upon riparian vegetation for survival and tend to be limited to areas of damp soil. These three species are largely restricted to the margins of waterways.

4.8 Waterbirds

No specific waterbird species lists were found for Wilyabrup Brook. However, for information regarding the importance of permanent water to waterbirds see section 2.8.

4.9 Other riparian fauna



Plate 35. Brushtail possum *Trichosurus vulpecular* (photo by Scott Jennings).

brush-tailed phascogale (see section 2.9).

A number of species have been observed inhabiting the riparian zone of the Wilyabrup Brook. Foreshore condition assessments and landholders have reported the following species; brushtail possums (*Trichosurus vulpecular*), western ringtail possums (*Pseudocheirus occidentalis*), the brush-tailed phascogale (*Phascogale tapoatafa*), chuditch (*Dasyurus geoffroi*), the water rat (*Hydromys chrysogaster*) and pygmy possums (*Cercartetus concinnus*) (Jury 2006). Of these, water rats are the most closely associated with the river system (see section 2.9). In addition, three of the species are reliant upon dense vegetation and the availability of hollow-bearing trees such as which occurs close to rivers and wetlands, including brushtail possums (Plate 35), ringtail possums (see section 2.9) and the

4.10 Carbon sources/processing

The headwaters of the Wilyabrup Brook are largely cleared for agricultural and viticultural landuse. The classic model of forested headwaters providing terrestrial carbon to drive instream processes and to provide a downstream flow of carbon therefore no longer applies to the Wilyabrup system. Instead, it is likely that the Riverine Productivity Model plays a greater role, with in-stream algal carbon likely a significant contributor to food webs and processes in headwater tributaries since much of the riparian zone in the upper Wilyabrup has been cleared. This therefore likely limits the quantity and quality of downstream movement of carbon. Also, there are many dams along the length of the brook which will act as carbon sinks, further restricting carbon flow. Therefore, the River Continuum Concept is not likely to explain the carbon flux in this system. The upstream environment would not provide carbon to the downstream ecosystem. In this river, carbon is more likely derived from localised terrestrial inputs. Interestingly the downstream reaches of Wilyabrup Brook still possess very good condition native vegetation. The riparian inputs from this vegetation, combined with the shade provided by overhanging trees probably means that riparian sources play a greater role in providing food web carbon with increasing distance downstream, compared with in-stream algal productivity.

For information on the importance of carbon to aquatic ecosystems and a description on the three models of ecosystem function see section 2.10.

5 CHAPMAN BROOK

5.1 Study Area

Chapman Brook (Plate 36) is located to the east of Witchcliffe in the southwest of W.A. (see Figure 1). It has two main branches, the Chapman and the Upper Chapman, which together extend over 80 km in length. Mean annual flow is 19 700 ML (Pen 1999). The brook drains to the south and flows into the Blackwood River near Warner Glen Mill Road. Numerous large pools are present in the mid and lower reaches, including Rosa (Fishers) Pool. The Chapman Brook catchment covers an area of approximately 1600 km², and is the largest catchment in the Augusta-Margaret River Shire (Lehman 2004). The catchment is part of the Lower Blackwood Zone, which forms part of the Blackwood Basin. This is the largest river basin in the southwest, covering 23 000 km² (Lehman 2004).



Plate 36. The Chapman Brook at Reach 2 (western branch of Chapman) (photo taken by Katherine Bennett / DoW).

The Chapman Brook passes through two major geomorphic regions; the Margaret River Plateau and the Blackwood Plateau. As discussed previously, the Margaret River Plateau is a narrow formation

on granitic and gneissic basement rock of the Leeuwin Block. It contains fertile valleys and is characterised by deep gravely sandy loam soils. Within the Margaret River Plateau, the Chapman Brook crosses two land systems, the Cowaramup Upland and Wilyabrup Valleys land systems (Lehman 2004). The former is an undulating plain with an extensive network of shallowly incised drainage depressions. The Wilyabrup Valleys system forms undulating low hills which have incised from an elevation of between 80-100 m above sea level to 20-40 m (Lehman 2004). Broad U-shaped drainage depressions have formed which have swampy floors with well drained loamy soils. The Blackwood Plateau has a gently undulating surface of moderately raised land (between 80 to 180 m above sea level) that is formed on laterised sedimentary rocks. Within this Plateau, the Chapman Brook is found within the Treeton Hills land system. This system includes some alluvial flats, narrow V-shaped areas and broad poorly drained sections (Lehman 2004).

Approximately 65% of the catchment has been cleared of native vegetation. The main land use throughout the catchment includes dairy, beef cattle, vineyards, horticulture, tourism, State Forest, and some small rural residential blocks. The headwaters of the brook are located in State Forest, but flows through agricultural land as it heads south. The lower reaches of the Chapman Brook flow through areas of State Forest and proposed National Park. These areas represent a significant habitat for the critically endangered white-bellied frog *Crinia alba* (see section 4.6). The majority of the lower branch flows through agricultural land, but there are a few large remanent bush blocks (Lehman 2004).

5.2 Riparian vegetation

The vegetation of the Chapman Brook catchment is part of the Menzies subdistrict in the Southwest Botanical Province (Beard 1990). The riparian vegetation in this area is dominated by jarrah-marri forest. Other vegetation communities along the brook were described by Lehman (2004) and are as follows:

- “Karri (*Eucalyptus diversicolor*), blackbutt (*Eucalyptus patens*), marri (*Corymbia calophylla*), with peppermint (*Agonis flexuosa*) and swamp peppermint (*Agonis linearifolia*)
- Blackbutt and marri, with grey honey myrtle (*Melaleuca incana*; Plate 37 and swamp peppermint.



Plate 37. Grey honey myrtle *Melaleuca incana* (photos by G. Ronk and M. Seale, taken from florabase.calm.wa.gov.au).

- Jarrah-marri, with scattered sheoak (*Allocasuarina fraseriana*) and *Hypocalymma cordifolium*?

Lehman (2004) reported that only a few paddocks along the brook have been completely cleared of vegetation. In sections where agriculture is the dominant land use, the brook has become degraded due to grazing pressure and weed invasion. In fact, the RAP identified weed invasion as a major issue in the catchment, with the dominant weeds being arum lilies, bridal creeper and blackberry. There are, however, some areas of near pristine riparian vegetation remaining which have a diverse range of species (Lehman 2004).



Plate 38. The native sedge *Mesomelaena tetragona* (taken from florabase.calm.wa.gov.au).

Foreshore condition assessments have been undertaken along the length of the brook as part of the River Action Plan (Lehman 2004). The EWR survey reach on the Upper Chapman corresponded with foreshore condition assessment site 9. The vegetation in this area was considered healthy and diverse. The overstorey was dominated by blackbutt and marri over tea tree (*Agonis linearifolia* and *Astartea fascicularis*), prickly hakea (*Hakea amplexicaulis*), grey honey myrtle (*Melaleuca incana*), *Hypocalymma cordifolium*, and tree hovea (*Hovea elliptica*). Native sedges included *Mesomelaena tetragonal* (Plate 38), *Lepidosperma tetraquetrum*, and *Juncus kraussii*. The most upstream EWR survey reach along the lower Chapman Brook was in the vicinity of foreshore assessment site 5. Whilst, the brook in this area had some near pristine areas of riparian vegetation, the survey reach was situated in a section classified as B1-B3 (understorey dominated by weeds). The overstorey comprised blackbutt and marri over tea tree (Lehman 2004). Weeds in this area included thistles, wild radish and kikuyu. The most downstream EWR survey reach corresponded with foreshore assessment site 7. The brook in this area flowed through proposed National Park. The vegetation was in near pristine condition and comprises an overstorey of marri-jarrah-blackbutt over grey honey myrtle, peppermint, tea tree, *Hakea linearis*, heartleaf poison (*Gastrolobium bilobum*). Native sedges include

Lepidosperma effusum, *Baumea* spp., and *Hypolaena exsulca* (Plate 39). There were no weeds adjacent to the Chapman Brook in this reach (Lehman 2004).

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Plate 39. The native sedge *Hypolaena exsulca* (taken from florabase.calm.wa.gov.au).

5.3 Freshwater macroinvertebrates

No information could be found on the aquatic macroinvertebrates of Chapman Brook.

5.4 Freshwater crayfish

Little information could be found on the freshwater crayfish fauna of the brook, however, Lehman (2004) reported marron (presumed to be *Cherax cainii*, but referred to as *Cherax tenuimanus* by Lehman 2004) had been observed. An extensive literature review located no specific studies aimed at sampling the crayfish fauna of this system. For information concerning the dependence of marron on permanent water see section 2.4.

5.5 Fish fauna

Similarly, this literature review revealed no specific studies targeted at the fish fauna of Chapman Brook. However, Lehman (2004) suggested lamprey (*Geotria australis*) had been observed. For further information about lampreys see section 2.5.

5.6 Amphibian fauna

A species of high conservation significance, the white-bellied frog (*Geocrinia alba*; Plate 40), is known from the riparian zone of Chapman Brook (Lehman 2004). This species is currently listed as 'Critically Endangered' with the IUCN Redlist of Threatened Species due to its small area of occupancy (less than 10 km²), its fragmented distribution, and continuing declines in the number of locations, number of mature individuals, and extent and quality of habitat (Hero and Roberts 2004). This frog has an extremely small geographic range of about 130 km² between Margaret River and Witchcliffe in the southwest of W.A. (Tyler *et al.* 2000). It is dependent on aquatic systems, living in dense vegetation in damp or swampy areas kept moist into spring and summer by seepage along creek lines. Wardell-Johnson and Roberts (1993) estimate that 70% of creek systems suitable for breeding have been cleared since European settlement. Major threats to the survival of *Geocrinia alba* include habitat loss/change (clearing, groundwater drawdown drying seeps, invasive weeds, degraded water quality, increased nutrients, herbicides/insecticides) and inappropriate fire regimes.

Also likely to be present in the Chapman Brook catchment is the western green tree frog, or motorbike frog (*Litoria moorei*; Plate 41) (Lehman 2004). This species is also closely associated with water and they spend most of their time in close proximity to swamps and watercourses (see section 1.6). For further information concerning the reliance of southwestern frog species on aquatic systems see section 1.6.



Plate 40. The white-bellied frog *Geocrinia alba* (photo by Dale Roberts (taken from <http://frogsaustralia.net.au/frogs>))



Plate 41. The western green tree frog, *Litoria moorei* (photo by Rob Davis, 2001; taken from www.westernwildlife.com.au).

5.7 Reptilian fauna

The long-necked turtle (*Chelodina oblonga*) is likely to inhabit Chapman Brook (Lehman 2004). This is an aquatic reptile species (see section 1.7). Other reptile species, either known to occur or considered likely to be present, include the tiger snake (*Notechis scutatus*), dugite (*Pseudonaja affinis*

affinis), king skink (*Egernia kingii*), mourning skink or western glossy swamp egernia (*Egernia luctuosa*), and the bobtail (*Tiliqua rugosa*) (Lehman 2004). Of these, tiger snakes and mourning skinks (Plate 42) can perhaps be regarded as semi-aquatic since they are reliant upon riparian vegetation for survival and tend to be limited to areas of damp soil. These species are largely restricted to the margins of waterways.



Plate 42. Western glossy swamp egernia *Egernia luctuosa* (photo taken from members.iinet.net.au/~bush/gecko.html)

5.8 Waterbirds

The Chapman Brook Action Plan reported that white-faced heron (*Egretta novaehollandiae*) and dusky moorhen (*Gallinula tenebrosa*) have been observed from the catchment (Lehman 2004). For information regarding waterbird reliance on aquatic systems see section 2.8.

5.9 Other riparian fauna

Fauna observed within the Chapman Brook catchment include brush-tailed possums (*Trichosurus vulpecular*), western ringtail possums (*Pseudocheirus occidentalis*), brush-tailed phascogale (*Phascogale tapoatafa*), water rat (*Hydromys chrysogater*), southern brown bandicoot or quenda (*Isodon obselus*), western grey kangaroo (*Macropus fuliginosus*), and emu (*Dromaius novaehollandiae*) (Lehman 2004). Other fauna considered likely to be present (Lehman 2004) include the bush rat (*Rattus fuscipes*), chuditch (*Dasyurus geoffroii*), common dunnart (*Sminthopsis murina*), yellow-footed antechinus (*Antechinus flavipes*), echnida (*Tachyglossus aculeatus*), western pygmy possum (*Cercatetus concinnus*) and honey possum (*Tarsipes rostratus*). Of these, water rats are the most closely associated with the river system (see section 1.9). Quenda are also closely associated with the river system, only occurring in areas with dense covering vegetation, such as the margins of wetlands and Banksia woodland/Jarrah forest (see section 1.9). In addition, three of these species are reliant upon dense vegetation and the availability of hollow-bearing trees such as which occurs close to rivers and wetlands, including brushtail possums, ringtail possums and the brush-tailed phascogale (see section 2.9).

5.10 Carbon sources/processing

The headwaters/upstream environment as well as the downstream reaches of the Chapman Brook have a largely intact remnant riparian zone, with little of clearing. Therefore, carbon flow in this system is probably best described by the River Continuum Concept, with lower reaches relying to a certain extent, on downstream flux of carbon derived from upstream terrestrial sources. However, given the forested nature of the riparian zone in the lower reaches, the Riverine Productivity model probably also plays a role here, with localised inputs of riparian-derived carbon. In-stream production by algae is probably minimal given the extensive shading provided by the dense riparian vegetation.

For information on the importance of carbon to aquatic ecosystems and a description on the three models of ecosystem function see section 2.10.

6 COWARAMUP BROOK

6.1 Study Area

Cowaramup Brook is a small system in the south west of the state. It begins west of the Bussell Highway and southwest of the town of Cowaramup and drains into the ocean at Cowaramup Bay. The creek has two main channels and many small tributaries. It is approximately 10km long and has a catchment area of 24km².

Agricultural practices dominate landuse within the catchment, with 1357 hectares of broad acre agricultural and 164 hectares of intensive agriculture. Native vegetation, including National Park and remnant vegetation makes up 871 hectares of the catchment.

The condition of the Brook varies considerably. Some areas of the creek are totally clear of native vegetation and in parts actively eroding. Other areas have an upper canopy of peppermint trees with little lower canopy except introduced grasses. Most of the last 3km of the creek is almost in pristine condition having suffered very little disturbance and home to at least 150 different species of plants.

Cowaramup Brook occurs within two distinct landform units. Most of the creek system is within the Margaret River Plateau, a gentle plateau dissected by a series of valley systems. It is formed on granitic and gneissic basement rock of the Leeuwin Block. It is 5 to 15km wide and extends from Dunsborough to Augusta.

At the coast the brook enters the Leeuwin- Naturaliste coast, a natural strip of land 0.2 to 6 km wide, running between Cape Naturaliste and Cape Leeuwin. It is a discontinuous ridge of Tamala Limestone, with the underlying Leeuwin Block granite being exposed in places (Hanran-Smith, 2004).

6.2 Riparian vegetation

The majority of vegetation within the Cowaramup catchment has been cleared or degraded as a result of agricultural practises. Native vegetation, including National Park and remnant vegetation, makes up 35% of the catchment (CCG 2002).

The condition of Cowaramup Brook varies considerably. Some areas of the creek are totally cleared of native vegetation and in parts actively eroding. Other areas have an overstorey of peppermints (*Agonis flexuosa*) with little understorey except introduced grasses. Parts of the brook that although grazed at some stage, still contain many species of native understorey. Most of the last 2 and a half kilometres of the creek is in almost pristine condition having suffered very little disturbance and is home to at least 150 different species of plants (Hanran-Smith 2004).

The flora of this system is contained within the Menzies subdistrict of the South West Botanical Province (Beard, 1990). The dominant canopy trees are jarrah (*Eucalyptus marginate*), marri (*Corymbia calophylla*) and wandoo (*Eucalyptus wandoo*).

Broad vegetation communities along the river were reported by Hanran-Smith (2004) in the Cowaramup Brook Action Plan (draft), and were as follows:

- Peppermint (*Agonis flexuosa*), tea tree (*Taxandria linearifolia*), marri, pale rush (*Juncus pallidus*) – Beginning between Cowaramup Bay Road and Ellenbrook Road South Of Cowaramup Township
- Spreading sword sedge (*Lepidosperma effusum*), peppermint, marri, weeping grass (*Microlaena stipoides*) and *Trymalium ledifolium* – North of Cowaramup Bay Road continuing to Ellen Brook Road
- Tea tree, pale rush, wonnich (*Callistachys lanceolata*), and *Centella asiatica* – East of Cinella Road
- Peppermint, marri, swamp paperbark (*Melaleuca raphiophylla*), *Trymalium floribundum*, *Taxandria linearifolia*, *Callistachys lanceolata* – North east of the Gracetown township
- Peppermint, marri and sparse tea tree towards Gracetown and the coast



Plate 43. Cowaramup Brook Riparian Vegetation (Supplied by Gracetown Progress Association)

The main weeds of Cowaramup Brook include kikuyu grasses (*Pennisetum cladestinum*), weedy rushes (*Juncus microcephalus* and *Isolepis prolifera*), tree ferns (*Sphaeropteris cooperi*) and dock (*Rumex crispus*). Scattered in various locations along the riverbank are the blackberry (*Rubis ulmifolius*) and arum lily (*Zantedeschia aethiopica*).

Two endangered flora species are known to occur close to Cowaramup Brook. These are the grand spider orchid (*Caladenia huegelii*) and the giant spider orchid (*Caladenia excelsa*). Priority flora that are likely to occur within the catchment area are the western karri wattle (*Acacia subracemosa*) and parrot bush (*Dryandra sessilis* var. *cordata*) (GPA 2006).

6.3 Freshwater macroinvertebrates

The macroinvertebrate fauna of Cowaramup Brook was studied during 2002 by the Cape to Cape Catchments Group. Two sites along the brook were sampled using the SIGNAL method. Habitats sampled were from either a pool/edge or a riffle, and samples were collected using a sweep net during baseflow conditions at each site during spring. Samples were processed using live sorting over a 20 -30 minute period, with specimens being identified to family-level. Both sites produced five families, with CB3 (see Figure 2) recording the higher SIGNAL score 4.6, indicating moderate disturbance. The sample collected for this site was taken upstream of the river mouth, with national

park on the southern bank, providing excellent shade and scattered trees and understorey on the northern bank. Site CB1 (Figure 2), recorded a score of 3.6 indicating severe disturbance. This site had scattered trees and shrubs and some woody debris in the stream (CCG, 2002).

Table 4. Macroinvertebrates found in Cowaramup Brook, taken from Stream Condition in the Cape to Cape subregion, 2002 - Centre for Water Research, UWA

Site CB1		
Macroinvertebrate families recorded	Common name	SIGNAL score
Oligochaeta	segmented worms	2
Chironomidae	non-biting midges	3
Dytiscidae	diving beetles	2
Leptophlebiidae	mayfly	8
Hydraenidae	beetle	3
SIGNAL score		3.6
Site CB3		
Macroinvertebrate families recorded	Common name	SIGNAL Score
Oligochaeta	segmented worms	2
Aeshnid like dragonfly	dragonfly	5
Leptophlebiidae	mayfly	8
Amphipoda	side swimmers or scuds	3
Baetidae	mayfly	5
SIGNAL score		4.6

In addition, as part of a school involvement project, Ribbons of Blue and Southwest Rivercare have undertaken some sampling with community and school groups. Macroinvertebrate sampling was conducted at three sites along the Brook; Gracetown, Caves Road and Merribrook. Fifteen different species were found including mayfly, snails, worms, stonefly, shrimp and stonefly.

6.4 Freshwater crayfish

Two species of crayfish native to the southwest of Western Australia are known to occur in Cowaramup Brook, these include the smooth marron (*Cherax cainii*) and the gilgie (*Cherax quinquecarinatus*). In a study by Morgan and Beaty (2005a), six sites along Cowaramup Brook were sampled using an electrofisher and dip net. A total of six marron were captured at three of the sites (see figure 4 sites 1, 2 and 4). All of the marron were small and probably in their first year of life. A total of 963 gilgies were captured in Cowaramup Brook and they were found in all sites, although densities were at their highest at sites 2 and 5 (see figure 4). All of the sites that were sampled in the brook offered excellent in stream habitat and shade for freshwater crayfish (Morgan and Beatty 2005a). For information concerning the dependence of marron and gilgies on permanent water see section 2.4.

6.5 Fish fauna

The fish fauna of the Cowaramup Brook was surveyed by Morgan and Beatty in 2005. The main aim of this survey was to determine the freshwater fish and crayfish fauna in the brook, identify and feral species and make suggestions regarding the conservation of the southwest regions aquatic fauna. The only fish species captured at the six sites sampled in Cowaramup Brook was the introduced mosquitofish (*Gambusia holbrooki*). A total of 1280 mosquitofish were captured from three sites (3, 5 and 6 – see plate 44 for site locations).



Plate 44. Sampling sites on Cowaramup Brook (left) map from Beatty & Morgan Fish and Crayfish of Cowaramup Brook, 2005.

6.6 Amphibian fauna

No studies of Cowaramup Brook frog fauna were found during an extensive literature review. However, the banjo frog (*Limnodynastes dorsalis*) has been sighted on several occasions by DEC staff and the local Cowaramup community (Cherie Kemp, DEC, pers.comm). Other species that have been documented within the WA Museum database over the past three years are the slender tree frog (*Litoria adelaidensis*), quaking frog (*Crinia georgiana*), glauertsfrog (*Crinia glauerti*) and the moaning frog (*Heleioporus frog*). For further information concerning the reliance of southwestern frog species on aquatic systems see sections 2.6 and 3.6

6.7 Reptilian fauna

Although no studies were found detailing the reptilian fauna of Cowaramup Brook, Museum records and sightings by DEC staff and the local community provide a broad range of species found within

the riparian zone or catchment. One marine reptile species, the loggerhead turtle (*Caretta caretta*), is known to occur in the mouth of the brook where it meets Cowaramup Bay. It is considered to be an endangered species in the south west (DEC Threatened species 2007).

Other reptile species known to occur include the tiger snake (*Notechis scutatus*), dugite (*Pseudonaja affinis*), king skink (*Egernia kingii*), racehorse goanna (*Varanus gouldii*), bobtail skink (*Tiliqua rugosa*), marbled gecko (*Christinus marmoratus*), carpet python (*Morelia spilotametcalfei*), gwardar (*Pseudonaja nuchalis*), blind snake (*Ramphotyphlops australis*) and burton's legless lizard (*Lialis burtonis*). Of the tiger snake, king skink and bob tail skink can be regarded as semi-aquatic reptiles as they are highly reliant on accessing streamside habitats for survival.

6.8 Waterbirds

No waterbird reports were located during an extensive literature review. However, bird sightings have been recorded by DEC, the Gracetown Progress Association and Birds Australia. Bird species that have been observed frequently in the area are the black swan (*Cygnus atratus*), australian shelduck (*Tadorna tadornoides*), australian wood duck (*Chenonetta jubata*), pacific black duck (*Anas superciliosa*), australian pelican (*Pelecanus conspicillatus*), white faced heron (*Egretta novaehollandiae*), australian white ibis (*Threskiornis molucca*), straw neck ibis (*Threskiornis spinicollis*), red capped plover (*Charadrius ruficapillus*), hooded plover (*Thinornis rubricollis*) and the sacred kingfisher (*Tordirhamphus sanctus*). The hooded plover is the only waterbird in this area on the DEC Threatened Species List as a Priority 4 species. Other waterbirds that have been observed less frequently, or considered likely to be present within the area are the musk duck (*Biziura lobata*), the mallard (*Anas platyhychos*), pink eared duck (*Malacorhynchus membranaceus*), white necked heron (*Ardea pacifica*), nankeen night heron (*Nycticorax calendonicus*), glossy ibis (*Plegadis falcinellus*), royal spoonbill (*Platalea regia*), yellow billed spoonbill (*Platalea flavipes*), blue billed duck (*Oxyura australis*), the domestic goose and feral ducks.

6.9 Other riparian fauna

There is no specific information on other fauna associated with riparian zone of Cowaramup Brook, but species found in or near the nearby Wilyabrup Brook would be likely to inhabit the area

6.10 Carbon sources/processing

The headwaters of Cowaramup Brook are largely cleared for agricultural and viticultural landuse. The classic model of forested headwaters providing terrestrial carbon to drive in stream processes and to provide a downstream flow of carbon therefore no longer applies to the Cowaramup system. Instead, it is likely that the Riverine Productivity Model plays a greater role, with in-stream algal carbon likely a significant contributor to food webs and processes in headwater tributaries since much of the riparian zone in the upper Cowaramup has been cleared. This therefore likely limits the quantity and quality of downstream movement of carbon. Also, there are many dams along the length of the brook which will act as carbon sinks, further restricting carbon flow. Therefore, the River Continuum Concept is not likely to explain the carbon flux in this system. The upstream environment would not provide carbon to the downstream ecosystem. In this river, carbon is more

likely derived from localised terrestrial inputs. Interestingly the downstream reaches of Cowaramup Brook still possess very good condition native vegetation. The inputs from this vegetation, combined with the shade provided by overhanging trees, probably means that riparian sources play a greater role in providing food web carbon than in-stream algae with increasing distance downstream.

For information on the importance of carbon to aquatic ecosystems and a description on the three models of ecosystem function see section 2.10.

7 CAPEL RIVER

7.1 Study Area

The Capel River is a relatively small system in the southwest of the state. It rises on the edge of Darling Scarp near the town of Kirup and flows across northern part of Blackwood Plateau (Whicher Range) and Swan Coastal Plain, through Capel before discharging to the Indian Ocean. The Darling Scarp is about 200-300m above sea level and is a line of fracture that separates the Yilgarn Block and the Perth Basin (Pen, L, 1999). The Blackwood Plateau is sediment collected between the Darling Scarp and Leeuwin Naturaliste Ridge to form the 100m high plateau (Pen, 1999).



Plate 45. The Capel River at the Capel Railway ridge (photo taken by Richard Pickett / DoW).

The mouth of the Capel used to be connected to Stirling wetlands and eventually into the Vasse-Wonnerup estuary through a chain of connected wetlands. In 1880 an artificial river mouth was cut through the dunes allowing the river to flow into Geographe Bay (Kirrily White and Sarah Comer).

The river travels about 45 km through the Shire of Donnybrook-Balingup and Capel and has a Surface Water Management Area of 723 km². Although there are no scheme supply dams on the Capel River, many farm dams exist in the upper catchment, some of a significant size (up to 25ha in area).

Traditional landuse within the catchment consisted largely of agriculture. Today it is predominantly horticulture and agriculture, including dairy and beef farming, fruit orchards, viticulture and bluegum production. Mining of mineral sands is also an important feature of the local economy (Hannon, Blake & Creswald, 2006).

7.2 Riparian vegetation

Although much of the Whicher Range remains uncleared, there is significant clearing along the majority of the Capel River channel. The Capel River Action Plan (White et al. 1999) covers the Shire of Capel, and along with Masters (1995), identified wetlands with significant conservation value near the river mouth and in reserve 3802 near the Darling Scarp.

The ecological water requirement (EWR) of riparian vegetation can be defined as the hydrological condition necessary to maintain the health of plant species and allow them to regenerate (Pen 1999). All riparian species require a certain amount of soil moisture to maintain metabolism and some require a hydrological regime that excludes competing species. In the Capel River, the seedlings of flooded gum (*Eucalyptus rudis*) and swamp paperbark (*Melaleuca raphiophylla*) both require the moist soil conditions that follow inundation followed by a year where they are not submerged to survive and potentially mature. Both these species may also require a particular groundwater regime that is maintained by recharge from surface flows when mature. The medium sized sedges *Baumea juncea*, *Juncus pallidus* and *Lepidosperma longitundinale* require at least annual inundation to exclude competing plants, but cannot survive if the inundation is more than half a metre for significant amounts of time.



Plate 46. *Corymbia calophylla* riparian forest with *Lepidosperma* fringing the channel (photo by Kath Bennett / WRM).

Rotting wood and vegetation is an important source of energy, carbon and nutrients, especially in upland streams. This is because the overhanging vegetation and tannin colours support very little algae or aquatic plant growth which provides significant sources in other streams (Pen 1999).

The Capel River catchment lies within the Drummond and Menzies sub-districts of the Darling Botanical District (Pen 1997). Inland from the Darling Scarp, Jarrah/Marri forest predominates whereas the native vegetation of the Coastal Plain is a mosaic of Jarrah/Marri forest, Banksia woodland on sandy rises and Melaleuca low woodland in seasonally inundated areas. On the Spearwood land system nearer to the coast, Tuart tall forest is the native vegetation.

The following four riparian vegetation communities were identified between the river mouth and the edge of the Capel Shire by White et al. in the Capel River Action Plan (1999):

1. Flooded Gum (*Eucalyptus rudis*) woodland over ti-tree (*Astartea fascicularis* & *Agonis linearifolia*) scrub.
2. Marri (*Corymbia calophylla*) forest over soapbush (*Trymalium floribundum*) and heart-leaf poison (*Gastrolobium bilobum*) scrub over *Lepidosperma* sedgeland

3. Peppermint (*Agonis flexuosa*) and Marri (*Corymbia calophylla*) woodland

4. Freshwater Paperbark (*Melaleuca raphiophylla*) and Flooded Gum (*Eucalyptus rudis*) open woodland.

Community 4 is found in the lower parts of the catchment where the river was historically connected with the Vasse-Wonnerup Estuary and community 3 is found upstream of community 4 to near the Capel town site. Between Capel and the shire boundary, vegetation community 1 is found immediately adjacent to the channel and community 2 fringes the river at some distance from the channel.

Foreshore and understorey condition is generally better in the upper parts of the catchment and decreases towards the mouth. In the southern parts of the upper catchment foreshore condition is A2 in areas that have not been cleared, and B3 in areas that have been (Pen 1997). Where the river dissects the Darling Scarp and agricultural use has been less intensive, there are some reaches of the river with good cover of *Agonis linearifolia* (White *et al.* 1999). On the Coastal Plain, a long history of stock access to the river has degraded the understorey and led to erosion of the channel. Even where the river has been fenced, the understorey has not regenerated and erosion of the channel has continued, in some cases causing damage to fences that have been erected too close to the river. Foreshore condition in this section of the river is generally B2-C2 and ranges from B1 to D1. Reserve 3802 contains some fenced vegetation in A2-A3 condition where the river first reaches the Coastal Plain (White *et al.* 1999, Hamilton 2002).

7.3 Freshwater macroinvertebrates

In January 2006, macroinvertebrates were sampled at one site on the Capel River extending about 200 m. This site is between both the reach sites for the hydraulic model used to determine the EWR. Sampling was undertaken with a 250 µm aperture mesh dip net for as many different in stream habitats as possible to maximise the number of taxa collected. Samples were preserved and taken back to the laboratory for identification.

Fifty nine species were recorded and 14 of these are endemic to the South West region. The freshwater mussel (*Westralunio carteri*) is listed as a Priority 4 species under the Wildlife Conservation (Specially Protected Fauna) Notice of 2005 and as 'vulnerable' under the IUCN Red List of Threatened Species. It is a filter feeder and as such is vulnerable to water pollutants and sedimentation. Water salinity in excess of 4000 µS/cm may prove fatal. It prefers shallow water habitats with a stable bottom and can survive prolonged periods of drought by burrowing into the sediment and sealing the bivalve, enabling it to inhabit seasonal and permanent waterways (WRM 2006).

7.4 Freshwater crayfish

Gilgies (*Cherax quinquecarinatus*), Marron (*Cherax cainii*) and Koonacs (*Cherax plebejus*) were all recorded during the January 2006 macroinvertebrate survey and there are numerous anecdotal reports of their presence in the Capel River. Marron are considered more vulnerable to environmental fluctuations

than Gilgies or Koonacs and require permanent water. For more information regarding the water requirements of freshwater crayfish, refer to section 2.4



Plate 47. Smooth marron, *Cherax cainii*.

7.5 Fish fauna

During an extensive survey of south west rivers, Morgan *et al.* (1998) recorded 5 species of freshwater fish in the Capel River and made note of another in Museum records. Species known to inhabit the Capel River are the Pouched Lamprey (*Geotria australis*), Western Minnow (*Galaxias occidentalis*), Western Pygmy Perch (*Edelia vittata*), Nightfish (*Bostockia porosa*) and the introduced species Mosquito Fish (*Gambusia holbrooki*) and Redfin Perch (*Percia fluviatilis*).

All the native freshwater fish of the Capel River are widespread throughout the south west region and are not under immediate threat at a regional level. However, individual populations can become vulnerable to habitat loss and the introduction of the introduced species *G. holbrooki*, and more particularly *P. fluviatilis*, which are predators. None of the freshwater fish in the Capel River have adaptations to withstand desiccation and therefore require permanent water. For more information on the ecology of freshwater fish, see section 2.5.

7.6 Amphibian fauna

There have been only limited frog surveys within the Capel River catchment, with only 3 species, the Slender Tree Frog (*Littoria adelaidensis*), Glauert's Froglet (*Crinia glauertia*) and Squelching Froglet (*Crinia insignifera*), being definitively located within the area WRM (2006). A further 6 species have been recorded in the general Ludlow area (Bamford 2001). Although none of the frog species

within the area are rare or have a restricted distribution, all are vulnerable to habitat loss through vegetation clearing. For more information on the biology and ecology of frogs, see previous sections on amphibian fauna

7.7 Reptilian fauna

There is anecdotal evidence that the long-necked tortoise *Chelodina oblonga* (Plate 11) inhabits the Capel River (Tom Hutton pers. comm.) In addition, a number of species of reptile likely to inhabit the riparian zone of the Capel River can perhaps be regarded as semi-aquatic since they are reliant upon riparian vegetation for survival and tend to be limited to areas of damp soil (Mike Bamford, Bamford Consulting pers. comm.). Such species include the tiger snake *Notechis scutatus*, the mourning skink or western glossy swamp skink (*Egernia luctuosa*) and the western three-lined or southwestern cool skink (*Acritoscincus trilineatum*); all of which are largely restricted to the margins of waterways.

7.8 Waterbirds

During a survey of the nearby Ludlow River, seven waterbird species were observed: The Black Fronted Dotterel (*Charadrius melanops*), Grey Teal (*Anas gibberifrons*), Pacific Black Duck (*Anas superciliosa*), Australian Wood Duck (*Chenonetta jubata*), Straw Necked Ibis (*Threskiornis spinicollis*), White Faced Heron (*Ardea novaehollandiae*) and the White Necked Heron (*Ardea pacifica*) (WRM 2006). The nearby Vasse-Wonnerup Estuary is a larger body of permanent water and is an acknowledged centre of avian diversity (Pen 1997) and as such, the significance of the Capel River as bird habitat is probably relatively low.

7.9 Other riparian fauna

There are anecdotal accounts of Water Rats (*Hydromys chrysogaster*) in the Capel River (Tom Hutton pers. comm.). The highly disturbed nature of the lower reaches of the river, where the permanent water that Water Rats rely on for habitat is most likely to be found, means that any populations are likely to be small and vulnerable. Water rats are adapted to an aquatic life and have distinctive broad partially-webbed hind-feet, water-repellent fur, and a thick tail. For more information on Water Rats, see section 2.9

Except for some minor streams in the headwaters, most of the Capel River catchment is cleared and as such, the riparian zone is probably of limited significance as habitat for the terrestrial Quenda (*Isodon obesulus*) and arboreal Western Ringtail Possum (*Pseudocheirus occidentalis*).

7.10 Carbon sources/processing

Large parts of the upper Capel catchment are well vegetated and supply carbon to the river from litter fall, so the river continuum concept can explain some of the carbon cycle. The riverine productivity model would also explain some of the carbon cycle in lower reaches where carbon

inputs occur via litter fall in the better vegetated reaches and algal production in the sunnier and exposed reaches where fringing vegetation is sparse.

8 LEFROY BROOK

8.1 Study Area

Lefroy Brook is located approximately 280 km south of Perth in the south west of the state. The Brook flows in a southerly direction before joining the Warren River approximately 25 km inland.

The catchment contains several smaller tributaries that flow into Lefroy Brook, such as Four Mile Brook, Five Mile Brook, Big Brook, Scabby Gully, Jarnadup Brook and East Brook. The total catchment represents an area of 358 km² and is approximately 42 km long.

The Lefroy Brook catchment sits on the southward sloping part of the Darling Plateau known as the Ravensthorpe Ramp physiographical region (De Silva 2004). The area is geologically located on Biranup Complex within the Proterozoic Albany-Fraser Orogen.



Plate 48. Lefroy Brook near the Cascades gauging station (photo taken by Simon Brett / DoW).

The Biranup Complex is a deformed metamorphic belt with high-grade quartzofeldspathic gneiss and minor layers of paragneiss (De Silva 2004). The physiography has also been described as dissected undulating land of small relief (Beard 1990). Agricultural land use activities in the

catchment include cattle and sheep grazing, intensive livestock production, cropping, viticulture and other horticulture (especially apples and vegetables). Cleared catchment areas are characterised by the appearance of private farm dams and water supply reservoirs.

8.2 Riparian vegetation

During investigation of a reach near the cascades gauging station in June 2007, DoW staff identified the dominant species of the riparian vegetation. The small to medium tree *Taxandria juniperus* was found on lower benches, channel banks, higher benches and levees, while the medium tree *Agonis flexuosa* was restricted to levees. The perennial herb *Persicaria decipiens* was found on lower benches and the understorey of channel banks and higher benches was dominated by sedges of at least three *Lepidosperma* species.

8.3 Freshwater macroinvertebrates

In 2005 the Department of Environment and Conservation (DEC) monitored aquatic macroinvertebrates and measured various aspects of water physico – chemistry at a number of sites throughout the south west forests. Macroinvertebrates were sampled from only the channel habitat, which consists of un-vegetated river banks and the central portion of the stream. Macroinvertebrates were collected in 10 m of sweeping with a pond net, then were identified to family level and species level where possible. This process was repeated at one sampling site on Lefroy Brook in the spring of 2006. The list of species recorded is detailed in Table 5.

No other scientific reports detailing the aquatic macroinvertebrate fauna of Lefroy Brook were found during a literature review. However, Ribbons of Blue have undertaken monitoring with the St Josephs Primary School students for many years. Macroinvertebrate sampling has been conducted at the Pemberton Pool, Heartbreak Ford and below the Fish Farm. The families identified were stonefly larvae, riffle beetle larvae, mayfly larvae, diving beetle larvae, dragonfly larvae, damselfly larvae, water boatmen, mosquito larvae, non-biting midge larvae, amphipods, ostracods, copepods, springtails, water striders, snails and caddis fly larvae.

Table 5. Macroinvertebrate fauna recorded from Lefroy Brook in October 2006. Data courtesy Ben Smith (DEC)

Order	Family	LowestID	Number identified
Acariformes	Arrenuridae	Arrenuridae	1
Acariformes	Oxidae	Oxidae	11
Amphipoda	Ceinidae	Ceinidae	12
Amphipoda	Perthidae	Perthiidae	64
Decapoda	Parastacidae	Parastacidae	1
Coleoptera	Dytiscidae	Sternopriscus marginatus	10
Diptera	Chironomidae	Riethia V5	1
Diptera	Chironomidae	Tanytarsus B1	4
Diptera	Chironomidae	Rheotanytarsus underwoodi	1
Diptera	Chironomidae	Tanytarsus palmatus	1
Diptera	Chironomidae	Thienemanniella sp. (V19) (SAP)	5
Diptera	Chironomidae	Cricotopus annuliventris	9
Diptera	Simuliidae	Simuliidae	5
Diptera	Tipulidae	Tipulidae	1
Ephemeroptera	Baetidae	Baetid genus 1 sp. SW1 (SFM)	2
Ephemeroptera	Caenidae	Tasmanocoenis tillyardi	37
Ephemeroptera	Leptophlebiidae	Bibulmena kadjina	12
Ephemeroptera	Leptophlebiidae	Nyungara bunni	1
Hemiptera	Veliidae	Microvelia (Pacificovelia) oceanica	4
Odonata	Megapodagrionidae	Miniargiolestes minimus	1
Odonata	Synthemistidae	Archaeosynthemis spiniger	4
Odonata	Telephlebiidae	Austroaeschna anacantha	6
Plecoptera	Gripopterygidae	Newmanoperla exigua	6
Plecoptera	Gripopterygidae	Riekoperla occidentalis	1
Trichoptera	Leptoceridae	Notoperata tenax	5
Trichoptera	Leptoceridae	Lectrides parilis	1
Trichoptera	Leptoceridae	Condocerus aptus	1
Tubificida	Tubificidae	Tubificidae	3

8.4 Freshwater crayfish

Although there have been no reports detailing the crayfish of Lefroy Brook, two species of crayfish native to the southwest of Western Australia are known to occur within the Brook; the smooth marron (*Cherax cainii*) and the gilgie (*Cherax quinquecariantus*). For more information on the biology and ecology of freshwater crayfish, see section 2.4

8.5 Fish fauna

The fish fauna of Lefroy Brook was surveyed by Pen, Potter and Power in 1991. The aims of the survey were firstly to monitor the movement of lamprey over Big Brook dam, and also to continue monitoring the distribution and abundance of the various fish species. A previous study by Pen *et al* (1988) established a monitoring programme to determine the effect that the proposed dam would have on migratory species and aquatic fauna.

Table 6. Fish fauna recorded from Lefroy Brook by Pen *et al.* (1991).

Site	Western pygmy perch	Mud Minnow	Nightfish	Western minnow	Brown and Rainbow Trout	Lamprey (larvae)	Lamprey (adult)
1		34	7		1		
2		18	10		1		
3							
4	22	8	1				
5	2	8	1				
6	7	8	2				
7		11					
8					1		
9							
10	14		1		7		
11	6		3				
12	2	2	2				
13	25		5				
14	4			1	2	1	30
15	22						

Fifteen sites were surveyed by Pen *et al.* (1991). The location of the fish and lamprey study sites are provided in Plate 49. A seine net and mesh was used to sample the two sites within the impoundment of Big Brook dam. This net was dragged parallel to the shore for 85m before being hauled onto the beach. A portable electric fish shocker was used to sample all other sites. The fish were scooped into buckets and their body lengths measured. A list of the species collected during these surveys is presented in Table 6. The native species collected (in order of abundance) were western pygmy perch (*Edelia vittata*), mud minnow (*Galaxiella munda*), nightfish (*Bostockia porosa*), lamprey (*Geotria australis*) (adult), western minnow (*Galaxias occidentalis*) and lamprey larvae (*Geotria australis*). Of the five native freshwater fish collected, two have considerable conservation significance, the mud minnow (*Galaxiella munda*) and the pouched lamprey (*Geotria australis*).

The mud minnow is listed as 'Lower Risk – Near Threatened' on the IUCN Redlist of Threatened Species. This listing means that the mud minnow is considered a species which does not qualify for 'Conservation Dependent', but is close to qualifying for 'Vulnerable'. This species is also listed as vulnerable on DEC's List of Priority Fauna. Furthermore, in February 2005, *G. munda* was also nominated for inclusion as 'Vulnerable' under the EPBC Act 1999. Its nomination was based on the substantial reduction in numbers over the past century, coupled with its restricted distribution. The mud minnow populations has become severely fragmented or lost from many of the rivers within its current distribution (i.e. Lefroy and Margaret rivers) due to loss of habitat (salinisation, damming, eutrophication and dewatering) and introduced species. A number of rivers in which it is currently found also support the introduced fishes known to predate on *G. munda*.

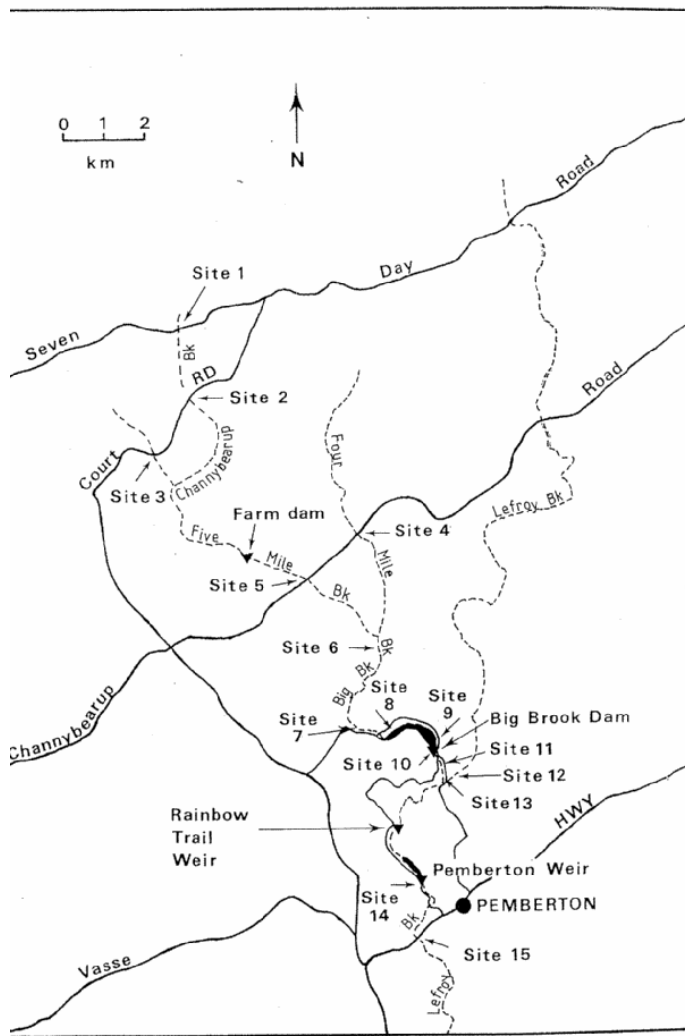


Plate 49. Location of dams and sampling sites on Lefroy Brook taken from Penn et al 1991

australis is the only surviving species of Geotriidae in Australia, and one of four extant lamprey species found in the Southern Hemisphere (Potter 1996) (Allen *et al.* 2002). Pen Potter and Power (1991) collected ammocoetes from one site, 14 (see Table 2 and Figure 3). The very low numbers of larval lampreys almost certainly reflect the barrier to upstream movement posed to adult lampreys by the Big Brook Dam.

The mud minnow has undergone a considerable reduction in range (Morgan & Beatty 2005). Currently, *G. munda* is essentially restricted to the extreme south-west corner of the State, between the Goodga and Margaret rivers, with an isolated population at Gingin, approximately 100 km north of Perth (Morgan *et al.* 1998, Allen *et al.* 2002). However, this population consists of very few individuals which are restricted to a small spring in Gingin Brook. Its centre of distribution is in the small lakes and streams around Windy Harbour in the D'Entrecasteaux National Park (Morgan *et al.* 1998).

The major threats to the status of mud minnows are from habitat alteration and the introduction of exotic species (Morgan *et al.* 1998). In south-western Australia, habitat degradation is likely to occur through alterations to flow regimes (regulation and abstraction), increased salinisation, siltation and eutrophication, which occur through dam construction, groundwater extraction and agricultural/forestry practices in the uppermost catchment (Morgan *et al.* 1998).

The other species of conservation importance is the pouched lamprey. This species belongs to an ancient lineage of jawless fishes whose morphology has remained largely unchanged for approximately 280 million years. *Geotria*

Habitat alteration (including the construction of dams, extraction of groundwater and agricultural practices) and salinisation are believed to have led to the loss of pouched lamprey from many areas. In particular, agriculture in the southwest has reduced the abundance of suitable ammocoete beds due to increased run-off adversely affecting the composition of the substrate. Pouched lamprey ammocoetes burrow into soft substrate beds where they feed on diatoms, detritus and micro-organisms (Potter 1996). Ammocoetes spend 4-5 years in freshwaters, before metamorphosing and migrating to the sea. Adults remain in the open ocean for at least two years before returning to the rivers to spawn which is believed to take place in November.



Plate 50: Pouched lamprey mouth *Geotria australis* from www.biocity.edu.au (left) and pouched lamprey taken from www.ifs.tas.gov.au (photo taken by S.Moore)

None of the freshwater fish in the Lefroy Brook have adaptations to withstand desiccation and therefore have a requirement for permanent water. Components of the biology of native species most likely to be affected by altered flow regimes are fish migration and reproduction. In fact, migration and reproduction in native fish species is stimulated by changes in flow patterns, water levels, temperature and photoperiod (Morgan *et al.* 1998). Western minnows, western pygmy perch and nightfish migrate up tributaries to spawn during winter months. Cues for migration by these species include breaking late autumn/early winter flood pulses and higher water levels, increased flow and currents, as well as increased turbidity, lower temperatures and diminishing daylight.

Sufficient water is also required to inundate trailing riparian vegetation, a favoured spawning habitat of the western minnow during winter. If water levels fall too soon, or fluctuate greatly, eggs may be left dry and desiccate. Flooded vegetation and shallow, flooded off-river areas also provide sheltered, low velocity nursery areas for growing juveniles (WRM, 2007).

A study by Morgan in 1996 presented the distribution and abundance of native and introduced species above and below the dam on Lefroy Brook. An electro fisher was used to sample upstream and downstream of the dam, while gill nets, seine nets and the electro fisher were used to sample the dam itself. There were 20 sites in total that were sampled, and nine species of freshwater fish and the lamprey were collected. Natives collected were the lamprey (*Geotria australis*), western minnow (*Galaxias occidentalis*), mud minnow (*Galaxiella munda*), nightfish (*Bostockia porosa*) and western pygmy perch (*Edelia vittata*). Introduced species collected were brown trout (*Salmo trutta*), rainbow trout (*Onocorhynchus mykiss*), the mosquitofish (*Gambusia holbrooki*) and the redfin perch (*Percia fluviatilis*).

The distribution and abundance of the various native fish is very different to that of Pen *et al* 1991. This study indicates that the large numbers of *Galaxiella munda* previously found are no longer present above the dam and only one *G. munda* was caught below the dam. Similarly, *Edelia vittata*, which was once widespread and abundant throughout the whole sampling areas, is now relatively uncommon downstream and upstream is very rare. Also *Bostockia porosa*, which was relatively common and widespread, is now only found in very low numbers.

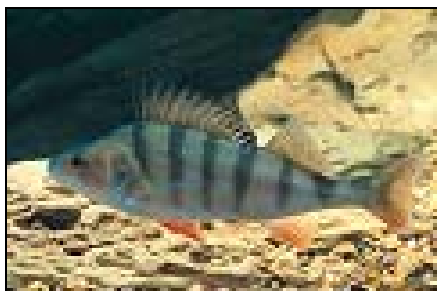


Plate 51: Redfin perch *Perca fluviatilis* (left) and rainbow trout *Oncorhynchus mykiss* (right), taken from www.mdbc.gov.au

Although Pen *et al.* (1991) failed to collect any *Gambusia holbrooki* or *Perca fluviatilis* during their sampling, both species are now extremely abundant and widespread throughout the study area, particularly within the dam itself.

8.6 Amphibian fauna

During an extensive literature review no studies could be found detailing the amphibian fauna of Lefroy Brook. However, WA Museum records (2003 -2007) contain detailed information on species that reside within the Lefroy catchment. Frog species within this collection include the slender tree frog (*Litoria adelaidensis*), motorbike frog (*Litoria moorei*), tschudi's froglet (*Crinia Georgiana*), glauerts froglet (*Crinia glauerti*), small western froglet (*Crinia subinsignifera*), leas's frog (*Geocrinia leai*) and the moaning frog (*Heleioporus eyrie*). For more information on the biology and ecology of frogs, see sections 2.4 and 3.4

8.7 Reptilian fauna

Although no studies were found detailing the reptilian fauna of Lefroy Brook, museum records dating back to 2003 provide a broad range of species found within the riparian zone and catchment area. Species recorded for the Lefroy Brook area include the tiger snake (*Notechis scutatus*), marbled gecko (*Christinus marmoratus*), bardick (*Echiopsis curta*), red legged skink (*Ctenotus labillardieri*) and the four toed earless skink (*Hemiergis peronii*). Of these only the bardick (*Echiopsis curta*) is listed on the IUCN Redlist as a 'Vulnerable' species.

8.8 Waterbirds

No waterbird reports were located during an extensive literature review. However, bird sightings have been recorded by Pemberton Tourism and Birds Australia. Bird species that have been observed in the area are the black swan (*Cygnus atratus*), australian shelduck (*Tadorna tadornoides*), australian wood duck (*Chenonetta jubata*), pacific black duck (*Anas superciliosa*), white faced heron (*Egretta novaehollandiae*), australian white ibis (*Threskiornis molucca*), straw neck ibis (*Threskiornis spinicollis*), and the hooded plover (*Thinornis rubricollis*).

The hooded plover is the only waterbird in this area listed on the DEC Threatened Species List as a Priority 4 species.

Other waterbirds that have been observed within the area are the musk duck (*Biziura lobata*), white necked heron (*Ardea pacifica*), yellow billed spoonbill (*Platalea flavipes*) and the blue billed duck (*Oxyura australis*).

8.9 Other riparian fauna

No studies detailing the fauna of Lefroy Brook have been located during an extensive literature review. DEC records contain information on threatened species within the Lefroy Brook area. These include the western ringtail possum (*Pseudocheirus occidentalis*), quenda (*Isodon obesulus*) and the quokka (*Setonix brachyurus*). For information on these species, see section 2.9.

8.10 Carbon sources/processing

A relatively large percentage of riparian vegetation in the Lefroy Brook catchment is intact and shades the channel. However, there are a large number of dams in the catchment that restrict connectivity. Therefore, the riverine productivity model based on inputs from riparian vegetation is probably the most appropriate model to describe primary productivity of the system. For a description of the in-stream and other productivity concepts, see section 2.10.

9 RECOMMENDATIONS

While the ecological values of some reaches are well documented, there is a paucity of information for others.

Recommendations for further surveys are summarised in Table 7, and are as follows:

MARGARET RIVER

- 1) A foreshore condition assessment has not been undertaken for the uppermost survey reach (Reach 3) to identify riparian and channel condition. It is suggested that the survey reach be assessed using foreshore condition methods of Pen and Scott (1999).
- 2) Macroinvertebrates need to be sampled at all reaches over two seasons; autumn and spring. Seasonal sampling is important to identify species using the system at different times of the year for inclusion in EWRs. During autumn, the river would have receded thus concentrating fauna in pools to allow easier sampling. Spring is the breeding season for most macroinvertebrates, so larvae (the form used in most taxonomic identification) tend to be more abundant at this time. Spring sampling should be timed for mid-late spring, giving sufficient time for larvae to mature to a stage where they may be reliably identified, but before species with single cohorts have emerged (Bunn 1988).

BRUNSWICK RIVER

- 1) Macroinvertebrates need to be sampled at both reaches over two seasons

WILYABRUP BROOK

- 1) Macroinvertebrates need to be sampled at both reaches over two seasons
- 2) Fish need to be sampled at the most downstream reach over two seasons. The study by Beatty *et al.* (2006) sampled either side of this high value section of the system. Seasonal sampling of fish fauna is important to record all species present in the system. This would allow for breeding and migration cycles.

CHAPMAN BROOK

- 1) Macroinvertebrates need to be sampled at all reaches over two seasons
- 2) Crayfish need to be sampled at all reaches over two seasons.
- 3) Fish sampling is required at all reaches over two seasons to identify the fish fauna present
- 4) Records of other vertebrate fauna, including tortoises, to be made from observations whilst sampling.

COWARAMUP BROOK

- 1) Macroinvertebrates need to be sampled over two seasons

CAPEL RIVER

- 1) Macroinvertebrates need to be sampled at both reaches over two seasons

LEFROY BROOK

- 1) Macroinvertebrates need to be sampled over two seasons
- 2) Fish need to be sampled over two seasons

Table 7. Ecological values which require further survey prior to EWR modelling. ✓ = value needs to be sampled from this survey reach.

System and reach number		Ecological Value			
		Vegetation	Macroinvertebrates	Crayfish	Fish
Margaret River	1		✓		
	2		✓		
	3	✓	✓		
Brunswick River	1		✓		
	2		✓		
Wilyabrup Brook	1		✓		✓
	2		✓		
Chapman Brook	1		✓	✓	✓
	2		✓	✓	✓
	3		✓	✓	✓
Cowaramup Brook	1		✓		
Capel River	1		✓		
	2		✓		
Lefroy Brook	1		✓		✓

9.1 Other values/issues**9.1.1 Riverine processes and carbon sources**

The review did not identify any specific studies that have examined food webs and the role of different carbon sources in any of these river systems. Based on current models and concepts of river function and process, and on results of previous studies on comparable rivers in southwestern Australia, assumptions have been made as to likely sources of carbon driving food webs in different parts of each river system. Recommendations to affirm these assumptions have not been made because such studies would be expensive to conduct, and would be unlikely to greatly influence how these systems are currently managed. Such studies would require a major research initiative.

9.1.2 EWRs for riparian zones

Foreshore condition has been assessed for most parts of the seven systems, and any gaps are recommended to be filled by field work planned for autumn/spring 2007. Foreshore condition surveys detail the general composition/vegetation complexes present in each reach, but do not provide detailed species lists, or transects to show position of species/complexes relative to the channel. To accurately determine the EWRs of riparian vegetation, ideally the species at each reach would be known, and their elevation/position relative to the channel would be known. With this information, specific flows could be provided to cater for the EWRs of individual species/complexes. Species-specific transect data could be collected for each reach relatively easily,

however, currently the major flaw in this approach is a robust understanding of the water requirements of the target species. Not only is the different reliance on surface versus groundwater/soil moisture unknown, but the timing, frequency and duration of any inundation is unknown. As such, calculating specific flows for individual species of riparian plants is currently not possible. It is therefore recommended that there is little value in assessing riparian vegetation in more detail, since such information will not enhance the determination of EWRs for riparian vegetation. However, at the time of channel survey, broad zonations of riparian vegetation were identified and elevations recorded on the cross-sections. This will allow the calculation of stage heights (flows) to reach these vegetation zonations. Until more precise scientific knowledge of specific flow requirements of riparian vegetation is available, this approach will be used to provide 'floodplain/riparian zone' inundation flows to different zones (low/medium/high banks), to be based on current frequency and duration.

9.1.3 EWRs for terrestrial fauna dependent on riparian zones

The literature and professional opinion suggest a relatively diverse fauna of mammals, reptiles and amphibians utilise riparian zones of south west rivers, including the four rivers under study. However, the diversity of such fauna is very closely related to the structure and condition of the riparian vegetation, as well as proximity to undisturbed areas (forest etc) which can act as a buffer from disturbance. Generally, little is known of the direct water dependence of terrestrial fauna of riparian zones, although inference may be made for some species (i.e. nesting and feeding (diet) of water rats, spawning sites for frogs etc). It would be possible to collect detailed information on the fauna of riparian zones, however, quantitative (or qualitative) survey of riparian zones for birds, marsupials, mammals, lizards, snakes and frogs would be very time consuming and costly. Moreover, as with riparian vegetation, because definitive water requirements are currently unknown for individual species, the data would not provide for a more detailed/accurate determination of EWRs. However, the literature consistently notes a close association between the condition of the riparian zone and the fauna it supports, the inference being, that if the riparian zone is maintained, then the fauna will be protected. Therefore, it is argued that EWRs to maintain the riparian zone will adequately provide for water requirements of the dependent fauna. Other pressure such as grazing, weeds, feral predators, fire, clearing, erosion, chemicals etc will also affect riparian zones and dependent fauna independently of river flows and EWRs.

9.1.4 Timelines for completion of EWRs

The original project brief was to complete EWRs for the Margaret River by July 2007. Given the absence of macroinvertebrate data for any reach on this system, and no foreshore condition for the upper reach (which is yet to be surveyed for channel morphology), it is recommended that the required sampling is conducted in autumn/spring 2007 and EWRs for Margaret River delayed until December 2007.

10 REFERENCES

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