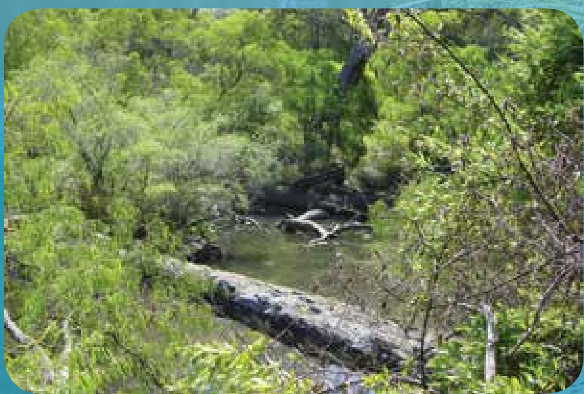
Strategic Action Plan for Protecting Aquatic Biodiversity in the Cape to Cape Region



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Strategic Action Plan for Protecting Aquatic Biodiversity

in the Cape to Cape Region

Report prepared for the Cape to Cape Catchments Group and Department of Environment and Conservation, Government of Western Australia.

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Summary

- The aquatic macrofauna of the Cape to Cape region includes six (6) native freshwater fish species, seven (7) species of native freshwater decapod crustaceans, and a solitary (1) freshwater mussel species. All but one of these are found only in south-western Australia.
- Four (4) of these species are currently listed as threatened or endangered: Hairy Marron (*Cherax tenuimanus*); Margaret River Burrowing Crayfish (*Engaewa pseudoreducta*); Balston's Pygmy Perch (*Nannatherina balstoni*), and; Western Mud Minnow (*Galaxiella munda*). Two (2) others are listed by DEC as Priority Fauna: Pouched Lamprey (*Geotria australis*) and Carter's Freshwater Mussel (*Westralunio carteri*).
- Many aquatic ecosystems in the region are degraded, and the areas that do remain in good condition face a number of serious threats that will need to be countered with strategic planning, on-ground conservation actions, monitoring, and adaptive management.
- The major threatening processes identified were: 1) introduced species; 2) instream barriers and water abstraction; 3) loss and degradation of riparian vegetation; 4) climate change, and; 5) fire.
- There are records of five (5) introduced fish species and two (2) introduced/translocated decapod crustacean species in the Cape to Cape region. Of these, the translocated Smooth Marron (*Cherax cainii*) poses a major threat to the **CRITICALLY ENDANGERED** Hairy Marron (*C. tenuimanus*) in the Margaret River.
- Artificial barriers reduce stream flow, impede access to important habitats, and fragment populations of aquatic species. Abstraction of water for human uses reduces the amount of water available to aquatic ecosystems and can stress aquatic macrofauna.
- Riparian vegetation provides vital ecological services for aquatic habitats and is the major foundation level source of carbon (leaf litter) driving aquatic food webs. As the scale of degradation and loss of natural riparian vegetation increases, so to does the threat to native aquatic and terrestrial fauna.
- There has been a drying trend in the region's climate since the 1970s and this is predicted to continue. Climate change is the biggest looming danger to aquatic ecosystems of south-western Australia and threatens to imperil the majority of aquatic species, particularly the **CRITICALLY ENDANGERED** Margaret River Burrowing Crayfish.
- The impact of fire on the aquatic macrofauna is largely unknown and represents a huge knowledge gap in our understanding of aquatic ecology in south-western Australia.
- A list of recommended actions aimed at protecting aquatic biodiversity in the Cape to Cape region is presented and discussed, including: 1) monitoring of endangered and threatened species; 2) survey and removal of introduced and translocated species; 3) targeted macrofauna surveys and action plans to address knowledge gaps in the region; 4) riparian vegetation fencing and rehabilitation; 5) captive breeding/restocking of endangered species; 6) instream barrier and aquatic refuge assessments; as well as other initiatives.

Background

This project was undertaken at the request of the CCG who were tasked, by DEC, with the directive of developing a strategic action plan for protecting the aquatic biodiversity of the Cape to Cape region. This region houses a number of rare and endemic aquatic taxa (including species listed as critically endangered and vulnerable to extinction) that face numerous current and/or future threats to their conservation. This comprehensive review of current knowledge will facilitate the prioritisation of actions that can be taken to protect the aquatic biodiversity values of the Cape to Cape region.

Our knowledge of the aquatic fauna of the Cape to Cape region has increased substantially in recent years during which time there have been numerous surveys conducted on the freshwater fishes and decapod crustaceans of most of the major catchments. In addition to this, nine River Action Plan (RAP) documents have been published outlining environmental issues affecting the majority of catchments in the region and actions required to address them. There have also been a number of hydrological and ecological water requirements reports published for the major Cape to Cape catchments.

Study Aims

The overarching objective of this review is to assemble the information required to conduct strategic planning of conservation actions to protect the significant biodiversity values of the Cape to Cape region. This will be achieved by:

- Collating all relevant information and data from publications and unpublished data on the aquatic biodiversity of the Cape to Cape region.
- Mapping the distribution of macrofauna species, both native and introduced.
- Identifying major threats to the survival of native species in the region.
- Compiling a list of recommendations for actions to help protect the aquatic biodiversity.

1. Introduction

The south-west of Western Australia is a globally recognised hotspot of biodiversity (Myers *et al.* 2000) with the region being most well known for its exceptional floral variety rather than its freshwater aquatic biodiversity. However, whilst the fresh waters are depauperate in terms of their species richness, they house a largely endemic fauna that is found nowhere else on the planet. In excess of 90% of the native fishes, decapod crustaceans, and bivalve molluscs that inhabit fresh waters are found only in south-west Western Australia and many of these occur in very restricted ranges (Unmack 2001; Morgan *et al.* 2011). Consequently, a number of them are now listed as vulnerable or, in some instances, critically endangered, and their conservation status is likely to become increasingly threatened in the future (Morgan *et al.* 2011).

The Cape to Cape region is home to six native species of freshwater fishes (plus numerous other estuarine species that use fresh water opportunistically), six native freshwater decapod crustaceans, and a solitary freshwater mussel species. Most of these species occur in the Margaret River, including all of the aquatic macrofauna species that are currently listed as threatened or endangered in the region: the Hairy Marron (*Cherax tenuimanus*); the Margaret River Burrowing Crayfish (*Engaewa pseudoreducta*); Balston's Pygmy Perch (*Nannatherina balstoni*), and; the Western Mud Minnow (*Galaxiella munda*). Additionally, the Pouched Lamprey (*Geotria australis*) and Carter's Freshwater Mussel (*Westralunio carteri*) are also recognised as Priority Fauna by DEC.

Substantial change has occurred in parts of the Cape to Cape region in terms of land usage and population growth in the past few decades (CCG 2005a, 2005b, 2006; DoW 2009, 2010). There has been a substantial intensification of agriculture, particularly viticulture, which has resulted in a growing demand for water resources and consequently increased threat to aquatic biodiversity (CCG 2005a, 2005b, 2006). In light of this, the Department of Water, Government of Western Australia, has recognised the need for sweeping reforms in the way water is consumed and managed in south-western Australia in its South West Regional Water Plan 2010 – 2030 (DoW 2010). Additionally, some water resources in the Cape to Cape region, which in the past were unregulated and managed haphazardly, have also recently been proclaimed for allocation under license by the Department of Water (DoW 2009). These are positive steps aimed at meeting the challenge of balancing human demands for water with ecological requirements under the backdrop of a drying climate where demand for water is predicted to be at the limit of supply within 20 years (DoW 2010). There is uncertainty about the state of affairs beyond this time frame, but a substantial body of literature suggests the climatic trend of warmer and drier conditions is likely to continue which will place further pressure on aquatic ecosystems and resident fauna (Suppiah *et al.* 2007; CSIRO 2009a,b; Morrongiello *et al.* 2011).

Climate change and water abstraction are not the only threats to the aquatic biodiversity of the region. In the past 40 years the incidence of species introductions has soared (75% increase since 1970) in fresh waters of south-western Australia (Morgan *et al.* 2011). There are records of at least five introduced freshwater fishes (plus another that is stocked in private farm dams) and two decapod crustaceans in natural waterways of the Cape to Cape region. Introduced species threaten native species through predation, competition for food and habitat, degradation of habitat, and the introduction of diseases and parasites. Further introductions of exotic species are probably inevitable unless there is a substantial increase in public awareness of the detrimental impact these species have on the native aquatic biodiversity.

It is timely, therefore, that this work has been commissioned. A strategic action plan for protecting aquatic biodiversity is the first step towards safeguarding this component of the native fauna which is so imperilled by a combination of significant threats.

2. Study Area

2.1 Geographical scope

This report focuses on the area between Cape Naturaliste in the north and Cape Leeuwin in the south and encompasses all intervening catchments draining westward into the Indian Ocean (Figure 1). Attributes of the major catchments (ordered geographically from north to south) for which detailed information were available are summarised below, followed by a general description of the climate of the Cape to Cape region. The reader is referred to the numerous reports published in recent years by CCG, DoW and others for descriptions of the landforms, soils, flora, fauna, historical heritage and other general information about the Cape to Cape region (see for example CCG 2003; WRM 2007; DoW 2008a; Green *et al.* 2011; and many others).

2.2 Catchments (north to south)

2.2.1 Yallingup Brook

A very small catchment draining an area less than 10 km^2, and with only 5.5 km of stream length (Taylor & Tinley 1999). The system is ephemeral in the upper reaches, but is spring-fed and permanent in two separated sections of the lower reaches (Taylor & Tinley 1999). Most of the catchment lies within the Leeuwin-Naturaliste National Park with remnant native vegetation covering 64% of the catchment, the remainder, predominantly in the upper reaches, is cleared for agriculture (Taylor & Tinley 1999). Data for the number of instream dams and other artificial barriers in the catchment and water quality are not available. The main environmental issues are erosion and sedimentation, and the loss and degradation of riparian vegetation in the upper catchment (Taylor &

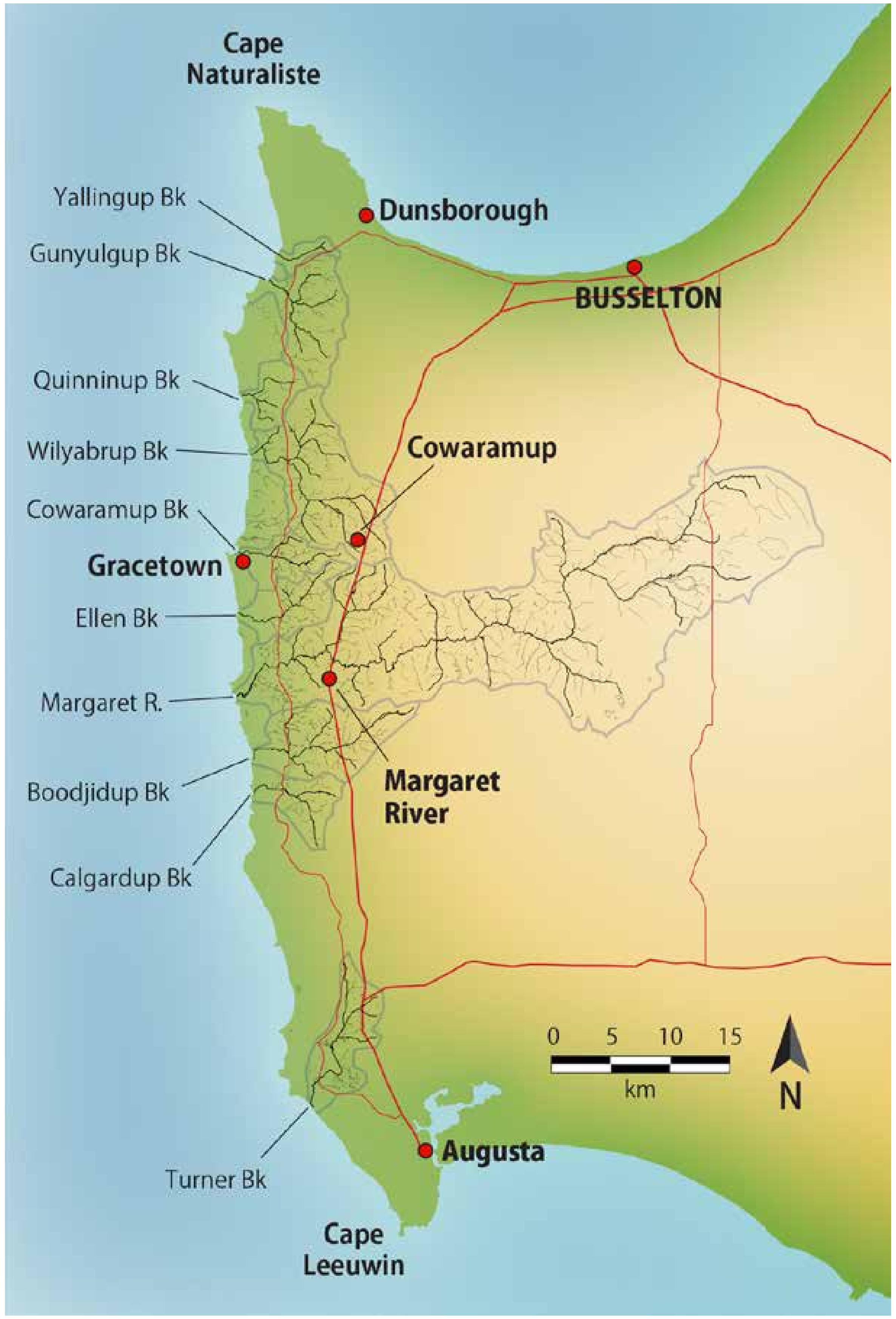

Figure 1. Map of the Cape to Cape region showing major drainage systems.

Tinley 1999). This system has not been comprehensively surveyed for aquatic macrofauna.

2.2.2 Gunyulgup Brook

The Gunyulgup Brook catchment drains an area of 47 km^2 and empties into the sea at Smith's Beach, south of Yallingup townsite (Hunt *et al.* 2002). There are two major branches of the system and a number of small tributaries (CCG 2005b). Underground springs feed a number of isolated permanent pools throughout the catchment but most parts are ephemeral (CCG 2005b). Approximately 65% of the catchment is agricultural land, with most of the remainder covered by remnant native vegetation (Hunt *et al.* 2002). A foreshore condition assessment conducted in 2005 revealed 58% of the catchment was erosion prone or eroded (C), 29% was degraded/weedy (B), 6.5% was reduced to ditches (D), and less than 1% was in near-pristine condition (A) (CCG 2005b). Only 7.5% of the length of stream assessed was fenced off from livestock and 110 instream dams were identified in the catchment (CCG 2005b). Clearing of farmland and destruction of riparian vegetation has resulted in erosion and sedimentation issues in the catchment, particularly in the lower reaches (CCG 2005b). Agricultural land use is intensifying and the human population is also growing in the catchment (CCG 2005b). This system was surveyed for aquatic macrofauna in spring 2004 (see Morgan & Beatty 2005).

Figure 2. Some of the sites sampled during an aquatic macrofauna survey of Gunyulgup Brook in spring 2004 (photos: S. Beatty and D. Morgan).

2.2.3 Wilyabrup Brook

The second largest catchment in the Cape to Cape region covering an area of 89 km^2 (Hunt *et al.* 2002) and approximately 100 km of stream length (CCG 2006). The catchment has been extensively cleared, with 84% used for agriculture (grazing pasture and vineyards), 12% comprising remnant native vegetation (mainly in the lower reaches), and 4% residential (Hunt *et al.* 2002). A foreshore condition assessment conducted in 2005 revealed 44% of the catchment was reduced to ditches (D), 22% was eroded or erosion prone (C), 17% was degraded/weedy (B), 11% comprised instream dams (approximately 100 in number), and 6% was near pristine (A) (CCG 2006). Furthermore, livestock have direct access to approximately half of the stream length and almost 100 km of stream was identified as requiring fencing (CCG 2006). This is the most highly modified of all the catchments in the Cape to Cape region that have been comprehensively assessed. Agricultural land use has intensified and diversified and human population has grown significantly in recent years which has placed increased demand on water resources in the catchment (CCG 2006). From 2000-2005 water quality in the system was consistently within ANZECC guidelines (2003), with the exception of ammonia levels, and occasional spikes in phosphorous (see CCG 2006 for multiple data sources). A limited number of sites were surveyed in this system for aquatic macrofauna in spring 2005, late summer 2006, and spring 2008 (see Beatty *et al.* 2006a; Beatty & Allen 2008).

Figure 3. Some of the sites sampled during aquatic macrofauna surveys of Wilyabrup Brook in 2004 and 2008 (photos: S. Beatty, D. Morgan, and C. Jury).

2.2.4 Cowaramup Brook

A relatively minor system with two main channels and numerous tributaries covering a catchment area of 24 km^2 and 30 km of stream length (CCG 2008). Agriculture (mainly viticulture) is the dominant land use (64%) with the remainder comprising remnant native vegetation (Hunt *et al.* 2002). A foreshore condition assessment conducted in 2008 revealed that 32% of the catchment was degraded/weedy (B), 28% was reduced to ditches (D), 25% was eroded or erosion prone (C), and 15% was in near pristine condition (A) (CCG 2008). Livestock have direct access to 25% of the stream length, and 20 km of riparian zone fencing was recommended (CCG 2008). The main environmental issues in this system include reduced hydrological flows due to water abstraction from 19 on-stream dams and numerous bores, sedimentation of pool habitats, livestock access to streams, and isolated occurrences of salinised springs and soaks on cleared private land (CCG 2008). A recently published Ecological Water Requirements (EWR) report found that water abstraction in the catchment was already close to the ecologically sustainable yield and there was only a limited capacity for the system to accommodate an increase in water consumption (Donohue *et al.* 2010). Water quality was generally within ANZECC guidelines, with the exception of nitrate levels which were consistently high, and salinity which fluctuated seasonally and peaked during autumn at which time water was moderately brackish at a number of sites (see CCG 2008 for multiple data sources). There is a paucity of natural permanent refuge habitat in this system (Donohue *et al.* 2010). An aquatic macrofauna survey was conducted in this system in spring 2004 (see Morgan & Beatty 2005).

Figure 4. Some of the sites sampled during the aquatic macrofauna survey of Cowaramup Brook in spring 2004 (photos: S. Beatty and D. Morgan).

2.2.5 Ellen Brook

A small catchment located centrally in the Cape to Cape region, covering an area of 29 km^2 (Hunt *et al.* 2002) and approximately 40 km of stream length (CCG 2005a). Numerous springs within the catchment contribute to flows, increasing the availability of permanent refuge habitat to the native aquatic fauna (CCG 2005a). Agriculture is the dominant land use (70%) with remnant native vegetation comprising the remainder (Hunt *et al.* 2002). A foreshore condition assessment conducted in 2004 revealed 37% of the catchment was reduced to ditches (D), 29% was degraded/weedy (B), 27% was eroded or erosion prone (C), 5% was near pristine (A), and 2% was unassessed (CCG 2005a). Only 7.25% of stream length was fenced off from livestock (CCG 2005a). The catchment has undergone recent intensification of agriculture and there are upward human population pressures (CCG 2005a). Instream barriers include 32 dams and a single weir that was built in the 1950s (CCG 2005a). Water quality issues were identified from sampling in 2002 including elevated nitrogen, nitrate and phosphorous levels which probably account for the frequent algal blooms in the lower reaches of the system (CCG 2005a). The system was surveyed for aquatic macrofauna in spring 2004 (see Morgan & Beatty 2005).

Figure 5. Some of the sites sampled during the aquatic macrofauna survey of Ellen Brook in spring 2004 (photos: S. Beatty and D. Morgan).

2.2.6 Margaret River

Margaret River is the only true river system in the Cape to Cape region and comprises a catchment area of 477 km^2 and a main channel length of 60 km (Pen 1999). There are extensive permanent pool systems throughout the middle reaches and in some parts of the upper reaches (WRM 2007). The river is in relatively good condition and is one of only a few major river systems in south-western Australia that has not become impacted by salinisation (Morgan *et al.* 2003). The entire upper catchment and significant portions of the lower catchment are uncleared, comprising mostly remnant native forest, but pine plantations are also common (Green *et al.* 2011). Only 21% of the catchment has been cleared (DoW 2008b), mostly in the middle section where there is a mixture of agricultural land uses, timber plantations, and residential subdivisions (CCG 2003). In a survey conducted in 2002, roughly 50% of the main channel foreshore was assessed as near-pristine (A), 45% was degraded/weedy (B), but much of this was low level weed infestation, and the remaining 5% was eroded or erosion prone (C) (CCG 2003). Recommendations from this assessment were for approximately 20 km of riparian zone fencing to protect the river from livestock access (CCG 2003). Two other RAPs have been published for tributaries of the Lower Margaret River (CCG 2009a) and Bramley Brook, Margaret River's largest tributary (CCG 2011). Foreshore condition in the lower tributary catchments was 46% degraded/weedy (B), 23% reduced to ditches (D), 20% eroded or erosion prone (C), and 11% near pristine (A) (CCG 2009a). In Bramley Brook the foreshore survey revealed that 35% was reduced to ditches (D), 31% was degraded/weedy (B), 28% was near pristine, and 6% was eroded or erosion prone (C) (CCG 2011). The main environmental issues identified in all RAPs included loss of riparian vegetation, weed infestation, altered hydrology due to water abstraction, aquatic species introductions, and pollution from agricultural and residential land uses (CCG 2003, 2009a, 2011).

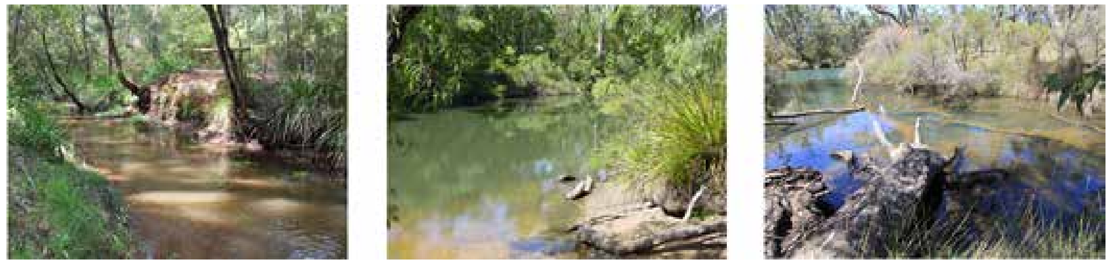

Figure 6. Some of the sites sampled during the aquatic macrofauna surveys of Margaret River and its tributaries between 2003-2008 (photos: S. Beatty, D. Morgan, and R. Jurjevich).

There are no dams on the main channel but water is pumped directly from the river in the middle and lower reaches by private landholders and the Water Corporation (Beckwith Environmental Planning 2007; Green *et al.* 2011). Three weirs exist in the main channel, two of which have had fishways installed in recent years to facilitate fish migrations (Morgan & Beatty 2004a; Beatty *et al.* 2007). About 670 dams and soaks have been built throughout the catchment including 43 commercial sized dams (i.e. > 8 ML storage capacity), but dam density is not as high as in neighbouring catchments (Green *et al.* 2011). A report on the Ecological Water Requirements of the river suggested that current levels of water abstraction were within ecologically sustainable limits but ongoing monitoring was required to ensure they were not exceeded with future allocation of additional water licenses and climate change (Green *et al.* 2011). Long term sampling has not identified any issues of concern regarding water quality in the Margaret River main channel, but there have been occasional spikes in phosphorous in its largest tributary, Bramley Brook (see CCG 2003, 2011 for multiple data sources). A number of aquatic macrofauna surveys have been conducted over the past 15 years (Morgan *et al.* 1998; Morgan & Beatty 2003, 2004a, 2007a; Bunn 2004; Beatty *et al.* 2008; de Graaf *et al.* 2009; Lawrence *et al.* 2010).

2.2.7 Boodjidup Brook

The third largest catchment in the Cape to Cape region, with an area of 60 km^2 and approximately 55 km of stream length (CCG 2009b). Native vegetation covers the majority of the headwaters, but the rest of the basin is largely cleared (CCG 2009b). Land uses, in decreasing order of prevalence, are agriculture (49%), remnant native vegetation (36%), rural residential (10%), with timber plantations and other land uses comprising the remainder (Hunt *et al.* 2002; CCG 2009b). A foreshore condition assessment conducted in 2009 showed 38% of the catchment was degraded/weedy (B), 30% was

eroded or prone to erosion (C), 17% was reduced to ditches (D), and 15% was near pristine (A) (CCG 2009b). Livestock have unfettered access to around 27% of stream length (CCG 2009b). Water abstraction from approximately 90 on-stream dams and soaks throughout the catchment has raised concerns over impacts on environmental flows, and erosion and sedimentation are other pertinent issues (CCG 2009b). Water quality falls within ANZECC guidelines except nitrate levels which were consistently high (see CCG 2009b for multiple data sources). The system was surveyed for aquatic macrofauna in spring 2007 (Morgan & Beatty 2008).

Figure 7. Some of the sites sampled during the aquatic macrofauna survey and river foreshore assessment of Boodjidup Brook in spring 2007 (photos: S. Beatty, D. Morgan, and C. Jury/CCG).

2.2.8 Other catchments

There are a number of other catchments in the Cape to Cape region that have not been covered by a RAP, EWR, or other similarly detailed assessment report. In the northern half of the region these include Wyadup Brook, Biljedup Brook, Veryiuca Brook, and Miamup Brook, and in the southern half the moderately sized catchments of Calgardup Brook and Turner Brook. A RAP is currently being prepared for the Quinninup Brook catchment (D. McKenzie pers. comm.).

2.3 Climate

The region has a Mediterranean climate characterised by hot dry summers and mild wet winters. Long-term mean annual precipitation at Margaret River is 1131 mm, and is similar at other weather stations in the region (BoM 2012). Precipitation decreases to around 900 mm further inland near the headwaters of the Margaret River catchment (BoM 2012). There has been a decline in rainfall since the mid-1970s of between 10-25% across south-western Australia (Suppiah *et al.* 2007; see section 4.4 of this report for more information). On average, the majority of precipitation falls in the five months from May to September, with sporadic falls occurring outside of this period (BoM 2012), but there is a recent trend of less rain in autumn and early winter, and more rain in late winter and summer (IOCI 2008). Evaporation rates in the region are around 1.5 times greater than precipitation rates (Taylor & Tinley 1999; BoM 2012) resulting in highly seasonal flows in most drainage systems, except those fed by groundwater discharge.

3. Aquatic biodiversity

3.1. Native freshwater fishes

A total of six native, obligate freshwater fish species have been recorded in the Cape to Cape region. An obligate freshwater species is defined as one requiring the use of fresh water in order to complete its life cycle. Of these six species, all are endemic to south-western Australia, with the exception of the Pouched Lamprey (Allen 1982; Morgan *et al.* 1998, 2011). A number of other native fishes have been reported from Cape to Cape streams including Sea Mullet (*Mugil cephalus*), Zebrafish (*Girella zebra*), Black Bream (*Acanthapagrus butcheri*), Western Hardyhead (*Leptatherina wallacei*), Silverfish (*Leptatherina presbyteroides*), Blue-spot Goby (*Pseudogobius olorum*), and the South-western Goby (*Afurcagobius suppositus*) (Jaensch 1992; Morgan & Beatty 2005, 2008; Beatty *et al.* 2006a, 2008). These are marine and estuarine species that utilise freshwater habitats opportunistically, and are not covered in detail in this report.

3.1.1 Pouched Lamprey - *Geotria australis* (Geotriidae)

Identification and biology

A primitive species that has remained largely unchanged morphologically since prehistoric times. Lampreys are jawless and possess a specialised oral suctorial disc (Figure 8b) which is equipped with rows of teeth used to rasp the flesh from fish to which they attach during their parasitic ocean-going life cycle phase (Hilliard *et al.* 1985; Potter 1996). The fascinating life history of the species begins in the freshwater environment where the eyeless, brown, worm-like larvae (known as ammocoetes; Figure 8d) spend their first 4-5 years buried in soft sandy sediments in creek and river beds, filter feeding on plantkon, algae and detritus (Potter & Hilliard 1986; Potter 1996). At a length of around 10 cm, the ammocoetes metamorphose into a more colourful form (silvery below and blue on the back; Figure 8c), at which time they also develop eyes and undertake a downstream migration to the sea to commence the parasitic phase of the life cycle that is presumed to last for two years (Potter *et al.* 1980; Potter 1996). Each winter and spring is marked by an upstream migration of lampreys (about 50-60 cm in length) at which time it is not uncommon to see them congregated below barriers such as the Apex Weir at Margaret River (Morgan & Beatty 2004a, 2007a; Beatty *et al.* 2007; Figure 8e), although they seem to appear in larger numbers in the Margaret River during mid-late spring (D. Morgan unpubl. data). These fish are capable of bypassing such obstacles by climbing up walls or rocks, or even by traversing damp ground for short distances, as well as utilising fishways (Potter 1996; Morgan *et al.* 1998; Morgan & Beatty 2004a). The maturing lampreys (Figure 8a) spend up to 18 months in rivers and creeks where they do not feed, instead subsisting entirely on fatty tissue before they attain sexual maturity, spawn and then perish shortly thereafter (Potter 1996). This type of life cycle (i.e. mostly spent at sea with a freshwater breeding migration) is classified as anadromous. The oral disc of adult male lampreys becomes enlarged in fresh water and they also develop a large gular pouch on the underside of the head, hence the common name Pouched Lamprey (Potter 1996).

The extent of numbers of upstream migrant lampreys varies annually and has been linked to the amount of discharge in the river (Potter 1996; Morgan *et al.* 1998; Beatty *et al.* 2007). Years with higher discharge typically result in larger numbers of migrating lampreys (Potter & Hilliard 1986;

Figure 8. a) maturing female lamprey; b) suctorial disc of subadult female; c) metamorphosed juvenile or downstream migrant; d) larva (ammocoete); e) large congregation of upstream migrant lampreys traversing the Barrett St. weir in spring 2004. (photos: D. Morgan[c,d,e] and S. Beatty[a,b]).

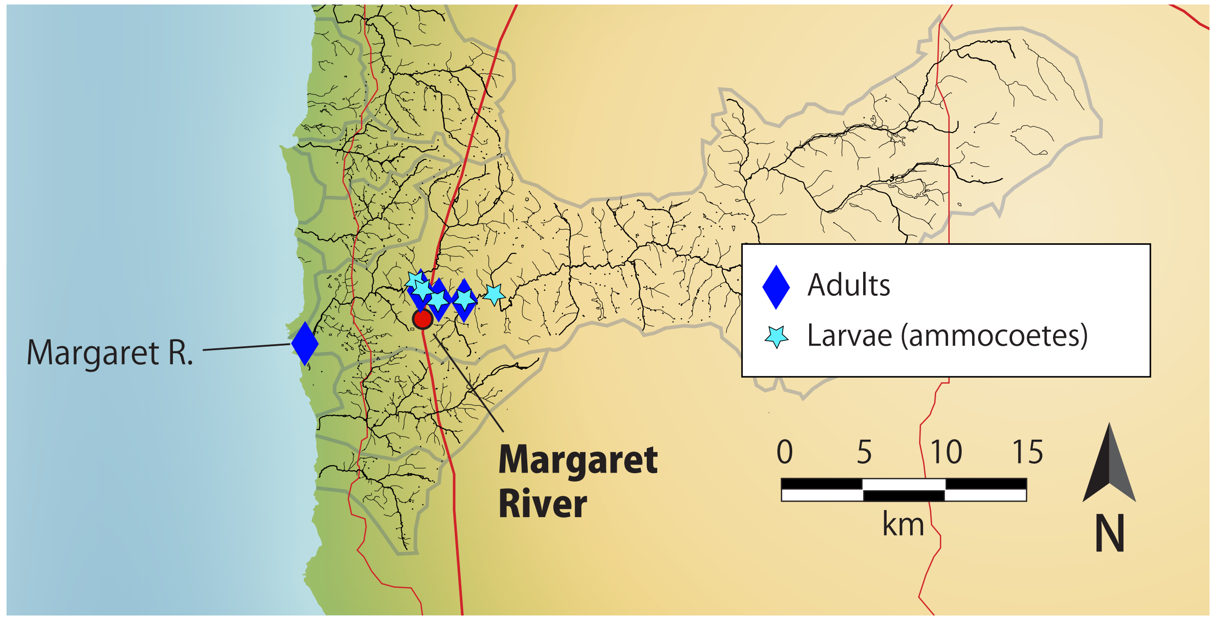

Figure 9. Distribution map of sites where Pouched Lamprey (*Geotria australis*) has been recorded in the Cape to Cape region.

Morgan & Beatty 2003). Presumably this is due to the greater level of connectivity between the ocean and the river. Conversely, in dry years, connectivity of ocean and estuary is reduced across the sand bar at the river mouth, inhibiting a strong flush of fresh water into the ocean which presumably acts as an attractant for lampreys returning to inland waters to spawn. Under future climate change scenarios, reduced rainfall and discharge seem likely to limit the strength of lamprey spawning migrations. Management of catchments in the future may involve human intervention with regards breaching the sand bar in order to allow lampreys to enter Margaret River in sustainable numbers.

Distribution (Figure 9)

The only records in the Cape to Cape region are from Margaret River (Morgan *et al.* 1998; Morgan & Beatty 2003, 2004a, 2007a; Beatty & Morgan 2008). Ammocoetes are common in the main channel in the middle reaches of the system where benthic organic material is more prevalent (Morgan & Beatty 2003). Most records of adults have been from below the two main instream barriers (i.e. Apex and Barrett Street weirs) between late winter and late spring (Morgan & Beatty 2003, 2004a, 2007a; Beatty *et al.* 2007). Elsewhere in the south-west, there are sporadic records of the species between Perth and Albany (Morgan *et al.* 2011) but the majority of recent records are from the Warren and Donnelly river catchments (Morgan *et al.* 1998). The species also occurs in rivers of the south-eastern Australian mainland, Tasmania, New Zealand, and South America (Potter 1996; Morgan *et al.* 1998, 2011).

Conservation status

Listed as **Priority 1** by the Department of Environment and Conservation, Government of Western Australia. Priority 1 taxa are defined as:

> "Taxa that are known from one or a few collections or sight records (generally less than five), all on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, Shire, Westrail and Main Roads WA road, gravel and soil reserves, and active mineral leases and under threat of habitat destruction or degradation. Taxa may be included if they are comparatively well known from one or more localities but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes."

Currently, there is no recovery plan for this species in Western Australia. However, in 2003 a potential benefit was identified for the migratory movements of native fish (including lampreys) in the installment of a fishway at the Apex Weir (Figure 39a; Morgan & Beatty, 2003). Pursuant to this, the Margaret River Regional Environment Centre and Department of Water, with input from the Shire of Augusta Margaret River, Department of Environment and Conservation, Aboriginal community representatives and other community groups, collaborated to construct a rock ramp fishway at this site in 2003 (Morgan & Beatty 2004a; illustrated in Figure 39a). Later surveys of the fishway found that subadult lampreys utilised the structure on their upstream spawning migration and large numbers of adults were also observed attempting to negotiate the Barrett Street Weir about 1 km further upstream (Figure 8e; Morgan & Beatty 2004a). Subsequently, a rock-ramp fishway was installed at this second obstacle in 2006 (Figure 39b), which also proved to be effective (Beatty & Morgan 2008).

Actions — 1) Annual survey of ammocoete beds to monitor status of the Margaret River population.

3.1.2 Western Minnow – *Galaxias occidentalis* (Galaxiidae)

Identification and biology

Western Minnows are elongate and slender, olive-green to tan-brown overall and easily recognised by the series of alternating light and dark vertical bars on the flanks (Figure 10). They can grow to a maximum size of 190 mm but most specimens captured are less than 120 mm (Morgan *et al.* 1998, 2011). They live in a range of freshwater habitats including rivers, creeks, lakes and wetlands, and have a reasonably broad salinity tolerance (maximum recorded tolerance of *ca* 27 ppt), allowing them to persist in salinised sections of catchments such as the Blackwood and Swan-Avon (Morgan *et al.* 2011, unpublished data). They form loose shoals and feed mainly on terrestrial insects that fall onto the water's surface as well as aquatic invertebrates (Pen *et al.* 1993; Morgan *et al.* 1998). They are one of the fastest swimming native species in the south-west (capable of swimming against stream velocities of 120 $cmsec^{-1}$), which makes them ideally suited to utilise fishway structures (Keleher 2010). Western Minnows move upstream to breed in small tributary creeks that commence flowing during winter with eggs being deposited amongst inundated vegetation at the banks (Pen & Potter 1991a). Newly hatched fry are later washed downstream into the permanent waters of tributaries and river channels where they grow to a length of around 70 mm and attain sexual maturity by the end of their first year (Pen & Potter 1991a). The maximum lifespan for this species is four to five years (Pen & Potter 1991a).

Distribution (Figure 11)

Has been recently recorded in the Margaret River, Wilyabrup Brook, and Boodjidup Brook catchments in the Cape to Cape region (Morgan & Beatty 2003, 2004a, 2005, 2007a, 2008; Beatty *et al.* 2006a, 2007, 2008; Beatty & Morgan 2008; Beatty & Allen 2008; Lawrence *et al.* 2010). The Western Australian Museum also has records from Turner Brook (Morgan *et al.* 1998). This species was not recorded during a fish survey of Ellen Brook in 2004, a surprising result given that Western Pygmy Perch and Nightfish, two species that often co-occur with Western Minnows, were common in this system (Morgan & Beatty 2005). Outside the Cape to Cape region, the species is widespread in fresh waters of south-western Australia between the Arrowsmith River (south of Dongara) and Waychinnicup River (east of Albany) (Morgan *et al.* 1998, 2011).

Conservation status

Not currently listed as threatened. This species is one of the most widespread and common native fishes in inland waters of the south-west, including the catchments in which it occurs in the Cape to Cape region.

Actions — 1) Regional barrier and refuge habitat assessment.

Figure 10. Western Minnow (*Galaxias occidentalis*). (photos: M. Allen).

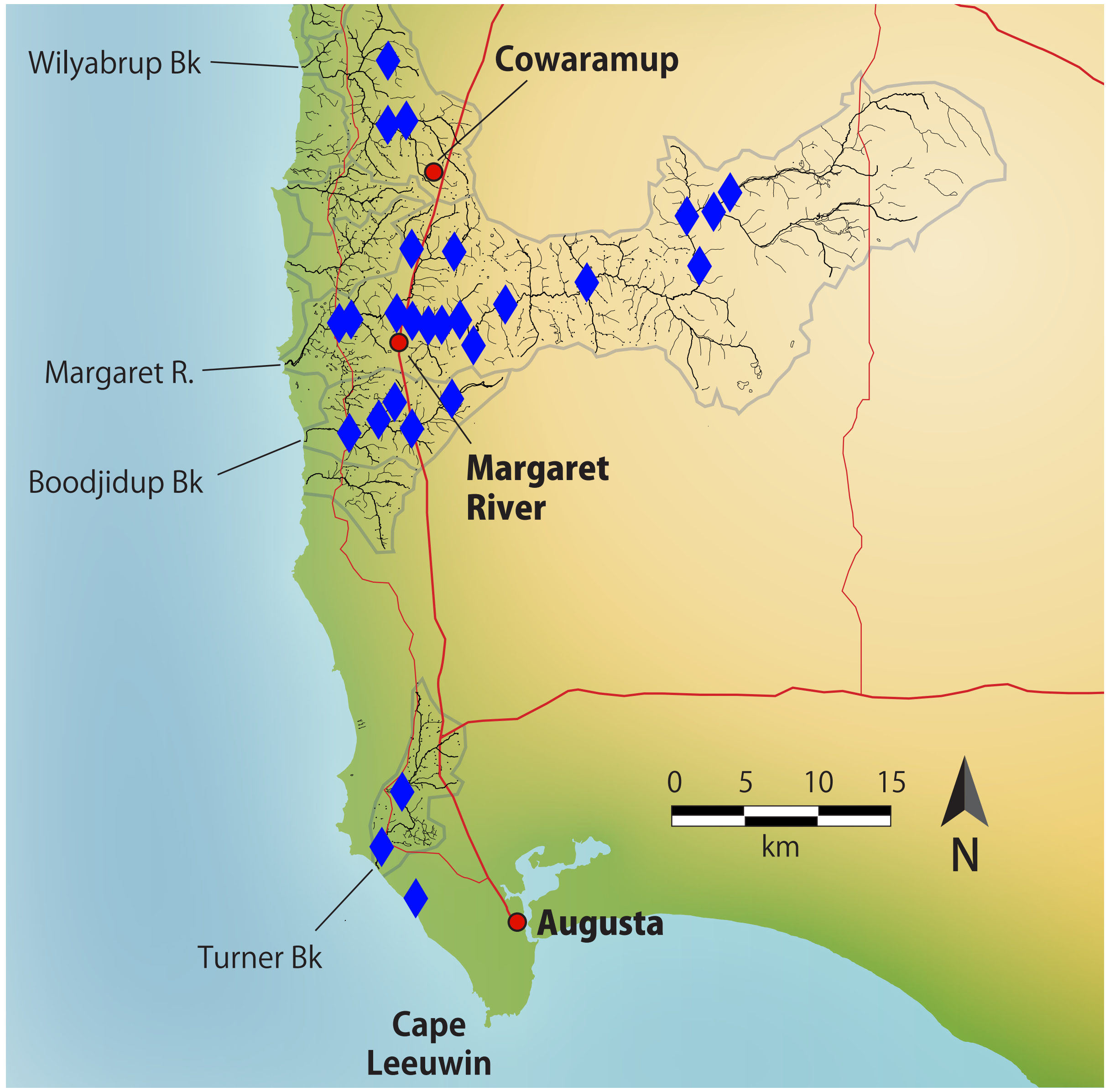

Figure 11. Distribution map of sites where Western Minnow (*Galaxias occidentalis*) has been recorded in the Cape to Cape region.

3.1.3 Western Mud Minnow – *Galaxiella munda* (Galaxiidae)

Identification and biology

Possesses a typical galaxiid morphology of a slender and elongate body with the single dorsal fin set well back towards the tail (Figure 12). Superficially resembles the juvenile stage of the Western Minnow (*Galaxias occidentalis*), especially when viewed from above, but in the hand the brown to blackish-grey coloration (often with paler spots on the back), coppery lateral stripe, white belly, and more rounded caudal fin (compared to the slightly forked version in *G. occidentalis*) are distinctive. The maximum size is 60 mm but specimens above 45 mm are rarely caught (Morgan *et al.* 2011). Western Mud Minnows are encountered most often in gently moving or still waters of small tributary creeks, retreating to permanent pools in rivers over summer (Morgan *et al.* 1998, 2011). They can tolerate very acidic conditions (pH as low as 3.0) but are intolerant of salt (generally found in salinities <2 ppt) (Morgan *et al.* 2003, 2011). The diet consists of small insects and their larvae, and aquatic microcrustaceans (Pen *et al.* 1991; Morgan *et al.* 1998). Breeding takes place over an extended period (July-October) during which time individual females produce multiple batches of eggs (Pen *et al.* 1991). Most fish live for only one year and perish after they spawn (Pen *et al.* 1991), therefore populations are highly susceptible to declines in years when spawning conditions are not favourable (e.g. dry years).

Distribution (Figure 13)

Has been recorded from the Margaret River, Wilyabrup Brook, and Boodjidup Brook catchments in the Cape to Cape region (Morgan *et al.* 1998; Morgan & Beatty 2003, 2004a, 2008; Beatty & Allen 2008; Beatty *et al.* 2008). The species is uncommon and when present usually occurs in low numbers, however, there are robust populations in the upper reaches of Margaret River (i.e. Canebrake Pool and further upstream), and in one tributary in the middle reaches of the Boodjidup Brook catchment (Morgan & Beatty 2003, 2008). Specimens have also been recorded from a pool in the main channel of Margaret River below the Apex Weir, Yalgardup Brook (a tributary of the Margaret River), and a tributary of Wilyabrup Brook (Morgan & Beatty 2004a; Beatty & Allen 2008; Beatty *et al.* 2008).

The distribution of the species extends southward in a few tributaries of the Blackwood River and a number of rivers between the Donnelly and Angove rivers (Morgan *et al.* 2011). There are also isolated populations to the north in the upper Vasse River, Moore River (near Gingin), and a tributary of the Swan River near Perth (Morgan *et al.* 2011).

Conservation status

Currently listed as **VULNERABLE** (WA DEC; Schedule 1 under the Wildlife Conservation Act 1950) and Least Concern/Near Threatened by the International Union for the Conservation of Nature (IUCN). An application was also recently lodged by the Threatened Species Scientific Committee to the Federal Government for listing under the Environmental Protection and Biodiversity Conservation Act 1999. The primary concern for this species is its disappearance from vast tracts of what was once a much larger range (Morgan *et al.* 2011). This has been attributed to broad-scale land and stream degradation through agricultural practices on the Swan Coastal Plain from Busselton northwards, compounded by the presence of feral fishes (Morgan *et al.* 2011). Furthermore, some remnant populations are reliant on groundwater discharge feeding the streams that they inhabit (Beatty *et al.* 2006b; Morgan *et al.* 2011). Groundwater levels have declined at many sites throughout south-

Figure 12. Western Mud Minnow (*Galaxiella munda*). (photos: G. Allen and D. Morgan).

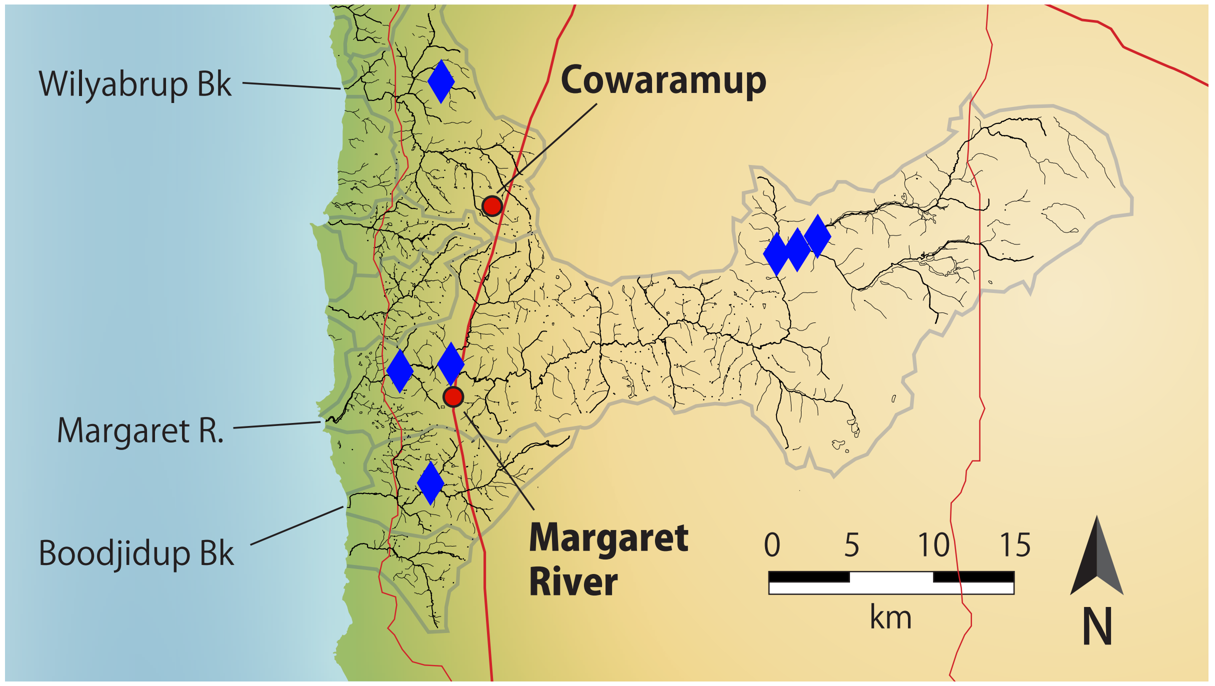

Figure 13. Distribution map of sites where Western Mud Minnow (*Galaxiella munda*) has been recorded in the Cape to Cape region.

western Australia in recent years due to a combination of abstraction for human consumption and declining rainfall (DoW 2010). With further reductions in rainfall due to climate change some aquifers may not receive any recharge through infiltration of rainfall (Commander 2000), therefore it seems likely that this species will become increasingly threatened.

The Boodjidup Brook, Wilyabrup Brook, and lower Margaret River populations are surrounded by agricultural or rural/residential land and face a higher level of threat compared with the upper Margaret River population which lies within relatively pristine native forest. Catchment-scale management will be important in the protection and recovery of the more threatened populations. Drainage lines in the vicinity, and upstream, of Western Mud Minnow populations in farmland should be fenced off from livestock in order to protect any remnant riparian vegetation and enhance

restoration efforts. An assessment of instream barriers (i.e. dams, weirs, road crossings) in the Boodjidup and Wilyabrup catchments would also be beneficial in identifying potential structures that may be restricting migratory movements of the Western Mud Minnow.

Restocking of the species in the headwaters of Boodjidup Brook has been suggested as a potential way of improving the sustainability and, hence conservation status, of the species in the region (Morgan & Beatty 2008). However, genetic studies on the Western Mud Minnow population of upper Margaret River identified unique haplotypes that were not found in any other population elsewhere in the State (Phillips *et al.* 2007). This is indicative of a long period of genetic isolation and has implications for restocking/translocation in the Cape to Cape region (Morgan & Beatty 2008). Supplementing wild stocks with captively bred fish has been demonstrated to reduce reproductive fitness in stocked trout populations in North America (Araki *et al.* 2009), so caution is advised before proceeding with any restocking program.

Actions — 1) Expanded survey of Wilyabrup Brook catchment; 2) fencing and rehabilitation of riparian habitat at degraded collection sites; 3) barrier and refuge habitat assessment; 4) annual feral fish monitoring of middle/upper Margaret River.

3.1.4 Nightfish – *Bostockia porosa* (Percichthyidae)

Identification and biology

The morphology of this species is similar to the Murray Cod from the eastern states but on a miniature scale (Figure 14). Incidentally that species belongs to the same family as the Nightfish. The drab mottled brown colour can be very dark when specimens are captured from tannin stained water (Morgan *et al.* 2011). The large mouth and conspicuous head pores are highly distinctive features (Allen *et al.* 2002). The largest ever recorded specimen (180 mm) was captured during a survey of Ten Mile Brook Dam in the Margaret River catchment by the Department of Fisheries (Lawrence *et al.* 2010). Nightfish inhabit still or slow-flowing reaches of rivers and creeks, and prefer areas with large woody debris and complex habitat structure (Morgan *et al.* 1998, 2011). They are solitary, ambush predators of insects, crustaceans, aquatic snails, and small fishes (Pen & Potter 1990; Pen *et al.* 1993). Adults are nocturnal but juveniles are more active during the day (Morgan *et al.* 2011).

This species breeds in tributaries during winter flows (August-September) before retreating to permanent pools over the dry summer period (Pen & Potter 1990). The sexes are distinguishable during the breeding season; the belly is pinkish in females and whitish in males. Males reach sexual maturity at the end of their first year of life, a year earlier than females, and the maximum lifespan is about six years (Pen & Potter 1990).

Distribution (Figure 15)

Occurs in the Margaret River, Wilyabrup Brook, Ellen Brook, Boodjidup Brook, and Turner Brook catchments in the Cape to Cape region (Morgan *et al.* 1998; Morgan & Beatty 2003, 2004a, 2005, 2008; Beatty & Allen 2008). This south-western Australian endemic is also found from the Hill River (near Jurien Bay) to the Kalgan River near Albany.

Figure 14. Nightfish (*Bostockia porosa*). (photos: S. Beatty and M. Allen).

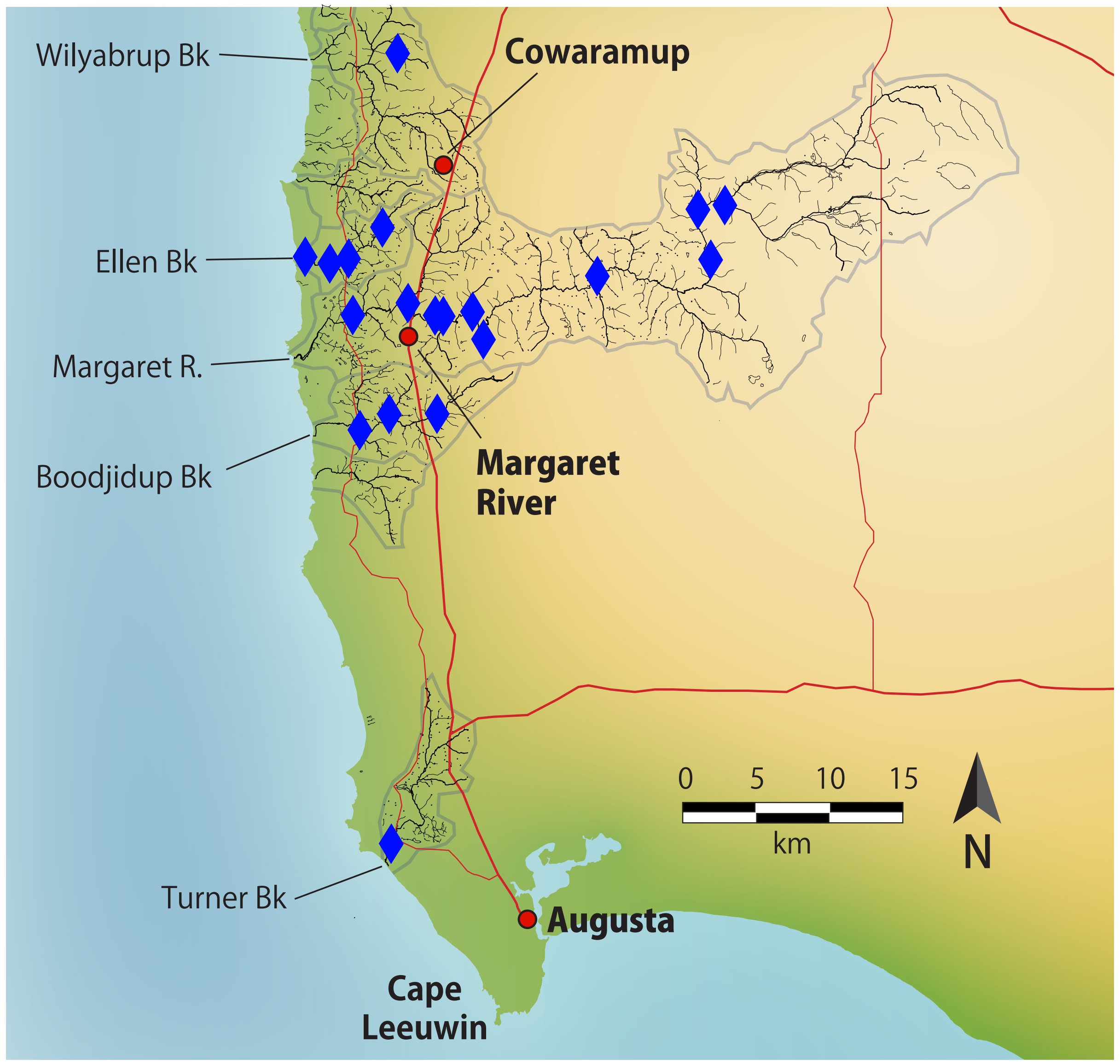

Figure 15. Distribution map of sites where Nightfish (*Bostockia porosa*) has been recorded in the Cape to Cape region.

Conservation status

Not currently listed as threatened as the species is widespread and reasonably common in south-western Australian inland waters (Morgan *et al.* 2011). However, fish surveys conducted in the Cape to Cape catchments have typically revealed low numbers of Nightfish at sites where they are present (Morgan & Beatty 2003, 2005, 2008; Beatty & Allen 2008; Beatty *et al.* 2008; Lawrence *et al.* 2010). As this species has a distinct preference for complex instream habitats, it is important that processes leading to the homogenisation of streams and rivers such as desnagging and channelisation be curtailed. Nightfish, and other native aquatic fauna, will benefit enormously from river restoration initiatives that include re-snagging of waterways with large woody debris.

Actions — 1) Regional barrier and refuge habitat assessment.

3.1.5 Western Pygmy Perch – *Nannoperca vittata* (Percicthyidae)

Identification and biology

A small species (to 80 mm), perch-like in overall appearance, with mottled golden-brown coloration (Figure 16). Breeding males develop vibrant gold flecks on the sides, darkened fins and a bright reddish-orange belly (Morgan *et al.* 2011). They are broad generalists in terms of their habitat requirements, occupying creeks, rivers, wetlands, and lakes, including slightly brackish waters (Morgan *et al.* 2011). They feed predominantly on benthic microcrustaceans and terrestrial insects, including large quantities of mosquito larvae (Pen & Potter 1991b). The maximum swimming speed is around 60 cmsec^{-1}, which limits their ability to traverse rapids and some fishway structures (Keleher 2010). Breeding takes place between July and November when mature fish move upstream into small creeks to spawn amongst flooded vegetation (Pen & Potter 1991b). Sexual maturity is attained at the end of the first year of life and the maximum lifespan is around five years (Pen & Potter 1991b).

Distribution (Figure 17)

Occurs in the Margaret River, Wilyabrup Brook, Ellen Brook, and Turner Brook catchments in the Cape to Cape region (Morgan *et al.* 1998; Morgan & Beatty 2003, 2004a, 2005; Beatty *et al.* 2006a, 2008; Beatty & Allen 2008). Oddly, it was not recorded in the Boodjidup Brook catchment (Morgan & Beatty 2008). The Western Australian Museum also has a record of this species from Boranup collected in 1965 (Morgan *et al.* 1998), but the exact whereabouts of this site is unknown. This is one of the most common and widespread native freshwater fishes endemic to south-western Australia, ranging from the Arrowsmith River (300 km north of Perth) to the Waychinnicup River (east of Albany) (Morgan *et al.* 2011).

Conservation status

Not currently listed as threatened. Although it is reasonably common in three catchments of the Cape to Cape region, this species is particularly vulnerable to fin-nipping by introduced Eastern Gambusia which can lead to bacterial and fungal infections and ultimately affect survival (Gill *et al.* 1999). In a fish survey of the Margaret River main channel (Morgan & Beatty 2003), densities of Western Pygmy Perch were found to be low at sites where Eastern Gambusia were prolific (i.e. the more degraded sites), but much higher in pristine parts of the catchment, where Eastern Gambusia

Figure 16. Western Pygmy Perch (*Nannoperca vittata*). (photos: S. Beatty and M. Allen).

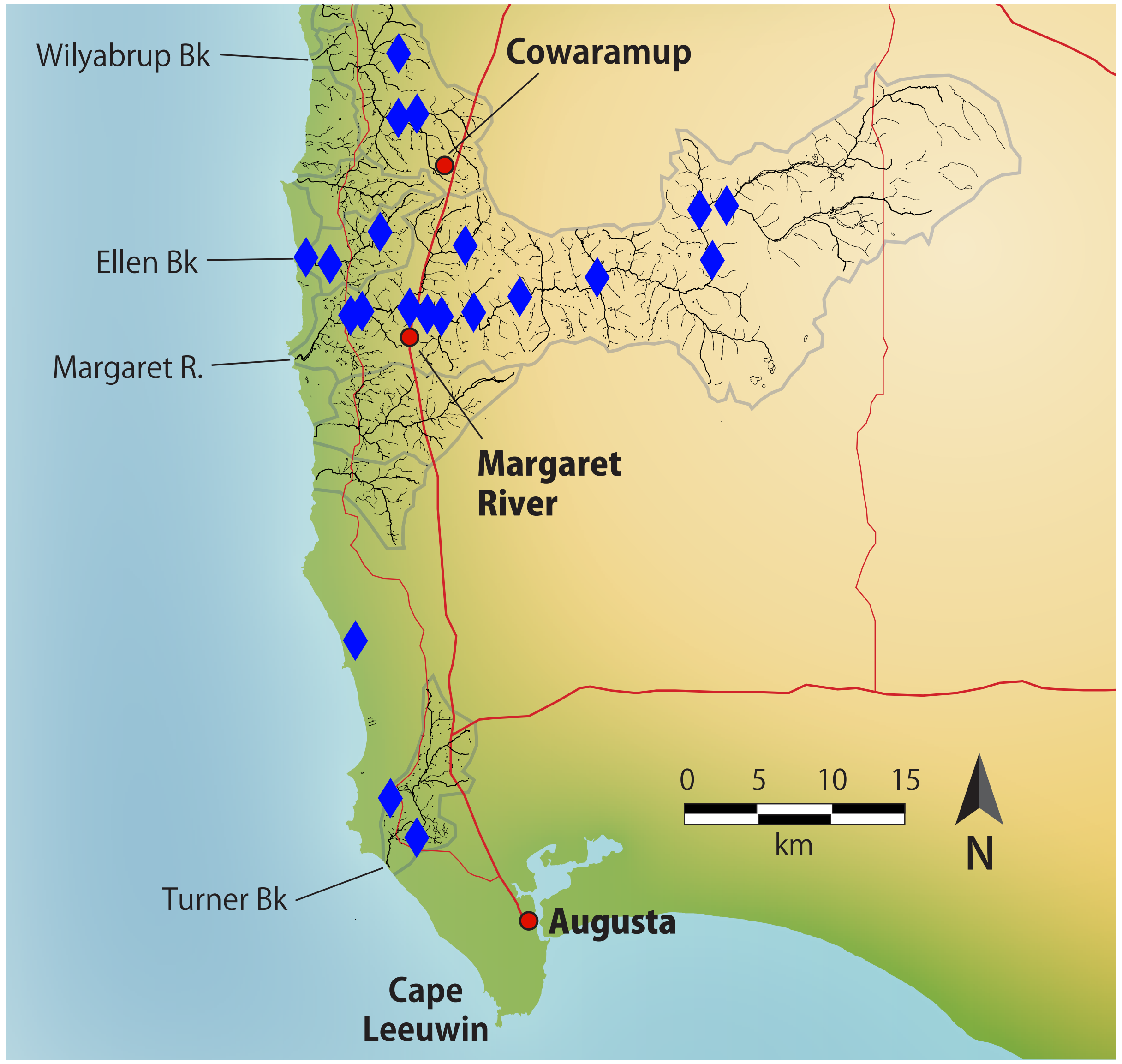

Figure 17. Distribution map of sites where Western Pygmy Perch (*Nannoperca vittata*) has been recorded in the Cape to Cape region.

were recorded in low numbers. The same trend was observed in the Ellen Brook catchment (Morgan & Beatty 2005).

Instream barriers are another factor to take into consideration when assessing the conservation status of the Western Pygmy Perch in the Cape to Cape region (and elsewhere). While the innate burst swimming capacity of this species is lower than for the Western Minnow (Keleher 2010) a recent survey of a rock-ramp fishway on Rushy Creek (a tributary of the Blackwood River) yielded some interesting results (Beatty *et al.* 2012). Large numbers were able to traverse the fishway structure in the month of October when mean flow velocities were about half the critical velocity determined by Keleher (2010) to be the mean maximum swimming speed able to be sustained over a reasonable amount of time (i.e. 65 cms^{-1} over 26.4 sec). However, in the earlier months of August and September when average flow velocities were much higher, they were unable to traverse the fishway (Beatty *et al.* 2012). These results show that while upstream movement through the fishway was possible, the reduced swimming capacity of this species restricted these movements to late in the breeding period, thus limiting upstream dispersal and potentially reducing the capacity for population expansion due to limited access to food and habitat resources. Furthermore, fish congregating below impassable barriers are at increased risk of predation (particularly by birds such as herons and egrets). Surveys of fish utilisation of the two rock-ramp fishways on the Margaret River recorded only the occasional solitary individual moving up the structure (Morgan & Beatty 2004a; Beatty & Morgan 2008). The Margaret River fishways are designed to more or less the same specficiations as the Rushy Creek fishway so more movement of this species up these structures would be expected in late spring. The fact that this was not the case may be explained by naturally low densities of this species in the lower and middle reaches of the Margaret River main channel (Morgan & Beatty 2003).

Limitations on dispersal are also apparent in the Ellen Brook and Wilyabrup Brook catchments where Western Pygmy Perch were found to be abundant below some barriers (e.g. Ellen Brook Weir), but much less so at sites upstream. The construction of any new instream barriers and/or fishways should be closely scrutinised with regard to the potential for limiting the movements of Western Pygmy Perch and other native fish species with limited swimming abilities (e.g. Nightfish). The identification and removal of under-utilised or redundant instream barriers could benefit the these species. Alternatively, “trap and haul” techniques may be considered in catchments with many instream barriers. It would be necessary, however, to first undertake an analysis of population genetics to ensure that any distinct populations in the same catchment are identified and that their genetic integrity is not compromised through intra-catchment translocation efforts.

Actions — 1) Regional barrier and refuge habitat assessment.

3.1.6 Balston’s Pygmy Perch – *Nannatherina balstoni* (Percichthyidae)

Identification and biology

Similar in overall appearance to the Western Pygmy Perch (*Nannoperca vittata*) but attains a larger size through faster growth (maximum of 90 mm, usually over 60 mm at age one), and has a number of distinctive features including a more elongated body, a series of dark brown stripes and bars on the flanks appearing as a diamond-pattern over a tan background, and large eyes relative to the head

Figure 18. Balston's Pygmy Perch (*Nannatherina balstoni*). (photos: M. Allen and D. Morgan).

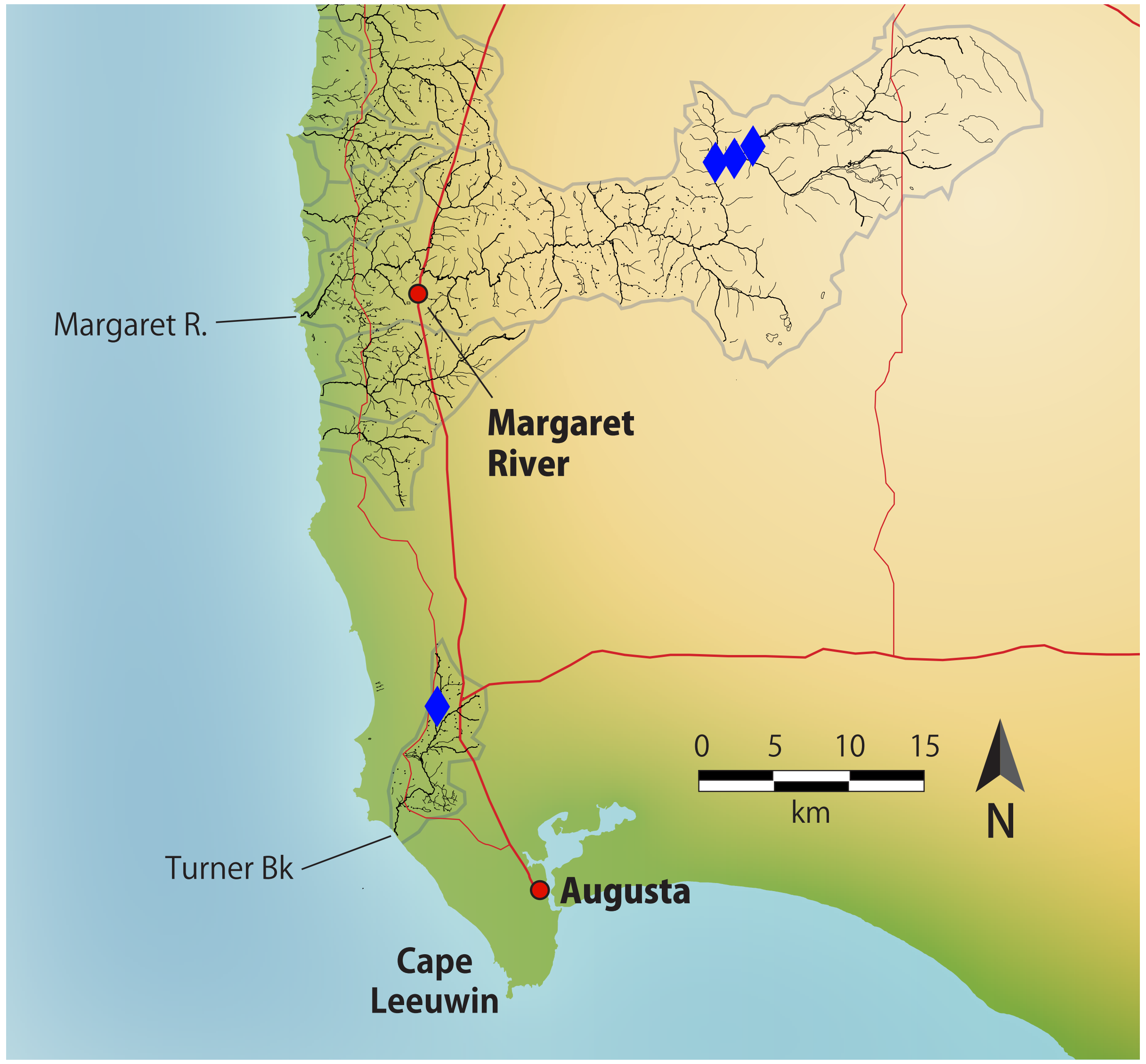

Figure 19. Distribution map of sites where Balston's Pygmy Perch (*Nannatherina balstoni*) has been recorded in the Cape to Cape region.

size (Morgan *et al.* 1995, 1998, 2011; Figure 18). Typically only occurs in near-pristine catchments where it prefers complex instream habitats in slow moving or static waters of rivers, creeks, lakes and wetlands (Morgan *et al.* 2011). The diet consists primarily of aquatic insects and terrestrial insects that fall onto the water's surface (Morgan *et al.* 1995). These fish reach maturity before the end of their first year of life and breed during winter and spring with many fish perishing shortly after spawning (Morgan *et al.* 1995). Some fish live longer, with the maximum age thought to be around three years (Morgan *et al.* 1995, 2011). The short lifespan renders populations of this species vulnerable to declines in dry years that do not favour recruitment.

Distribution (Figure 19)

The only recent records of this species in the Cape to Cape region are from the upper reaches of Margaret River in the vicinity of Canebrake Pool and further upstream (Morgan *et al.* 1998; Morgan & Beatty 2003). Records from the Western Australian Museum also reveal a collection that was made in Turner Brook in 1962 (Morgan *et al.* 1998), however no recent surveys have been conducted to verify if the species persists in this catchment. Margaret River is the northern limit of the patchy distributional range which extends southwards to the Goodga River, east of Albany (Morgan *et al.* 2011).

Conservation status

This is one of the least common fishes in south-western Australia and is listed as **VULNERABLE** at both State (WA DEC) and Federal (EPBC Act 1999) level. There are historical records of this species from Gingin Brook (north of Perth) which suggests that prior to European colonisation, the distributional range probably extended throughout the Swan Coastal Plain (Morgan *et al.* 1998, 2011). The disappearance of the species from near-coastal parts north of Margaret River is due to wide-scale land and stream degradation from agricultural practises, combined with water abstraction (for drinking and irrigation), and the introduction of exotic fish species (Morgan *et al.* 2011). Furthermore, this species has a very low salinity tolerance which precludes it from utilising vast sections of some of the larger river systems in the south-west (e.g. Blackwood River) that have become salinised due to broadscale land clearing in the upper catchment (Morgan *et al.* 2003). Some relict populations (e.g. in Milyeannup Brook, a tributary of the Blackwood) are completely reliant on groundwater expression through natural springs for their continued survival (Beatty *et al.* 2006b). The forested upper catchment of Margaret River largely lies within the Rapids Conservation Park and is a haven for this species.

Actions — 1) Survey of Turner Brook to confirm WA Museum record; 2) annual feral fish monitoring of middle/upper Margaret River; 3) refuge habitat assessment of upper Margaret River.

3.2 Native freshwater decapod crustaceans

A total of seven native freshwater decapod crustacean species have been recorded in the Cape to Cape region. All are endemic to south-western Australia (Morgan *et al.* 2011). These species occupy a range of habitat types from permanent pools to seasonal swamps and wetlands. An additional species, the Southwest Glass Shrimp (*Palaemonetes australis*), is a freshwater opportunist that mainly inhabits estuaries and near coastal marine waters and will not be covered in detail in this report.

3.2.1 Margaret River Burrowing Crayfish - *Engaewa pseudoreducta* (Parastacidae)

Identification and biology

There are several species of burrowing crayfishes of the genus *Engaewa* in south-western Australia and all are superficially similar in appearance (Horwitz & Adams 2000; Morgan *et al.* 2011). They are very rarely encountered and are usually only apparent due to the presence of chimneys (i.e. piles of spherical diggings that are deposited at burrow entrances), although this species constructs chimneys that are usually not as conspicuous as other *Engaewa* (DEC 2008). They are pale greyish brown overall with vibrant blue-purple coloration on upper parts of the body and claws (Figure 20), and claws are rotated on a vertical plane, distinguishing them from the more commonly encountered crayfishes of the genus *Cherax* which are on a horizontal plane (Horwitz 1995; Horwitz & Adams 2000). Generally the geographic location is a fairly reliable means of identifying different *Engaewa* species as most have highly restricted distributions (Horwitz & Adams 2000), however, *E. pseudoreducta* and *E. similis* overlap in the Margaret River catchment and therefore can not be reliably distinguished in this way (Q. Burnham pers. comm.). *Engaewa pseudoreducta* is best distinguished from *E. similis* by the absence of head ridges and more extensive patches of setae (or hairs) on the claws (Horwitz & Adams 2000). Not much is known of the breeding biology of this species, other than juveniles have been recorded during the month of August (Burnham *et al.* 2007). The majority of time is spent underground in a burrow system that can be several metres deep in heavy clay soils of seasonal swamps and wetlands (Burnham *et al.* 2007). The largest known specimen is about 40 mm in length (Horwitz & Adams 2000).

Distribution (Figure 21)

Currently known from Treeton Forest Block in the headwaters of two separate branches of a single drainage system located in the middle section of Margaret River (Burnham *et al.* 2007, 2012; DEC 2008). In 2007, another population of *Engaewa*, similar morphologically and genetically to *E. pseudoreducta,* was discovered in the upper Carbunup River, a short distance to the north outside of the Cape to Cape region (Burnham *et al*. 2012).

Conservation status

This species is listed as **CRITICALLY ENDANGERED** at Federal (EPBC Act 1999), State (Wildlife Conservation Act 1950), and international level (IUCN). It was originally discovered when a farm dam was built on an unnamed creek in the Margaret River catchment in 1985, however, this population has since disappeared (Horwitz 2003; DEC 2008). Only two other populations are known to exist: 1) less than 2 km away from the type locality on a separate branch of the same drainage line in Treeton Block and adjoining private property (DEC 2008), and; 2) from a separate catchment (Carbunup River) to the north of the type locality (Burnham *et al*. 2012). There is less than 2.5 ha of suitable habitat available at the Treeton site (DEC 2008; Q. Burnham pers. comm.). Recent surveys of likely habitat nearby to this site have not located any additional populations, although this does not necessarily indicate that they are absent from the sites surveyed because of their cryptic nature (Burnham *et al.* 2007, 2012). The recently discovered upper Carbunup population is likely to be more robust as there is a greater amount of suitable habitat available at this site (Burnham *et al*. 2012), however, it is thought that this population may represent a separate undescribed species based on genetic evidence (Q. Burnham pers. comm.). A recent review of *E. pseudoreducta* by Burnham *et al*. (2012) recommended no change to its **CRITICALLY ENDANGERED** status.

Figure 20. Margaret River Burrowing Crayfish (*Engaewa pseudoreducta*). (photo: Q. Burnham).

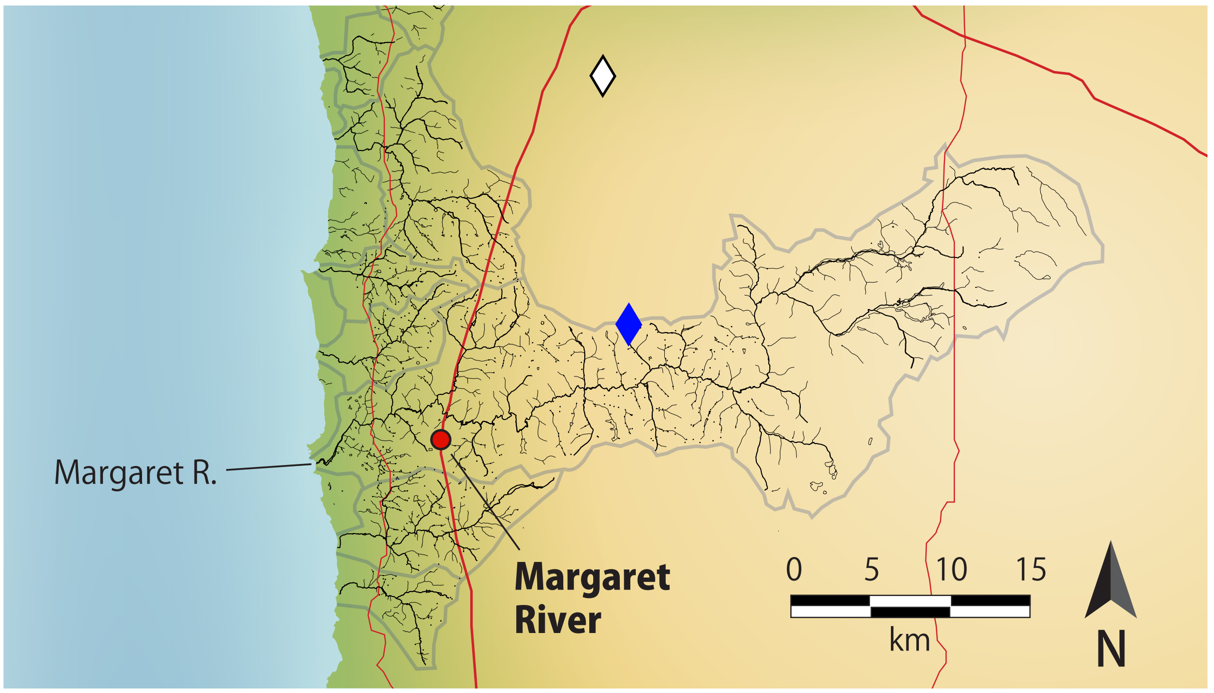

Figure 21. Distribution map of sites where Margaret River Burrowing Crayfish (*Engaewa pseudoreducta*) has been recorded in the Cape to Cape region (blue diamond) and nearby in the upper Carbunup River (white diamond).

The area known to be occupied by this species is very small and the outlook for the survival of this species is precarious. It faces threats from wildfires, declining water tables due to groundwater abstraction and climate change, and habitat degradation due to farming practises, feral animals (e.g. pigs), forestry, and fire management procedures (e.g. clearing of access tracks and contamination by fire retardant chemicals) (DEC 2008). DEC (2008) compiled a management plan for the conservation of this species outlining a number of actions needed to protect this species from becoming extinct. These included further surveys of the area to try and identify additional populations, increasing public awareness and participation in conservation of the species, habitat protection, and further study of its life history and ecology. Being a river/stream zone, the habitat of the presumed extant population of the species is currently afforded informal reserve status under the Forest Management Plan 2004-2013 (Conservation Commission 2003). Protection has also been sought for a small section of the drainage line adjacent to the Treeton Block habitat area which lies on private property (DEC 2008). Cooperation from land holders and the community in general is necessary if any actions taken to prevent the extinction of this species are to be successful, and funding should be sought for fencing and riparian rehabilitation along the drainage line of the presumed extant Treeton Block population. The Recovery Plan for the species also recommended giving consideration to a captive breeding and translocation/restocking program (DEC 2008). Maintaining stocks in captivity could reduce the risk of a catastrophic event (e.g. chemical spill, disease outbreak, severe wildfire) wiping out an entire population of this highly restricted species, however obtaining a captive brood stock of this extremely rare species may prove to be too difficult.

Actions — 1) Protection of remaining habitat in reserves/Fish Habitat Protection Areas; 2) fencing and rehabilitation of remnant likely habitat on the drainage line housing the presumed extant populations; 3) trial population monitoring using motion sensor camera technology; 4) continued opportunistic surveys of remnant likely habitat on the drainage line housing the presumed extant populations; 5) ongoing monitoring of physico-chemistry and depth fluctuation of water table in the habitat; 6) feasibility study of supplementing water to the wild populations in dry years; 7) maintaining captive stock and establishing breeding program.

3.2.2 Augusta Burrowing Crayfish – *Engaewa similis* (Parastacidae)

Identification and biology

Greyish brown underneath and bluish-purple on the upper surface of the body, head, and claws (Figure 22a; Horwitz & Adams 2000). Distinctive features include prominent head ridges on the rostrum and a small patch of setae (i.e. hairs) on the lateral side of the cutting edge of the claws (Riek 1967; Horwitz & Adams 2000). Maximum size is 50 mm (Morgan *et al.* 2011). Occupies a range of swampy habitats in peat and sandy soils, spending the majority of time underground in burrows (Horwitz & Adams 2000; Burnham *et al.* 2007). The chimneys at the burrow entrances of this species are usually conspicuous (Figure 22b; DEC 2008). Nothing is known of the biology.

Distribution (Figure 23)

Known from the headwaters of a few tributaries of the middle section of Margaret River catchment (Q. Burnham pers. comm.), the upper Boodjidup Brook catchment, and Turner Brook (Horwitz & Adams 2000). Outside the Cape to Cape region, the range extends southwards to Lake Jasper and possibly beyond to Windy Harbour (Horwitz & Adams 2000; Morgan *et al.* 2011).

Conservation status

Listed as Least Concern (IUCN) but status maybe should be upgraded to Endangered due to the likely past, present and future fragmentation and extirpation of populations throughout the restricted distributional range (Morgan *et al.* 2011). The broader threats to this species include habitat loss

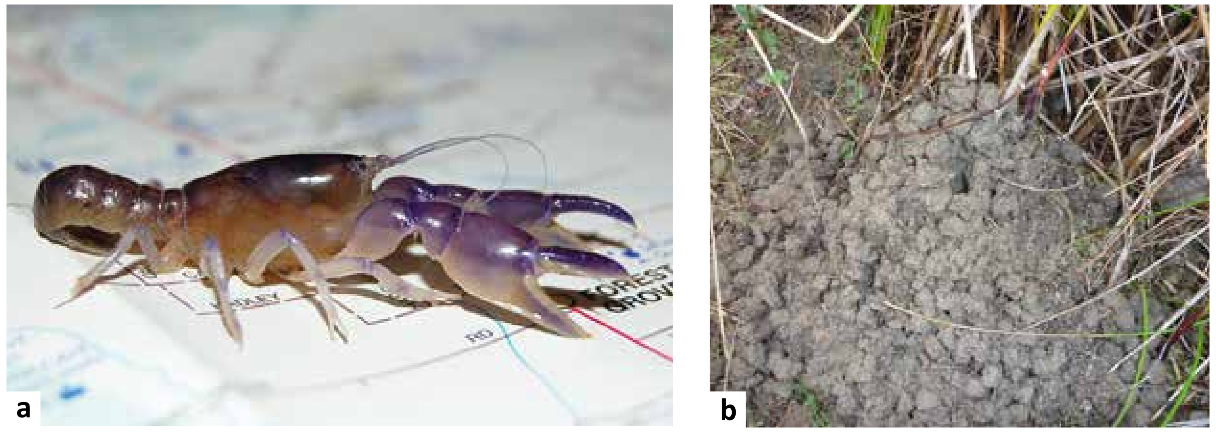

Figure 22. a) Augusta Burrowing Crayfish (*Engaewa similis*); b) chimney of spherical diggings at burrow entrance. (photos: Q. Burnham and S. Beatty).

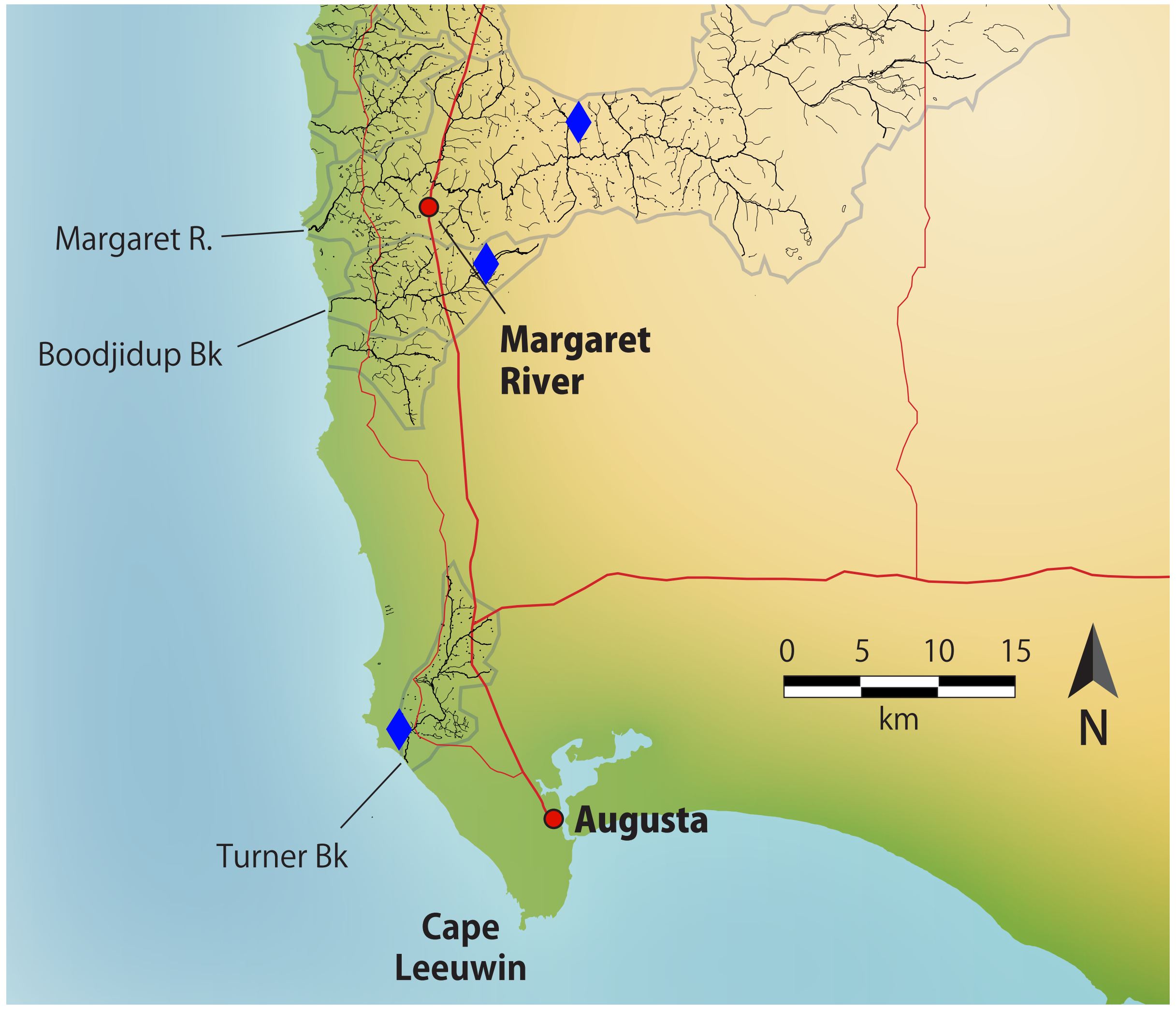

Figure 23. Distribution map of sites where Augusta Burrowing Crayfish (*Engaewa similis*) has been recorded in the Cape to Cape region.

through agricultural practises, land clearing and inundation due to damming of streams. Declining water tables resulting from water abstraction and climate change also pose a threat. In the Cape to Cape region, it is imperative that any drainage line, no matter how ephemeral, and whether it be on private or public land, is thoroughly surveyed for the presence of *Engaewa* spp. before any activities (e.g. track construction, logging, clearing, damming) are carried out that might impact negatively upon the habitat.

Actions — 1) Establishing captive breeding program; 2) trial population monitoring using motion sensor camera technology.

3.2.3 Hairy Marron – *Cherax tenuimanus* (Parastacidae)

Identification and biology

Similar in appearance to Smooth Marron (*C. cainii*) but best distinguished by the setae (i.e. hairs) covering the cephalothorax (sometimes reduced in juveniles) and by the central head ridge which extends back almost as far as the cervical groove (i.e. arc-shaped groove at the fused junction of the head and thorax) (Figure 24a; Austin & Knott 1996; Austin & Ryan 2002; Bunn *et al.* 2008). Colour is dark brown to blackish and the maximum size is around 380 mm (Morgan *et al.* 2011). Hybrids can be extremely difficult to tell apart from pure-bred specimens (see Figure 24b). The taxonomic status of this species is contentious with some claiming that Smooth and Hairy Marron may be geographical subspecies (de Graaf *et al.* 2009). Dwells in permanent water of rivers, streams and dams, preferring the shelter of large woody debris (Molony *et al.* 2004). The diet and biology are not well known but presumed to be similar to the closely related Smooth Marron (Morgan *et al.* 2011).

Distribution (Figure 25)

Currently occurs only in the upper reaches of the Margaret River catchment, upstream and inclusive of Canebrake Pool (Bunn 2004; de Graaf *et al.* 2009).

Conservation status

Listed as **CRITICALLY ENDANGERED** (DEC, IUCN, EPBC Act 1999). Originally occurred throughout Margaret River but has undergone a dramatic decline since the 1980s and is now found only in the upper reaches of the catchment (Bunn 2004; De Graaf *et al.* 2009). Less than 10,000 individuals were estimated to exist in the wild in 2004 (Bunn 2004) and this number is likely to have declined further. They have largely been displaced by Smooth Marron which are believed to have been first released in the lower Margaret River around 20-30 years ago and have since spread throughout the catchment (Austin & Ryan 2002; Molony *et al.* 2004; de Graaf *et al.* 2009). They have severely impacted Hairy Marron through competition for habitat and resources, and hybridisation which has compromised the genetic integrity of Hairy Marron stocks (Imgrund 1998; Molony *et al.* 2004; Lawrence 2007; Bunn *et al.* 2008; de Graaf *et al.* 2009). In the mid-1990s Hairy Marron comprised 100% of marron stocks in the upper reaches but by 2002 this percentage had dropped to around 30%, with Smooth Marron increasing from 0% to 70% (de Graaf *et al.* 2009).

Another threat comes in the form of illegal poaching. It is against the law to remove Hairy Marron from the wild and the Department of Fisheries established a recreational fishing exclusion zone in 2002 for

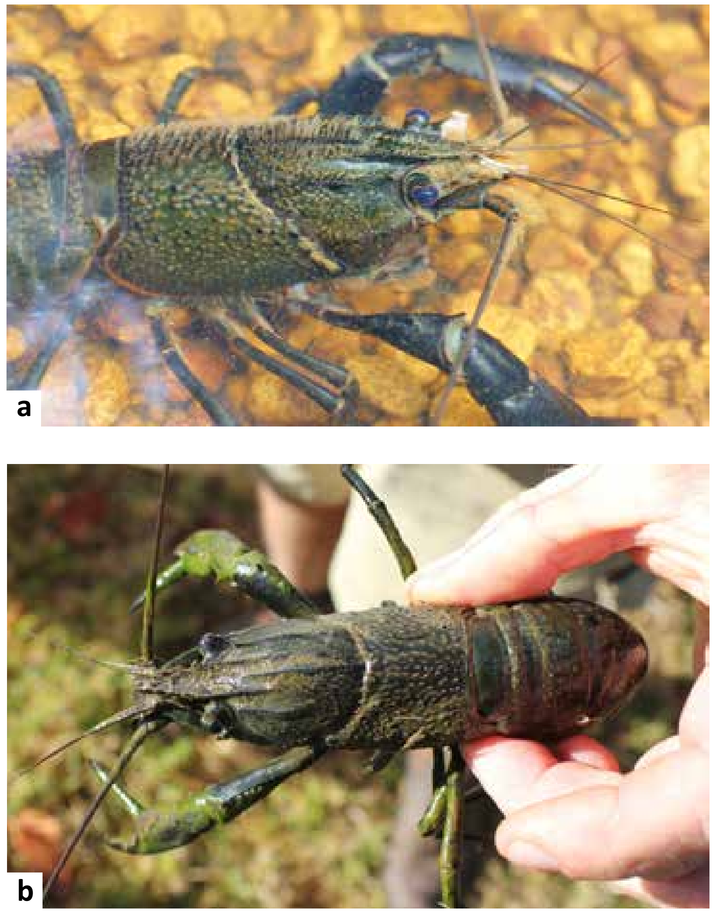

Figure 24. a) pure strain Hairy Marron (*Cherax tenuimanus*) from upper Margaret River, and; b) hybrid marron specimen from a farm dam in the Margaret River catchment (photos: S. Visser[a] and D. McKenzie[b]).

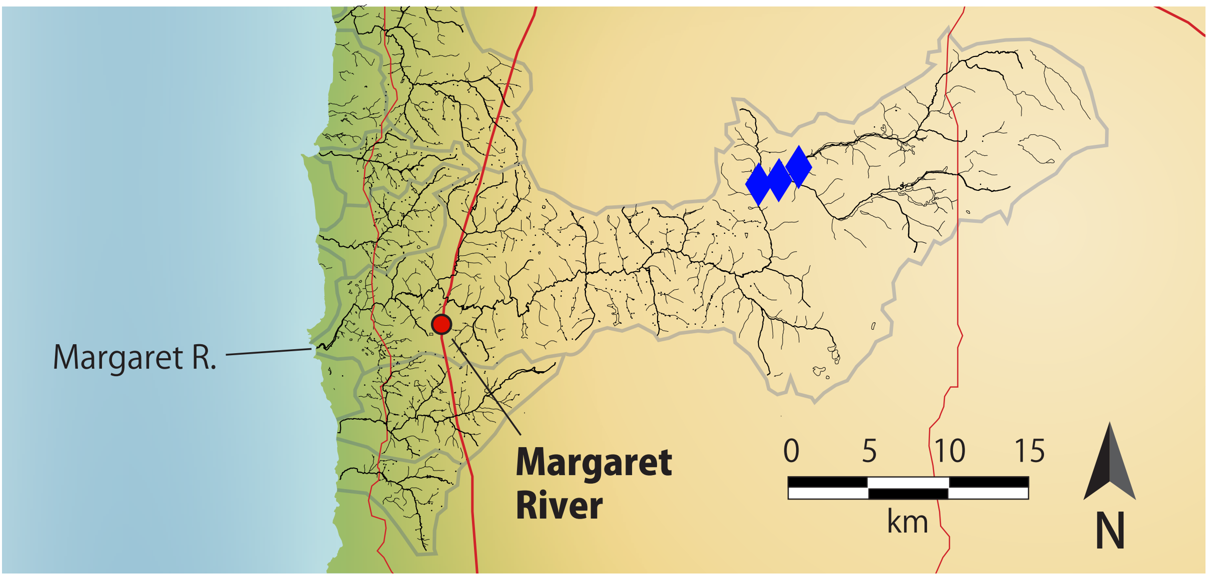

Figure 25. Distribution map of sites where Hairy Marron (*Cherax tenuimanus*) has been recorded in the Cape to Cape region.

the entire Margaret River catchment upstream of the confluence with Ten Mile Brook (Molony *et al.* 2004). A captive breeding program of genetically validated pure-strain Hairy Marron has also been established at the Department's Pemberton Hatchery, for supplementation of wild stocks (de Graaf *et al.* 2009). Removals of increasing numbers of Smooth Marron from the upper Margaret River have also taken place since 2004 (de Graaf *et al.* 2009), but these efforts were recently suspended pending the development of a more accurate method of identifying pure-strain Hairy Marron specimens in the field (R. Duffy, Department of Fisheries, pers. comm.).

CCG and Department of Fisheries recently undertook surveys after receiving anecdotal reports of two dams that had been stocked with marron from Margaret River in the 1970s (i.e. prior to introduction of Smooth Marron) (D. McKenzie pers. comm.). Genetic testing revealed that specimens taken from these dams were hybrids however (see Figure 24b) (R. Duffy, Department of Fisheries, pers. comm.). Nonetheless, strictly quarantined small dams on private land have potential to provide refuge habitat for Hairy Marron (Lawrence *et al.* 2010).

Actions — 1) Resumption of Smooth Marron removal from upper Margaret River; 2) continuation of captive breeding/restocking; 4) annual feral fish monitoring of middle/upper Margaret River; 5) scoping study of utilising small private dams as refuge 'arks' for Hairy Marron.

3.2.4 Gilgie – *Cherax quinquecarinatus* (Parastacidae)

Identification and biology

This species has variable morphology and coloration, and is similar in appearance to other *Cherax* making field identification difficult (Austin & Knott 1996; Morgan *et al.* 2011). Best distinguished by the five head ridges (less pronounced than in marron), rounded claws, and lack of spines on the telson (i.e. central segment of tail fan) (Horwitz 1995; Austin & Knott 1996). Most similar to the Restricted Koonac (*C. crassimanus*), but that species has four head ridges that are less prominent, and an acutely curved spine on the inner edge of the carpus (i.e. wrist) (Morgan *et al.* 2011). Gilgies are brown to blackish, sometimes mottled and/or with vibrant orange stripes on the tail and reach a maximum length of around 140 mm (Figure 26; Morgan *et al.* 2011). They inhabit rivers, streams, and wetlands, including slightly brackish waters, as well as ephemeral habitats as they are capable of digging burrows to reach the underlying water table (Austin & Knott 1996; Beatty *et al.* 2005a; Morgan *et al.* 2011). They are omnivores/detritivores and can breed up to three times over the spring and summer months in permanent water (Beatty *et al.* 2005a).

Distribution

Has been recorded from the Margaret River, Wilyabrup Brook, Ellen Brook, Cowaramup Brook, Gunyulgup Brook, and Boodjidup Brook catchments in the Cape to Cape region (Morgan & Beatty 2003, 2004a, 2005, 2008; Beatty *et al.* 2006a, 2008; Beatty & Allen 2008; Lawrence *et al.* 2010). The WA Museum collection has a specimen captured from Calgardup Brook. Also occurs throughout south-western Australia from Moore River (north of Perth) to the Denmark region (Morgan *et al.* 2011).

Figure 26. Gilgie (*Cherax quinquecarinatus*) (photos: D. Morgan).

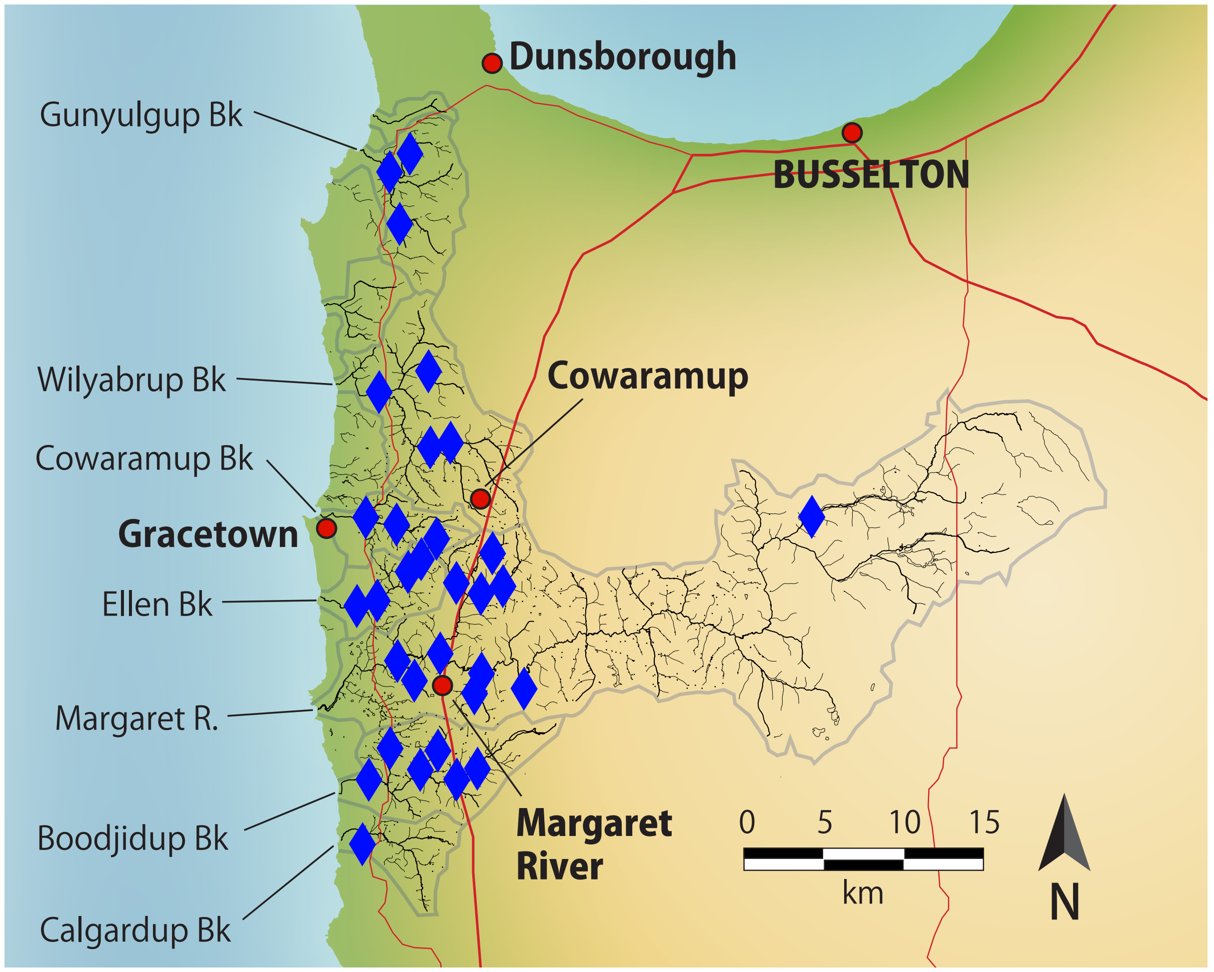

Figure 27. Distribution map of sites where Gilgie (*Cherax quinquecarinatus*) has been recorded in the Cape to Cape region.

Conservation status

Not currently listed as threatened. Besides Smooth Marron, this species is the most common and abundant *Cherax* species found in south-western Australia (Morgan *et al.* 2011). Its ability to inhabit ephemeral habitats by burrowing down to the water table during dry periods should allow this species to cope with the threat of climate change more successfully than other aquatic species that rely on permanent water (e.g. native fishes and marron).

Actions — none.

3.2.5 Restricted Koonac – *Cherax crassimanus* (Parastacidae)

Identification and biology

A small (maximum length 70 mm) species that is difficult to distinguish from other *Cherax*, particularly the Gilgie and Koonac (Morgan *et al.* 2011). It has four head ridges that are less pronounced and a spine on the inner edge of the carpus (i.e. wrist) that is more acutely curved than the other species (Figure 28b; Horwitz 1995; Morgan *et al.* 2011). Colour is variable from light to dark greenish-brown, often mottled with a central reddish-orange stripe, and pale orange at the base of the legs and claws (Figure 28a; Morgan *et al.* 2011). Inhabits permanent and ephemeral streams, more often encountered in smaller creek systems (Morgan *et al.* 2011). Very little is known of the biology of this species.

Distribution (Figure 29)

Has been recorded from the Ellen Brook (northern limit of range), Margaret River, and Turner Brook catchments in the Cape to Cape region (Austin & Knott 1996; Morgan & Beatty 2004a, 2005). Also ranges southwards in coastal drainages as far as Denmark (Morgan *et al.* 2011).

Conservation status

Not currently listed as threatened, however it is rarely encountered throughout its range (Morgan *et al.* 2011). The preference shown for ephemeral habitats suggests a burrowing capability therefore this species may fare better than aquatic species reliant on permanent water in the face of declining rainfall and dropping water tables. Additional research is required to determine if it should be officially listed as threatened.

Actions — 1) Regional surveys of seasonal habitats.

3.2.6 Koonac – *Cherax preissii* (Parastacidae)

Identification and biology

Similar in appearance to the Gilgie and Restricted Koonac but is best distinguished on the basis of its four head ridges (the two middle keels are not well defined) and generally broader claws (much more evident in larger specimens) (Horwitz 1995; Morgan *et al.* 2011). Reaches a maximum length of 200 mm but specimens around half that size are more common (Morgan *et al.* 2011). Colour varies from dark purplish-black to brown overall, sometimes mottled and/or with a prominent orange stripe

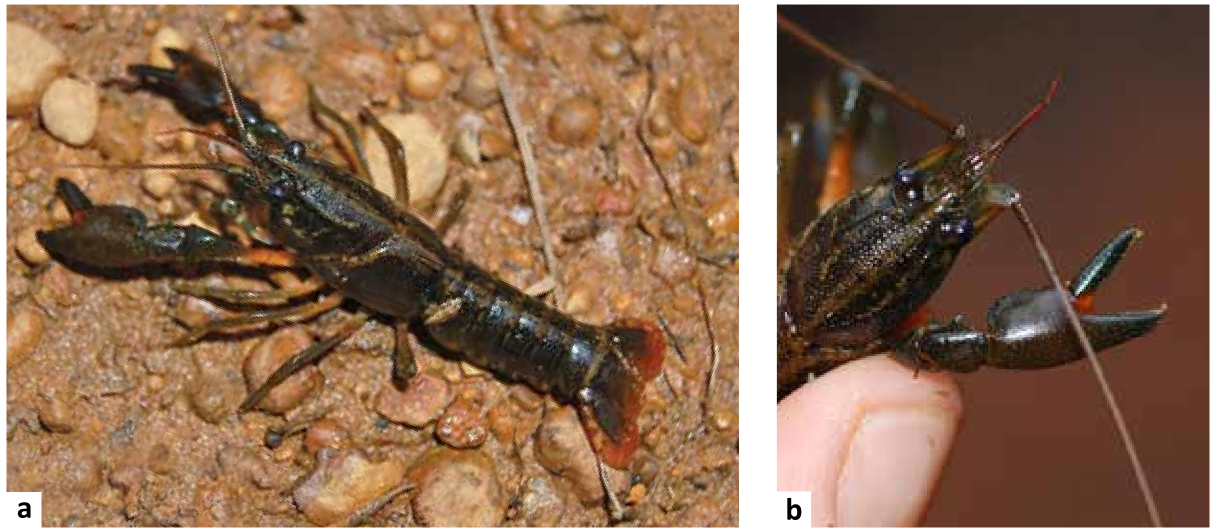

Figure 28. Restricted Koonac (*Cherax crassimanus*): a) dorsal view of specimen, and; b) close-up view of acutely curved spine on inner edge of carpus. (photos: S. Beatty).

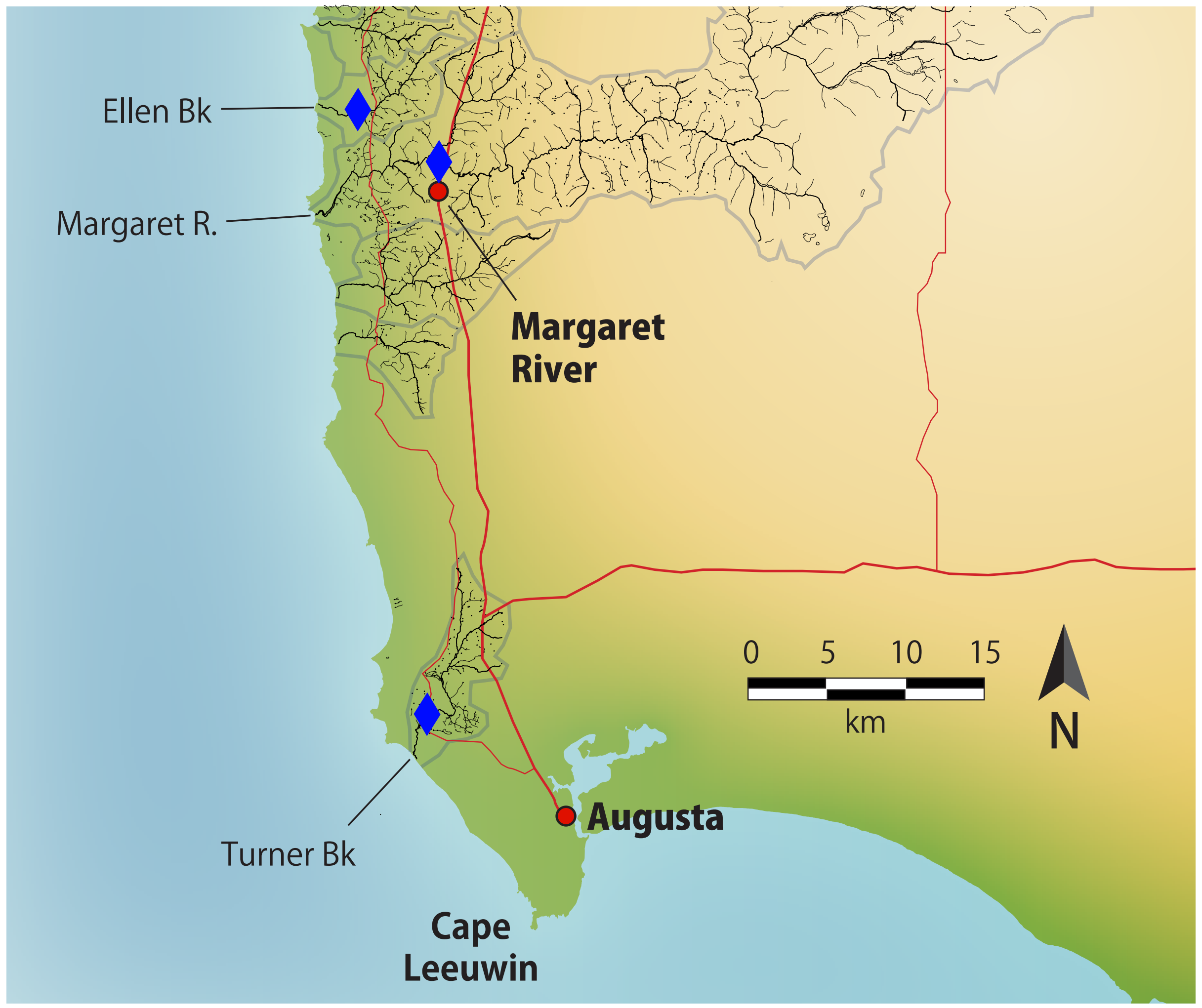

Figure 29. Distribution map of sites where Restricted Koonac (*Cherax crassimanus*) has been recorded in the Cape to Cape region.

Figure 30. Two colour forms of the Koonac (*Cherax preissii*). (photos: D. Morgan and S. Beatty).

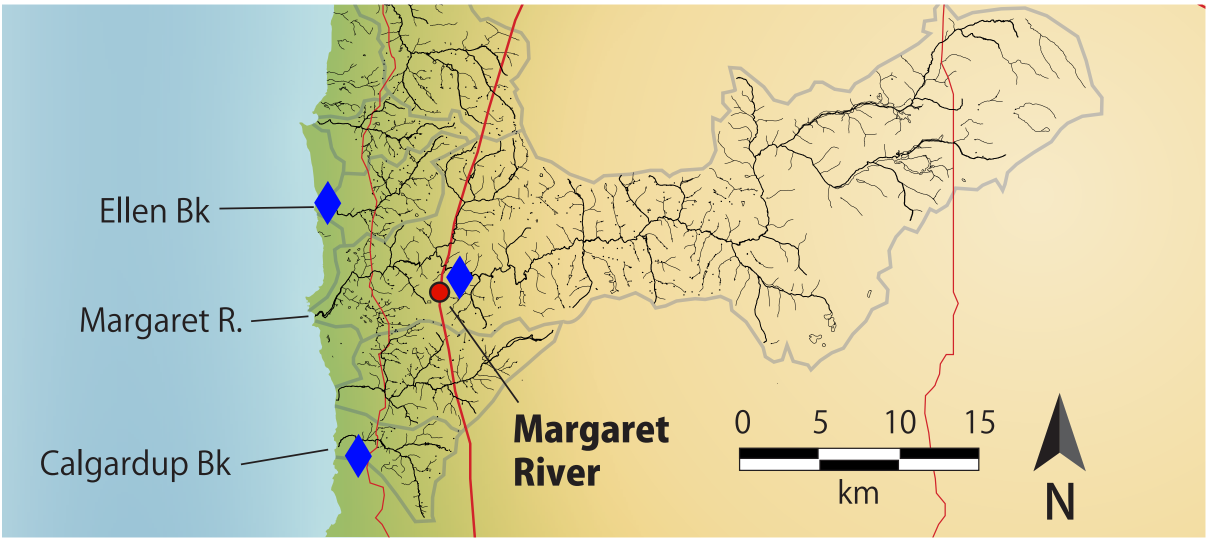

Figure 31. Distribution map of sites where Koonac (*Cherax preissii*) has been recorded in the Cape to Cape region.

running the length of the body (Figure 30; Riek 1967; Morgan *et al.* 2011). This species possesses broad, spade-like claws adapted for burrowing down to the water table, which allows it to inhabit ephemeral headwater streams and seasonal wetlands (Austin & Knott 1996; Morgan *et al.* 2011). The reproductive biology and diet has not been studied but is probably similar to that of the Gilgie (Morgan *et al.* 2011).

Distribution (Figure 31)

The only record of this species in recent surveys in the Cape to Cape region is from Ellen Brook (Morgan & Beatty 2005). Specimens housed in the collections of WA Museum were also collected from Margaret River and Calgardup Brook. It prefers ephemeral sites (Morgan *et al.* 2011) which have not generally been sampled in previous fish/crayfish surveys. A survey specifically targeting these habitats is required in order to determine the true extent of the range of this species in the region. Elsewhere it occurs from Moore River (north of Perth) to east of Albany (Morgan *et al.* 2011).

Conservation status

Not currently listed as threatened. Like other burrowing *Cherax*, climate change may not have as severe an impact on this species as it will for those reliant on permanent water.

Actions — 1) Regional surveys of seasonal habitats.

3.2.7 Glossy Koonac – *Cherax glaber* (Parastacidae)

Identification and biology

Very similar to the Koonac but distinguished by having fewer fine punctuations (i.e. dimples) on the dorsal surface of the cephalothorax giving the shell a glossy appearance (Riek 1967; Horwitz 1995; Morgan *et al.* 2011). Colour is a mottled black-brown (Figure 32; Riek 1967; Morgan *et al.* 2011). Possesses broad, spade-like claws adapted for burrowing, which allows them to inhabit ephemeral habitats (Morgan *et al.* 2011). Very little is known of the biology of this species.

Distribution

This species generally inhabits near-coastal swamps and wetlands (Morgan *et al*. 2011) that are not usually sampled during aquatic macrofauna surveys. There appears to be a record from the Calgardup Brook catchment, south of Margaret River (Austin & Knott 1996), however precise coordinates of the collecting site are not given and the specimen may have come from a tributary of the Blackwood River. Also occurs between Dunsborough and Windy Harbour (Morgan *et al.* 2011).

Conservation status

Not currently listed as threatened. More research is required to determine if this species should be listed as threatened.

Actions — 1) Regional surveys of seasonal habitats.

Figure 32. Glossy Koonac (*Cherax glaber*). (photo: R. McCormack).

3.3 Native freshwater bivalves

3.3.1 Carter's Freshwater Mussel – *Westralunio carteri* (Hyriidae)

Identification and biology

The only large-sized (maximum shell length of around 100 mm) bivalve that occurs in fresh waters of south-western Australia (Morgan *et al.* 2011; Klunzinger *et al.* 2012). The elliptical shell is dark coppery brown to blackish in colour (Figure 33a), usually covered in a film of algae and detrital material (Figure 33b; Morgan *et al.* 2011). Prefers sandy or soft sediment bottoms amongst woody debris and submerged tree roots in still or slow moving waters of rivers, streams, lakes and dams (Morgan *et al.* 2011). They are capable of moving short distances using a muscular tongue-like appendage and can dig themselves into the substrate to best position their siphoning apparatus for filter feeding (Figure 33b; Morgan *et al.* 2011). They can not tolerate salinity above 3 ppt but can survive periods up to weeks at a time out of water (Klunzinger *et al.* 2011a, 2012a; Klunzinger in prep.). The complex life cycle involves a parasitic stage during which the larvae (also known as glochidia) attach themselves to the fins of fishes and remain attached for several weeks before dropping off and settling to the bottom where they develop into juvenile mussels (Morgan *et al.* 2011; Klunzinger *et al.* 2011b). This parasitic phase functions as an effective means of dispersal for these relatively sedentary animals (Morgan *et al.* 2011; Klunzinger *et al.* 2011b).

Distribution (Figure 34)

Has been recorded from the Wilyabrup Brook, Ellen Brook, Boodjidup Brook, and Margaret River catchments in the Cape to Cape region (Klunzinger in prep.). Also distributed widely throughout south-western Australia between the Moore River (north of Perth) and Waychinnicup River (east of Albany) (Morgan *et al.* 2011; Klunzinger *et al.* 2012b).

Conservation status

Currently listed as Least Concern (IUCN) and **Priority 4** Fauna (WA DEC), but this categorisation is under review and the species may in fact be Endangered according to IUCN criteria (M. Klunzinger pers. comm.). Museum records exist from the Gascoyne River in the north to Esperance in the south (Morgan *et al.* 2011), but these may be erroneous. Increasing levels of salinisation in inland waters has resulted in the extirpation of this salt-intolerant species from vast tracts of its former range (Klunzinger in prep.), but in the Cape to Cape region salinisation is not considered a major risk factor as most drainages arise from forested headwaters. Furthermore, the highest known densities of *W. carteri* have been recorded from Canebrake Pool in the upper reaches of Margaret River indicating that local populations of this species are robust (M. Klunzinger pers. comm.).

Actions — 1) Baseline assessment of population demographics of upper Margaret River population.

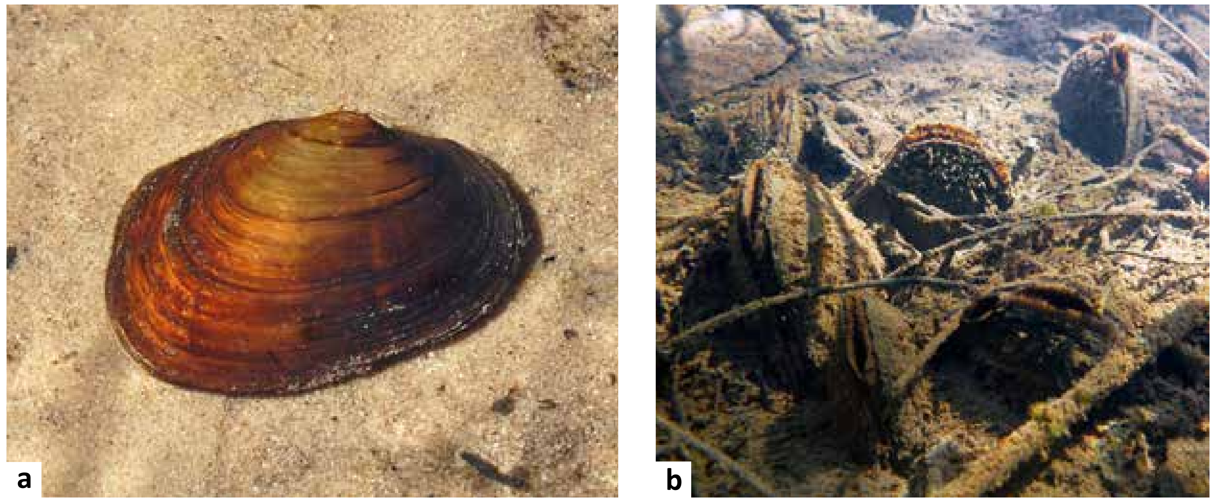

Figure 33. Carter's Freshwater Mussel (*Westralunio carteri*). a) solitary adult, and; b) aggregation of mussels embedded in the substrate (photos: D. Morgan and M. Klunzinger).

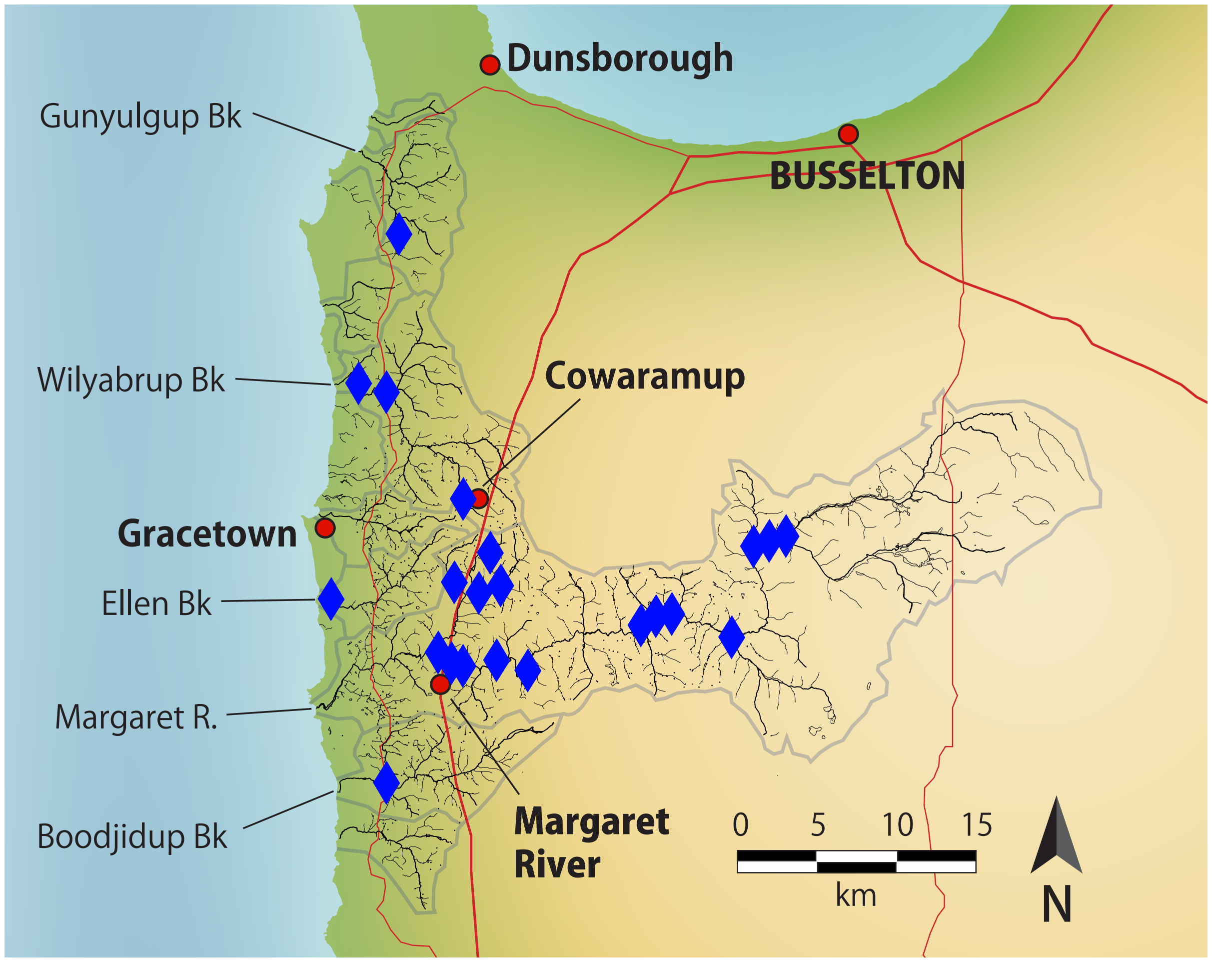

Figure 34. Distribution map of sites where Carter's Freshwater Mussel (*Westralunio carteri*) has been recorded in the Cape to Cape region.

4. Threatening Processes

4.1 Introduced species

There are believed to be as many as seven introduced aquatic fauna species that now occur in the Cape to Cape region. Additionally, despite being a south-west Australian endemic, the Smooth Marron (*Cherax cainii*) is also introduced in the Cape to Cape region having been stocked there since the 1980s (Austin & Knott 2002; Molony *et al.* 2004). Species were introduced by a number of means and for varying reasons. The earliest introductions were government sanctioned for the purpose of creating enhanced recreational angling opportunities (i.e. Redfin Perch, Trout) (Coy 1979) and for the biological control of mosquito larvae (i.e. Eastern Gambusia) (Mees 1977; Lloyd *et al.* 1986). More recently, species that are commonly kept as pets (Goldfish, Carp) or used in aquaculture (Yabby, Smooth Marron) have also become established in natural waterways (Morgan *et al.* 2004a, 2011).

Introduced species threaten the native aquatic biodiversity in a variety of ways. Some species compete with natives for food and habitat resources, while others predate directly on native species. They can be a vector for spreading exotic parasites and disease amongst the native fauna and some species can even degrade aquatic habitats and water quality by means of their feeding behaviour in benthic sediments (Fletcher *et al.* 1985; Morgan & Beatty 2007b).

Once established, introduced species can be notoriously difficult, or generally impossible, to eradicate from the wild (Horwitz 1990; Rowe *et al.* 2008). Some species such as Eastern Gambusia and Yabbies are so adaptable to local conditions that it is unlikely they will ever be eradicated. It is advised therefore, that any funding for the control of introduced species be spent on realistic target species (e.g. Carp and Goldfish) and in the delivery of educational and awareness raising campaigns and materials emphasising the threats posed by introduced species which will hopefully help to prevent further introductions of exotic species in natural waterways of the region. A brief synopsis of the introduced species occurring in the Cape to Cape region follows.

4.1.1 Introduced freshwater fishes

4.1.1.1 Rainbow Trout – *Oncorhynchus mykiss* (Salmonidae)

First introduced to south-western Australia in the 1930s for sport fishing purposes (Coy 1979). Very few self-sustaining populations are known in south-western Australia; most are sustained via annual stocking of hatchery-reared fish by the Department of Fisheries (Morrissy *et al.* 2002; Morgan *et al.* 2004a) although no streams have been stocked in the Cape to Cape region in recent years (R. Duffy, Department of Fisheries, pers. comm.). Rainbow Trout directly consume native fishes, decapod crustaceans, and amphibians, and also compete with natives for important invertebrate prey items (Pusey & Morrison 1989; Morgan *et al.* 2004a; Tay *et al.* 2007). A thorough review of the impacts of trout on south-west native species is provided by Morrissy *et al.* (2002). They are included on the IUCN's list of the world's 100 worst invasive alien species (Lowe *et al.* 2000)

They are silvery to olive in colour, with dark spots on the upper body and fins and have a reddish-orange midlateral stripe (Figure 35a). They grow to a maximum size of around 700 mm in south-western Australia and can reach up to four years of age (Morrissy *et al.* 2002). Native to Pacific drainages of North America and Siberia (Allen *et al.* 2002).

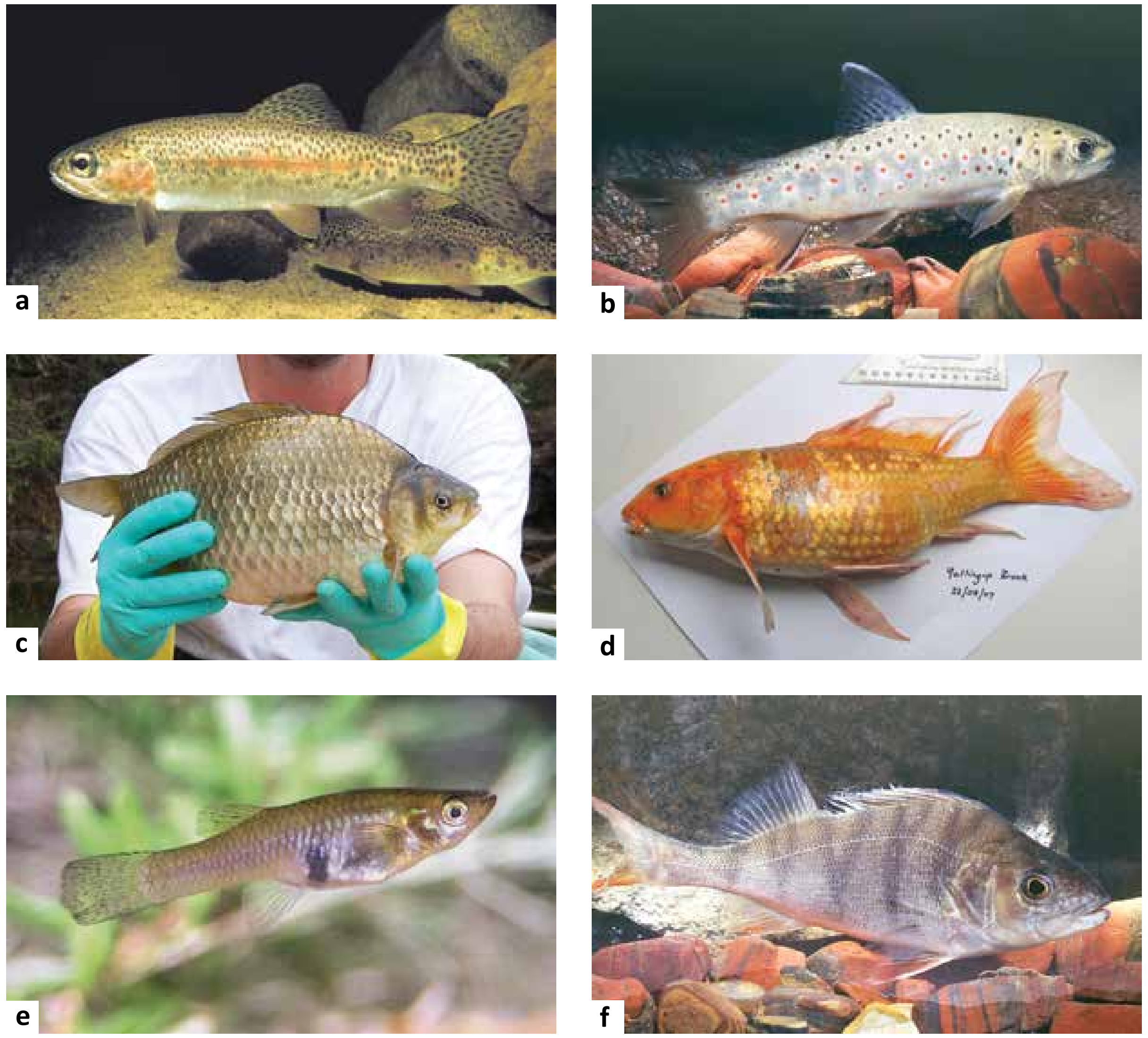

Figure 35. Introduced fishes in the Cape to Cape region: a) Rainbow Trout (*Oncorhynchus mykiss*); b) Brown Trout (*Salmo trutta*); c) Goldfish (*Carassius auratus*); d) Common Carp (*Cyprinus carpio*); e) Eastern Gambusia (*Gambusia holbrooki*), and; f) Redfin Perch (*Perca fluviatilis*) (photos: R. Kuiter [a], D. Morgan [b,e,f], S. Beatty [c], and R. Paice [d]).

Rainbow Trout are widely stocked in private farm dams throughout south-western Australia and any individual found in a natural water course in the Cape to Cape region is likely to have escaped from a stocked private dam. No Rainbow Trout have been recorded in any of the Cape to Cape fish surveys undertaken since 2003. Morgan *et al.* (1998) reported trout from Ten Mile Brook Dam (Figure 36), but did not differentiate between *O. mykiss* and *Salmo trutta*, although neither were recorded from a comprehensive recent survey of the reservoir (Lawrence *et al.* 2010). Rainbow Trout were observed in an on-stream dam in Bramley Brook (tributary of Margaret River) during a recent foreshore assessment survey (CCG 2011).

4.1.1.2 Brown Trout – *Salmo trutta* (Salmonidae)

Introduced around the same time as Rainbow Trout (i.e. 1930s-40s) and for the same purpose of enhancing recreational angling opportunities for Western Australians (Coy 1979). There are several self-sustaining Brown Trout populations known in the south-west but most populations are augmented by annual release of hatchery-reared fish by the Department of Fisheries, although in far less numbers than Rainbow Trout (Morrissy *et al.* 2002; Morgan *et al.* 2004a). Streams of the Cape to Cape region have not been stocked with this species in recent decades (R. Duffy, Department of Fisheries, pers. comm.) and there are no records of this fish in any of the Cape to Cape surveys undertaken since 2003. It is possible, however, that escapees from private farm dams may occur in streams here.

Brown Trout (like Rainbow Trout) prey upon native fish and crayfish and also compete for invertebrate food items (Pusey & Morrison 1989; Morgan *et al.* 2004a). A thorough review of the impacts of trout on south-west native species is provided by Morrissy *et al.* (2002). They are silvery to tan-brown overall, with reddish spots on the sides and dark spots on the upper body and dorsal fin, but lack spots on the tail (Figure 35b). They grow to a maximum size of around 700 mm in south-western Australia (Morrissy *et al.* 2002). Native to Europe (Allen *et al.* 2002).

4.1.1.3 Goldfish – *Carassius auratus* (Cyprinidae)

The distribution of Goldfish in Western Australia was first reported in detail by Morgan *et al.* (2004a), by which time they had been widely introduced in natural and artificial waterways between Moore River (north of Perth) and the Blackwood River. This popular ornamental fish species probably became naturalised in wild systems through numerous instances of careless disposal into natural waterbodies of unwanted pets by well-meaning but uninformed owners or escape from ornamental ponds during flooding (Morgan & Beatty 2004b). Goldfish were first found in the Cape to Cape region in 2007 in two artificial lakes located in the upper reaches of Darch Brook (a tributary of the Margaret River) within Brookfield Estate (Figure 36). Cape to Cape Catchments Group subsequently organised a “fish-out” event involving the local community and researchers from Murdoch University, aimed at eradicating Goldfish from the lakes, however this goal was not achieved. Goldfish have broad physico-chemical tolerances (Sollid *et al.* 2005), breed readily in both artificial and natural water bodies in south-western Australia, and once established are very difficult to eradicate (Morgan *et al.* 2005). The most effective means of eradication is dewatering of the habitat combined with the use of chemical ichthyocides and these methods were successfully employed to finally eradicate the two artificial lake populations in Brookfield Estate in 2010. Goldfish were caught and removed from Darch Brook downstream of Brookfield Estate at the Halcyon Crescent crossing in 2008 (Figure 36; Beatty *et al.* 2008), but are likely to still persist in the catchment and may have already spread into the Margaret River main channel. The only other confirmed record of this species in the Cape to Cape region is from a small artificial pond in the Wilyabrup Brook catchment located off Duggan Drive in the town of Cowaramup (Figure 36). Over 1,000 individuals were removed from here in 2011 using boat electrofishing methods but no follow-up survey has taken place to investigate the impact this had on the population, or whether they have spread further in the Wilyabrup Brook catchment.

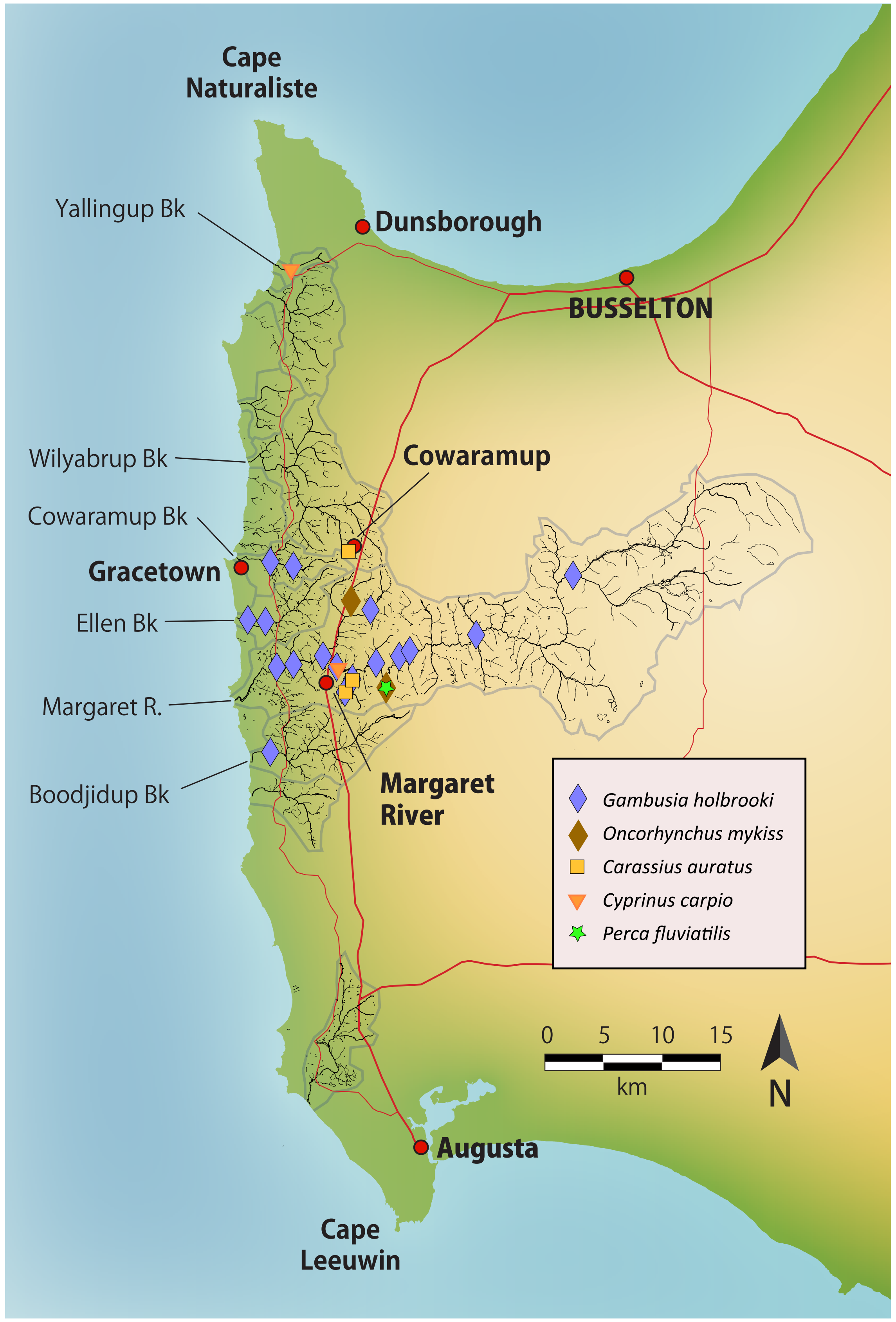

Figure 36. Distribution map of sites where introduced fish species have been recorded in the Cape to Cape region.

Goldfish pose a threat to native species primarily due to the impact they have on aquatic habitats and water quality through their foraging behaviour. A large proportion of the diet consists of blue-green algae, the growth of which is stimulated by passage through their intestinal tract (Kolmakov & Gladyshev 2003; Morgan & Beatty 2007b). Sediments on the bottom are constantly stirred up during feeding resulting in the re-suspension of nutrients contained in the sediment layer which has the potential to contribute to algal blooms (Morgan & Beatty 2007b). Native fish, decapod crustaceans and bivalves are generally intolerant of large diurnal fluctuations of dissolved oxygen levels that can occur during algal blooms and die *en masse* when conditions become extremely anoxic. Marron can also walk out of habitats when oxygen levels drop (Morrissy 1978), exposing them to increased levels of predation by birds, water rats and foxes.

Goldfish are also implicated in the spread of exotic parasites and diseases including the Anchor Worm (*Lernaea cyprinacea*) (Marina *et al.* 2008). This parasitic copepod has been documented in natural waterways in south-western Australia and Goldfish are believed to be the original vector for its spread into native fish populations (Marina *et al.* 2008; Lymbery *et al.* 2010). This parasite reduces fitness and can cause death of infested host fishes (Lester & Hayward 2006; Marina *et al.* 2008). At the time of writing this report, *L. cyprinacea* had not been recorded from the Cape to Cape region but further investigation may uncover its presence here. In order to minimise the risk of the spread of this parasite throughout local waterways, further incursions of Goldfish must be prevented.

Goldfish vary in colour from bright reddish-orange to a muted pale coloration overall, however, most wild-caught specimens are dusky golden in colour (Figure 35c; Allen *et al.* 2002). They are rotund with a deep body and can grow to around 440 mm (over 2 kg) and live for over 10 years (Morgan & Beatty 2007b). They prefer still or slow-flowing water and are native to eastern Asia (Allen *et al.* 2002).

4.1.1.4 Common Carp – *Cyprinus carpio* (Cyprinidae)

Carp are a ubiquitous pest species in the eastern states of Australia, particularly in the Murray-Darling system (Koehn 2004). Fortunately, they have not been as successful in establishing in Western Australian rivers with only a few isolated records known (Morgan *et al.* 2004a). In the Cape to Cape region they have been captured in Yallingup Brook (R. Paice, pers. comm.) and also the Margaret River (D. McKenzie pers. comm.) (Figure 36). On both occasions only a single specimen was caught indicating they are unlikely to have established self-maintaining populations in either of these catchments. They pose similar threats to Goldfish in that their feeding habits destroy aquatic vegetation (Fletcher *et al.* 1985; Roberts *et al.* 1995) and agitate bottom sediments, increasing turbidity which reduces water quality (Fletcher *et al.* 1985; King *et al.* 1997). Nutrients can also become resuspended, potentially exacerbating algal blooms in eutrophic systems (Morgan & Beatty 2007b). They are also potential vectors for spreading diseases and parasites such as *Lernaea cyprinacea*.

Carp are similar in appearance to Goldfish, but are easily distinguished by the presence of four short barbels (i.e. whiskers) around the mouth (Figure 35d). The natural colour form is dusky golden but there are numerous ornamental forms with varying amounts of orange, yellow, white and black coloration or combinations thereof. Carp can reach over a metre in length but seldom grow over 500 mm in Australian waters (Allen *et al.* 2002). Native to Asia (Allen *et al.* 2002).

4.1.1.5 Eastern Gambusia – *Gambusia holbrooki* (Poeciliidae)

Eastern Gambusia were first introduced throughout Australia in the 1930s by Government health authorities as a biological control agent for mosquito larvae (Wilson 1960). Unfortunately, the species has since been shown to consume less mosquito larvae than some native fishes (Lloyd 1986; Arthington & Lloyd 1989). Furthermore, Gambusia now threaten native species, including amphibians, through competition for habitat and food resources and larval predation (Arthington & Lloyd 1989; Hambleton *et al.* 1996; Reynolds 2003). They also have a predilection for harassing and nipping the tail fins of some native fish species (especially Nightfish and Pygmy Perch), exposing their victims to fungal infection and premature mortality (Gill *et al.* 1999). Native species can co-exist with Eastern Gambusia in habitats with abundant instream cover (e.g. submerged vegetation, woody debris, etc), but Gambusia tend to dominate in highly altered habitats lacking cover (e.g. dams, ponds, pools adjacent to weirs) (Morgan *et al.* 1998; Morgan & Beatty 2003).

Eastern Gambusia exhibit biological characteristics that typify all highly successful invasive species. They feed on a variety of food items, are quick to reach sexual maturity, have a high reproductive capacity, and have extremely broad environmental tolerances (i.e. temperature, salinity, dissolved oxygen) (Pen & Potter 1991c; see also Rowe *et al.* 2008 for a thorough biological review). This has allowed them to build their abundance up into plague proportions in many rivers, including Margaret River where they are by far the most numerous fish species (Morgan & Beatty 2003). They occur in many catchments in the Cape to Cape region and are commonly observed in loose groups along the edges of streams, lakes, dams, and wetlands in still or slow moving water (Figure 36; Morgan *et al.* 1998; Morgan & Beatty 2003, 2004a, 2005, 2008; Beatty & Morgan 2008; Beatty *et al.* 2008). The maximum size is around 60 mm for females (identified by a dark spot to the rear of the belly) and about 35 mm for males (Allen *et al.* 2002). They have a drab pale grey to olive coloration overall, with transparent fins (Figure 35e). Native to the Gulf of Mexico drainages of North and Central America (Allen *et al.* 2002).

4.1.1.6 Redfin Perch – *Perca fluviatilis* (Percidae)

First introduced into Western Australia in the 1890s as an angling species (Coy 1979) and now widespread in the south-west between the Swan and Warren rivers (Morgan *et al.* 1998, 2004a), but only a single record exists in the Cape to Cape region (Figure 36). They were recorded in Ten Mile Brook reservoir by Morgan *et al.* (1998), but a subsequent survey by the Department of Fisheries in 2010 failed to capture or observe a single specimen (Lawrence *et al.* 2010) indicating that this population may have since died out.

Redfin Perch pose a serious threat to native fish and decapod crustacean populations. They are voracious consumers of juvenile Marron and have been shown to be responsible for decimating populations of native aquatic species in systems such as Big Brook Dam in the Warren River catchment (Pen & Potter 1992; Morgan *et al.* 2002). For this reason, it is illegal to return any Redfin Perch alive into streams from which they are caught and it is imperative that they are not moved between catchments. This species grows to a maximum length of around 500 mm and breeds in winter/spring in Western Australia (Morgan *et al.* 2002). It has distinctive dark bars that branch above the midline on the body and red-orange pelvic, anal and caudal fins (Figure 35f). Native to Europe (Allen *et al.* 2002).

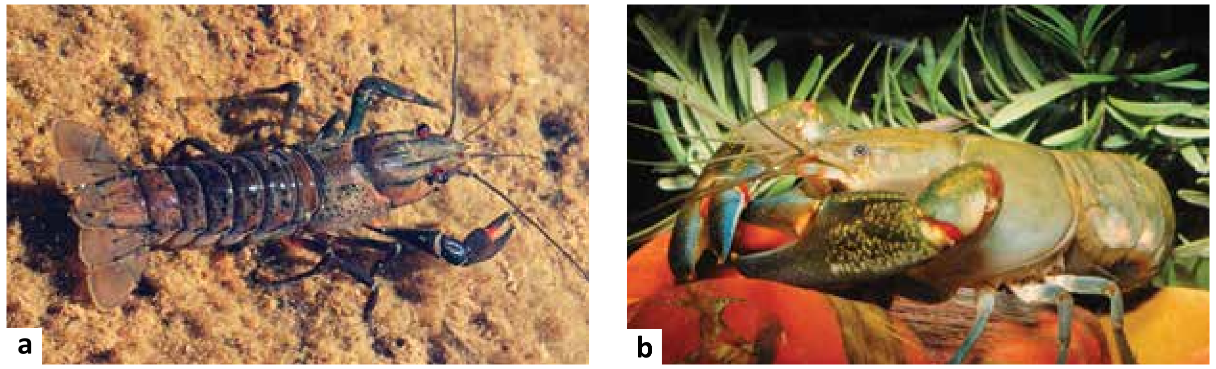

Figure 37. Introduced decapod crustaceans in the Cape to Cape region: a) Smooth Marron* (*Cherax cainii*), and; b) Yabby (*Cherax destructor*). (photos: D. Morgan). * Smooth Marron are endemic to south-western Australia but have been translocated in the Cape to Cape region since the early 1980s.

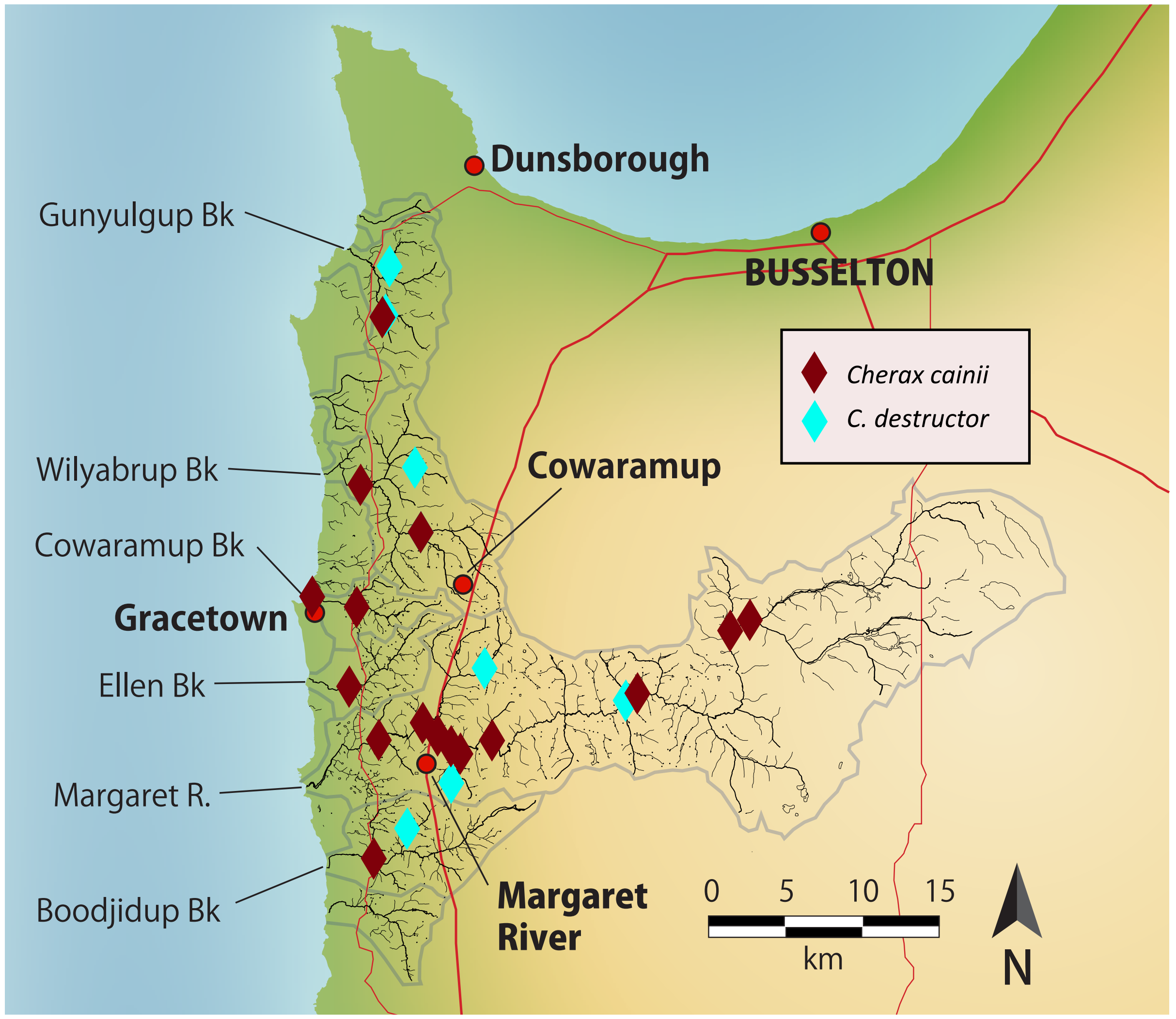

Figure 38. Distribution map of sites where introduced decapod crustacean species have been recorded in the Cape to Cape region.

4.1.2 Introduced freshwater decapod crustaceans

4.1.2.1 Smooth Marron – *Cherax cainii* (Parastacidae)

There is some uncertainty as to the original (i.e. pre-European colonisation) distribution of this species, particularly in the Cape to Cape region, which houses the closely related endemic Hairy Marron in Margaret River (see section 3.2.3). Smooth Marron were first stocked in the Margaret River catchment in the early 1980s (de Graaf *et al.* 2009). Since then, they have also been recorded in the Wilyabrup Brook, Cowaramup Brook, Ellen Brook, Gunyulgup Brook, and Boodjidup Brook catchments (Figure 38; Morgan & Beatty 2005, 2008; Beatty *et al.* 2006a) but the origin of these populations is uncertain. They are probably derived from translocated dam stocks that escaped into the wild and formed self-sustaining populations. Regardless of their origin, however, the populations outside the Margaret River catchment are now well established and probably do not pose a threat to any native aquatic species. Elsewhere in south-western Australia, Smooth Marron are believed to have originally ranged between Harvey and Albany (Morrissy 1978), but they are now much more widespread, occurring from the Hutt River (near Kalbarri) to Esperance (Morgan *et al.* 2011). They have also been introduced in South Australia and Victoria where they are considered a pest (Bryant & Papas 2007). A well-managed recreational fishery is based on Smooth Marron throughout inland waters of the south-west for a short period each summer.

Smooth Marron are large freshwater crayfish reaching a maximum length of around 400 mm and up to 2 kg (Morgan *et al.* 2011). They are brown to black overall, sometimes dark bluish and distinguished from other *Cherax* by the smooth shell, five head ridges, and paired spines on the telson (i.e. central segment of the tail fan) (Figure 37a; Austin & Ryan 2002). Males are distinguishable from females by their blue-tinged reproductive organs (penes) at the base of the fourth pair of walking legs. Hairy Marron (*C. tenuimanus*) are similar in appearance but distinguished by the setae (hairs) covering the cephalothorax, as well as a longer central head ridge which extends posteriorly almost to the cervical groove (i.e. arc-shaped groove at the fused junction of the head and thorax) (Austin & Ryan 2002). Hybrids of Hairy and Smooth Marron can appear very similar to pure-strain Hairy Marron, and at this stage genetic testing is the only fail safe method of distinguishing them.

Smooth Marron occupy permanent water of rivers, streams, lakes, and dams and favour areas with complex habitat featuring large woody debris and boulders (Morgan *et al.* 2011). They are intolerant of low dissolved oxygen and high temperature (i.e. > 29° C), and are typically found in waters less than 8 ppt but can survive for a period up to 17 ppt (i.e. around half that of sea water) (Morrissy *et al.* 1984; Morrissy 1990; D. Morgan & S. Beatty unpubl. data). They feed on a varied diet including detritus, plant material, aquatic invertebrates and fish (Beatty *et al.* 2004; Beatty 2005, 2006). Breeding takes place from July to October with brooded juveniles being released in early summer (Beatty *et al.* 2003, 2004). They grow quickly but take about three years to reach sexual maturity (Beatty *et al.* 2003).

Smooth Marron are primarily a threat to the Critically Endangered Hairy Marron as they reproductively outcompete them. The two closely related species also readily hybridise in the wild which is a major threat to the genetic integrity of Hairy Marron stocks (Imgrund 1998; Molony *et al.* 2004; Lawrence 2007; Bunn *et al.* 2008; de Graaf *et al.* 2009). Originally Hairy Marron were found throughout the Margaret River catchment but now only occur in the upper reaches where, in 2009, they comprised only 30% of total marron stocks (down from 100% in 1995) (de Graaf *et al.* 2009). This percentage has likely declined further to around 20% since then (D. McKenzie pers.

comm.). Smooth Marron also impact indirectly, on Hairy Marron in that they are a prized target of recreational fishers. Despite the fact that a fishing exclusion zone exists in the upper Margaret River and they are fully protected by law, Hairy Marron are undoubtedly caught by illegal poachers, but it is impossible to accurately estimate how many are removed from the wild each year in this way. The Department of Fisheries has undertaken captive breeding and restocking of Hairy Marron and, until recently, also conducted annual "fish-outs" of Smooth and hybrid Marron from the upper Margaret River (de Graaf *et al.* 2009; R. Duffy, Department of Fisheries, pers. comm.). These actions are believed to have helped to stabilise Hairy Marron declines to some extent (de Graaf *et al.* 2009).

4.1.2.2 Yabby – *Cherax destructor* (Parastacidae)

The Yabby is native to eastern Australia, and is commonly cultured in private farm dams throughout south-western Australia (Morgan *et al.* 2011). However, this practice is only legal in the wheatbelt and is banned west of an arbitrary line (the 'yabby line') that runs between Perth and Albany (DoF 2012). Therefore, any occurrence of this species in the Cape to Cape region has been illegally stocked and efforts should be made to extirpate them. Unfortunately, this species has already been widely introduced across the Cape to Cape region with records existing from the Margaret River (including Bramley Brook and Darch Brook), Wilyabrup Brook, Gunyulgup Brook, and Boodjidup Brook catchments (Figure 38; Morgan & Beatty 2005, 2008; Beatty *et al*. 2006a, 2008; Beatty & Allen 2008).

Yabbies possess life history traits typical of a successful invasive species. They are adaptable to a range of habitats (including ephemeral waters due to a burrowing ability) and have broad environmental tolerances to temperature, salinity, pH, dissolved oxygen, etc. (Morrissy 1978; Austin 1985; Horwitz & Knott 1995; Morris & Callaghan 1998; Beatty *et al.* 2005b; Morgan *et al.* 2011). They occupy an equivalent ecological niche to endemic *Cherax* spp. and directly compete with these species for food and habitat resources (Beatty 2006; Lynas *et al.* 2007). They are capable of breeding multiple times in a single year which allows them to rapidly recolonise habitats and potentially outnumber native species (Beatty *et al.* 2005b). Yabbies are also a host of the microsporidian *Thelohania parastaci* which causes wasting of muscle tissue in infected crayfish and there is concern over its potential spread into wild populations of native south-western endemic crayfishes (Horwitz 1990; Jones & Lawrence 2001). Every effort must therefore be made to prevent further releases, and minimise the spread of yabbies, in natural waterways of south-west WA.

Yabbies are similar morphologically to the endemic Koonac (*Cherax preissii*) in that they possess four head ridges and typically have broad, spade-like claws adapted for digging (Morgan *et al.* 2011). However, they are easily distinguished on the basis of their pale olive to bluish coloration and the presence of hairs on the inner surface of the "arm" and "wrist" segments of the claw appendages (Figure 37b). They reach a maximum length of about 160 mm (Morgan *et al.* 2011).

4.2 Artificial barriers and water abstraction

Artificial barriers across waterways (e.g. dams, weirs, road crossings) impact upon aquatic species in several ways. Most crucially, they can prevent or reduce access to habitats which may be necessary for breeding, feeding or as nursery areas, or they can reduce sustainability of populations through fragmentation (Lucas & Baras 2001; Morgan & Beatty 2003; Wofford *et al.* 2005). For example,

a number of native freshwater fishes (e.g. Western Minnow, Nightfish, Pouched Lamprey) move upstream to spawn in small side creeks with the onset of winter flows (Potter 1986; Pen & Potter 1990, 1991a, b). Artificial barriers impact negatively on such species firstly due to the physical restriction on upstream movements, and secondly due to alteration of flow regimes which provide a necessary cue to commence spawning. Early flows are also important for relieving water stress in riparian plant communities at the end of summer (SKM 2007). Catchments containing many instream dams have a reduced magnitude of shoulder period flow (i.e. April-June and November-January) due to the capture of the majority of surface runoff during these periods with little or no spillover (SKM 2007). This has the effect of shortening the potential duration of the breeding season of aquatic animals that rely on flow to trigger spawning. Both of these impacts impart a cumulative effect that can reduce the reproductive success of aquatic species, thereby reducing the carrying capacity of catchments thus altered. Underground bores can also contribute to a reduction in groundwater expression (i.e. flow from natural springs) (CSIRO 2009b) which can be necessary for maintaining aquatic habitats in some catchments (Beatty *et al.* 2009; Beatty & Morgan 2009). There are unequivocal examples of groundwater dependence for species such as Balston's Pygmy Perch in some south-west streams (Beatty *et al.* 2009; Beatty & Morgan 2009) but none have yet been demonstrated in the Cape to Cape region.

The instinctual behaviour of some aquatic species to move upstream during periods of flow results in the formation of large congregations below artificial barriers and exposure to increased risk of predation, particularly by piscivorous birds (Figure 39; Morgan & Beatty 2003). Artificial barriers can also have a negative impact on native aquatic fauna through habitat alteration. Dams and weirs are sediment traps that prevent the flushing of fine particulates down the catchment, and cause an accumulation of silt in the pools that are created behind instream barriers. These artificial pool habitats are more favourable to introduced species such as Eastern Gambusia (Morgan *et al.* 1998; Gill *et al.* 1999), allowing them to build up their numbers and compete with and harass native species.

Figure 39. A White-faced Heron (*Egretta novaehollandiae*) feeding on Western Minnows (*Galaxias occidentalis*) congregated below the crest of the fishway at Apex Weir, Margaret River. (photo: S. Visser).

Water resources are in high demand throughout south-western Australia. In the Cape to Cape region agriculture (particularly viticulture) has been intensifying in recent decades and there are now hundreds of artificial instream barriers (mainly gully dams) and underground bores throughout the catchments of the region and ongoing demand to install more (see for example CCG 2005a, 2006). Other water abstraction issues include the illegal pumping of river water, non-compliance by private land holders in the installation and use of flow-bypass valves in on-stream dams, and the impact of timber plantations that intercept run-off and cause draw down of water tables (Beckwith Environmental Planning 2007; DoW 2009). There is also sentiment in the region that many dams are excessive in capacity for their intended use (Beckwith Environmental Planning 2007).

It is crucial that water abstraction for the purposes of satisfying human consumption and agricultural productivity is balanced with ecological requirements if local aquatic biodiversity is to be sustained and conserved. Two reports on the Ecological Water Requirements (EWR) of catchments in the region have been published in recent years (Donohue *et al.* 2010; Green *et al.* 2011). For the Cowaramup Brook catchment it was concluded that the current level of water usage was at or just below the sustainable level to maintain aquatic ecological functions and therefore, any further water extraction through the building of new dams or sinking of new bores in this catchment should be limited (Donohue *et al.* 2010). Further EWR studies would be beneficial in order to determine if water use is encroaching on ecologically sustainable limits in other catchments of the region.

Measures designed to reduce the negative impacts on the aquatic fauna of barriers in the Cape to Cape region should be increasingly considered. Three fishway structures have already been installed in the Cape to Cape region for the purpose of allowing migrating fish to bypass obstacles. There are two rock ramp fishways on the Margaret River at the Apex Weir (constructed in 2003; Figure 40a) and Barrett Street Weir (constructed in 2006; Figure 40b), and a low gradient bypass channel fishway around a private farm dam in the middle section of Wilyabrup Brook (constructed in 2008; Figure 40c). While these structures allow fast-swimming species such as Western Minnows to bypass barriers, they are much less efficient at facilitating the passage of the majority of native freshwater

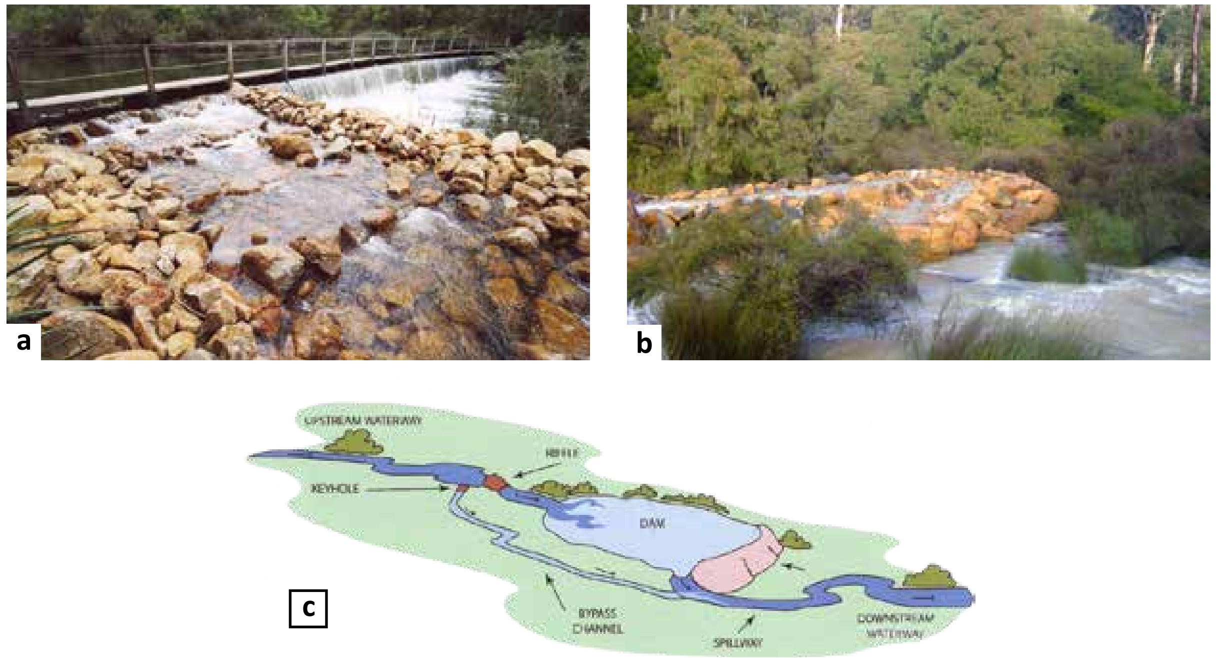

Figure 40. Fishway structures in the Cape to Cape region: a) Apex Weir, Margaret River; b) Barrett Street Weir, Margaret River, and; c) concept drawing of low gradient bypass fishway installed on a tributary of Wilyabrup Brook. (photos/artwork: S. Visser, CCG, and S. Lee)

fish species (Morgan & Beatty 2004; Beatty & Morgan 2008; Beatty & Allen 2008). Thus, there is a need for research to be conducted into modifications or alternative designs that will allow the full suite of native aquatic species to utilise these structures to bypass instream barriers.

A simpler and more effective solution may be the physical removal of artificial barriers from streams. The authors of this report are currently involved in project aimed at developing a protocol for the identification and assessment of instream barriers in catchments of south-western Australia. One of the main aims of this research is the identification of redundant barriers that will be targeted for removal, thus helping to restore natural hydrology and longitudinal stream connectivity.

The vast majority of artificial barriers will undoubtedly be found not be redundant, so other measures must be considered to limit the threat posed. Catchment groups have been advocating for the installation of flow bypass systems in on-stream dams that release water downstream when water level rises are detected within the dam (Figure 41). This will help to alleviate the problem of the delay of the onset of winter flows in catchments containing a large number of dams.

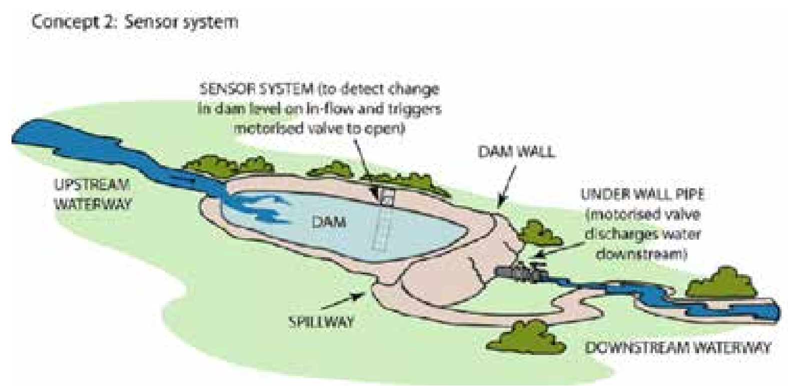

Figure 41. Flow bypass system design concept for on-stream dams. (artwork: S. Lee).

Finally, it should be mentioned that barriers can sometimes provide a benefit in some catchments by limiting the dispersal of introduced species. In Boodjidup Brook Eastern Gambusia were only found in Devil's Pool (located in the lower reaches) and were absent, presumably due to the presence of an instream barrier, from the entire upstream portion of the catchment (Morgan & Beatty 2008). This may, in part, explain why the rare and threatened Mud Minnow persists in reasonable numbers in the middle section of this system. It is important therefore that any such beneficial impacts of artificial barriers be taken into account in future barrier assessments.

4.3 Loss and degradation of riparian vegetation

Riparian vegetation provides habitat for a diverse array of fauna including mammals, birds, reptiles, amphibians and a host of different invertebrates. It also acts as an important link for native animals to move between patches of remnant native vegetation in human altered landscapes (Hussey *et al.* 1989) and plays a vital role in maintaining aquatic ecosystem function and health (Pen 1999).

There are considerable benefits to aquatic ecosystems when riparian vegetation is maintained in a pristine or near-pristine condition. As the scale of degradation and loss of natural riparian vegetation increases, however, so to do the threats to native aquatic and terrestrial fauna.

In the past riparian vegetation was commonly destroyed during the development of agricultural land. This practice is less common today, although it still occurs during the construction and initial flooding of on-stream dams. The case of the extirpation of an entire population of the Margaret River Burrowing Crayfish (*Engaewa pseudoreducta*) should serve as a sobering reminder of the dire consequences of such rapacious practice. The riparian habitat of this population (at the time the only one known for this species) was completely destroyed during the construction of a private farm dam and subsequent establishment of a timber plantation (Horwitz 2003; DEC 2008). Fortunately, two other populations of this Critically Endangered species were later discovered elsewhere (DEC 2008; Q. Burnham pers. comm.), but nonetheless, destruction of riparian habitat in this instance was culpable for the loss of a significant number of these rare animals.

The practice of clearing creek lines has mercifully waned in recent years, however, degradation of riparian vegetation remains a prevalent issue throughout the region, especially in livestock farming areas. Creek lines are prized by farmers as a convenient means of watering stock and for growing the best grazing pasture, particularly after winter rains have ceased and pasture is scarce. Current industry best practice, however, is for creek lines to be fenced off from livestock in order to conserve riparian and aquatic biodiversity, but fencing by itself is not a panacea that will ensure the protection of riparian vegetation. Excluding grazing livestock through fencing can lead to problems of weed incursion which also contributes to riparian zone degradation, and careful planning and ongoing management are required to prevent this from taking place (CCG 2006). Once weeds become established in riparian zones, they are very difficult to eradicate and can also increase the risk of bushfire (CCG 2006).

The matrix of interwoven roots underlying riparian vegetation helps to bind river bank soil together allowing it to better withstand erosive stream flow. The cohesive effect of intact riparian vegetation is up to 10 times more effective at binding soil together than a denuded river bank (Thorne 1990). Sedges, rushes and other emergent plants also play a vital role in bank stabilisation as they reduce flow velocities (Troeh *et al.* 1980), thus limiting erosion during periods of high flow. This is beneficial to aquatic ecosystems as sedimentation and increased turbidity caused by erosion can degrade aquatic habitats, disrupt food webs, and affect water quality (Henley *et al*. 2000). In degraded riparian zones semi-exposed root masses of trees are commonly observed and such trees will inevitably be lost when their support structure gives way with further erosion of the river bank. Mature trees provide shade which reduces water temperature and evaporation in aquatic systems (Pen 1999; Davies *et al*. 2007). They also drop branches and logs, providing important instream habitat for native aquatic species such as Nightfish and Marron (Pen 1999). Besides this woody debris, the leafy material that falls into aquatic systems is a foundation level source of carbon that drives aquatic food webs, which is vitally important in south-western Australia where streams have naturally low primary productivity (i.e. low biomass of macrophytes, phytoplankton, etc.) (Pen 1999).

Healthy native riparian vegetation with its deep roots contributes towards keeping salt-ladened groundwater deeper underground, thereby reducing the threat of salinisation which can lead to the extirpation of native aquatic species, as has occurred on a grand scale further inland in the wheatbelt (Pen 1999; Morgan *et al*. 1998). The greater overall plant biomass of a healthy riparian zone is also capable of assimilating water more rapidly following rainfall events compared with degraded or weedy river banks (Riding & Carter 1992). Not only does this help to prevent the occurrence of bank subsidence (Thorne 1990), but it also reduces pollution of waterways through the capture and assimilation of larger quantities of sediment and nutrient ladened runoff (Knauer & Mander 1989, Pinay *et al.* 1990). In this way, riparian vegetation acts as a filter or buffer for aquatic ecosystems, a function that is particularly important in agricultural areas where nutrient inputs in the form of fertilisers and animal waste can be high.

Much work has already been done in the region by the Cape to Cape Catchments Group in carrying out fencing and revegetation projects to protect and rehabilitate riparian zones. However, work still remains to be done and it is advised that these projects continue to attract government funding and community support. From the standpoint of conserving aquatic fauna, on-ground works should focus on sites that house threatened species, particularly Burrowing Crayfishes (*Engaewa* spp.), Balston's Pygmy Perch and Western Mud Minnow. Where appropriate, such projects should not be limited to the immediate vicinity of these sites, but should also encompass any degraded sections located upstream in the catchment in order to limit the downstream flow of negative impacts into these important habitats.

4.4 Climate change

Winter rainfall in south-western Australia has decreased substantially since the middle part of last century, and especially since the 1970s, a trend that is predicted to continue (Suppiah *et al.* 2007). Rainfall and surface discharge within the Cape to Cape region has declined by around 12% during this time (DoW 2008a) and temperatures have increased (IOCI 2002). There has also been a trend of lower autumn and early winter rain and increased late winter and summer rain (IOCI 2005b). Predictions are for further rainfall reductions of 8% over the next 20 years causing a *ca* 25% reduction in runoff (Suppiah *et al.* 2007; CSIRO 2009a,b). By 2030, water demand in south-western Australia is predicted to be at the limit of supply, therefore improvements in both water use efficiency and management of water supplies are required if human demands and ecological requirements are to be met (DoW 2010). Recognising this looming water crisis, the Department of Water, Government of Western Australia, has begun taking steps to reform applicable policy and legislation (DoW 2010).

While, rainfall is predicted to decrease, winter rainfall events are predicted to be more intense thus increasing the risk of flooding, erosion and sedimentation (CSIRO 2009a, b). Drought periods and days of extreme heat are also predicted to increase which will cause higher rates of evaporation of surface water (CSIRO 2009a, b). Consequently, the amount of available refuge habitat and carrying capacity of catchments throughout the region are likely to decline. There is concern that some species may not be able to withstand the predicted climate shift and extinctions of the rarest and most vulnerable species may be difficult to avoid (IPCC 2001a, b; DEC 2008). At a minimum, localised extirpations (as opposed to complete extinctions) of species in some catchments are likely in the absence of any direct human intervention (e.g. captive breeding, translocation into refuge habitat).

The predicted combination of declining precipitation and increasing temperatures will have dire consequences for some aquatic ecosystems in the region, particularly ephemeral headwater swamps and wetlands, which are likely to cease effectively functioning as such (DEC 2008). For species that occupy these habitats (e.g. *Engaewa* spp.), the outlook is bleak. The Margaret River Burrowing Crayfish

(*E. pseudoreducta*) is already teetering on the brink of extinction due to its small geographic range, limited dispersal capability, specialised ecological requirements and small extant population (DEC 2008). These attributes combine to make it the most seriously threatened aquatic species in the Cape to Cape region (and arguably the entire south-west) and its conservation should be given top priority.

Given the marginal nature of the habitat upon which it relies, however, this task will prove difficult and costly. Options should be investigated for safeguarding wild populations *in situ* if possible. This may eventually involve augmenting declining rainfall by supplying water by truck or pipeline to sustain populations during prolonged dry spells. Another future option might be strategically targeted groundwater recharge (using treated wastewater for example) to bolster dropping water tables in critical burrowing crayfish habitats. Captive breeding of *Engaewa* spp. is another conservation initiative that could be explored. Currently three of the five *Engaewa* species in the south-west are recognised as either Critically Endangered or Endangered, but all are likely to become increasingly threatened due to climate change in the coming decades (DEC 2008). We support the recommendation outlined in the *Engaewa* Recovery Plan (DEC 2008) to trial captive breeding methods, firstly with a less threatened species (e.g. *E. similis*) in order to perfect the technique before attempting husbandry of the endangered species whose populations would be more sensitive to removal of reproductively mature individuals. In recent years, successful captive breeding programs have been undertaken collaboratively between Perth Zoo and university researchers on local threatened species including the Western Swamp Turtle and frogs of the genus *Geocrinia*. A similar project for burrowing crayfishes would expand our biological knowledge and enhance the prospect for the survival of these endangered animals tremendously.

4.5 Fire (wildfire and prescribed burning)

The impact of fire on aquatic ecosystems is a huge knowledge gap across Australia. This is surprising given the prevalence of fire in the Australian landscape, and particularly in the south-west. Native vegetation is routinely burnt on a multi-annual rotational schedule as a land management tool for reducing fuel loads and associated risk of destructive wildfires and also to stimulate native plant growth and reproduction. Despite the lack of research on the impacts of fire on aquatic ecosystems there are concerns about its impact on *Engaewa* spp., especially the highly restricted *E. pseudoreducta*. There is potential for habitat destruction through fire management activities including clearing of firebreaks and containment lines, and the use of fire retardant chemicals (Horwitz & Rogan 2003; DEC 2008).

Controversy in the Cape to Cape region over the 2011 wildfire that started as a result of a DEC managed burn has put prescribed burning practices firmly in the spotlight. The drying climatic trend means that the threat of fire and the need to manage this threat will become even more prevalent in the future. In the *Engaewa* Recovery Plan it was stated that there was an “urgent need to improve the understanding of the effects of fire on *Engaewa* spp.” (DEC 2008) but little has been done to address this knowledge gap and we contend that the same applies to other native aquatic fauna as well. Funding and support for high level research is currently being sought by researchers at Murdoch University and will hopefully be obtained so that this conspicuous knowledge gap can be addressed in the near future.

5. Conclusions and Recommendations for Actions

The Cape to Cape region is an iconic part of south-western Australia. It has an expanding population and is also one of the premier tourist destinations in the State. A large part of the region’s appeal lies in the visual amenity of its landscapes and in the biodiversity of its flora and fauna. Rivers, streams, lakes, wetlands, and subsurface aquifers support an integral component of this biodiversity and also provide our most precious natural resource, water. Presently, many aquatic ecosystems in the region are degraded, while the areas that remain near pristine face a number of serious threats that will need to be countered with strategic planning, on-ground conservation actions, monitoring, and adaptive management. Below is a list of recommendations for actions that will contribute towards protecting the aquatic biodiversity of the Cape to Cape region (see also Appendix 1).

5.1 *Engaewa* conservation

One of the most pressing conservation concerns in the Cape to Cape region is the precarious state of *Engaewa pseudoreducta*. Its Critically Endangered status, low abundance, and cryptic habits make it an extremely difficult species to work with. It is imperative though, that the habitat of the two presumed extant populations be safeguarded against current and future threats. A comprehensive population assessment would provide valuable baseline data, but this is impossible using conventional methods of digging animals out of their burrows, as it causes unacceptable damage to the habitat (DEC 2008). An investigation into the use of motion sensor and/or orthoscopic camera technology as a tool for censusing populations and studying behaviour and burrow structure may be useful.

One important aspect of *Engaewa* conservation is the depth of the water table in relation to burrowing capability. Piezometers have been installed at various *Engaewa* sites to monitor physico-chemical properties and depth fluctuation of groundwater as part of a research study (Burnham 2006) and this monitoring should continue and be expanded to encompass other *Engaewa* sites. A feasibility study of methods by which supplemental water could be delivered to these habitats, in light of the threat of a drying climate, may be worthwhile. This component is rated as a medium priority and costs are speculative.

Whilst there has been thorough survey work undertaken recently in the vicinity of the Treeton Block populations of *Engaewa pseudoreducta*, there is still a need to continue searching this area. Due to their extremely cryptic habits, absence of *Engaewa* at sites previously surveyed is not a definitive result in itself. We recommend that further opportunistic surveying of these sites take place under a range of different conditions (e.g. post burn, post flood, etc) to search for previously undetected populations.

There is also some scope to involve the community in *Engaewa* conservation, following the successful model adopted in the recent “Mussel Watch” project (see http://www.musselwatchwa.com) which used a website to present information and raise awareness of Carter’s Freshwater Mussel (*Westralunio carteri*). The site also gave the public an opportunity to report sightings allowing distributional data to be gathered by researchers. An “*Engaewa* Watch” (or “Chimney Watch” as these structures at the burrow entrances are the most likely means of detection) website could allow researchers to gather valuable leads on the whereabouts of previously unknown *Engaewa* populations.

Estimated costs

$25,000 - $50,000 /year	(monitoring of the two extant *E. pseudoreducta* population/habitats, including opportunistic surveying of sites on Treeton Block drainage line)
$2,000 + $500 /year	(website development and maintenance)
$40,000 - $60,000	(study of supplementing water to *Engaewa* habitat)

5.2 Aquatic macrofauna surveys

A thorough knowledge of the distribution of the aquatic fauna for the entire Cape to Cape region is essential in order to focus conservation efforts most effectively. At present a number of catchments have not yet been comprehensively surveyed including Turner Brook, Calgardup Brook, Wyadup Brook, Yallingup Brook, and Quinninup Brook. Of these, the top priority is Turner Brook. The Western Australian Museum houses a collection of the listed threatened species, Balston's Pygmy Perch (*Nannatherina balstoni*), captured from this system in 1962 (see Morgan *et al.* 1998). Furthermore, the rare decapod *Cherax crassimanus* has also been sampled from this catchment (Austin & Knott 1986).

Relatively few sites have been surveyed for aquatic macrofauna in Wilyabrup Brook (the region's second largest catchment). A more thorough survey of this catchment is recommended as a high priority, particularly as the vulnerable Western Mud Minnow was recorded there in 2008 (Beatty & Allen 2008). Surveys of the remaining Cape to Cape catchments are rated as a lower priority.

Baseline aquatic macrofauna surveys typically take place in spring when water levels are near their annual peak. Depending on the size of the system, between 10-20 sites are preselected for sampling at different points throughout the catchment according to ease of access, and a range of methods are used to compile an inventory of the fish, decapod crustaceans, mussels, and other aquatic macroinvertebrates. These methods include the use of nets (fyke, seine, sweep), backpack electrofishing equipment, and visual survey. Valuable data on population demographics, breeding activity, and migratory movements are also gathered. Surveys can be conducted quickly (typically one month or less from commencement of field work to completion of final report), and on a relatively small budget (typically under $12,000 per system depending on number of sites).

Estimated costs (NB - total costs, not per survey)

$40,000 - $50,000	(high priority catchments: Turner Bk and Wilyabrup Bk)
$35,000 - $50,000	(other Cape to Cape catchments)

5.3 Introduced species control/eradication

In 2010, Goldfish were successfully eradicated from artificial ponds in the Brookfield Estate subdivision in the Darch Brook catchment (tributary of Margaret River), but prior to this they had already been found downstream in the brook itself (Beatty *et al*. 2008) and may have already made their way into the Margaret River main channel. It is recommended that a comprehensive survey and control program is undertaken in this area. It is preferable to undertake control efforts during low water levels

(i.e. late summer/autumn) as fish are concentrated in refuge pools at that time. Further control efforts may be required depending on results of the initial program. Over 1,000 Goldfish were removed from Duggan's Dam in the Wilyabrup Brook catchment near Cowaramup in 2010. We recommend further control efforts at this site as it is highly likely that Goldfish remain at liberty. By using a combination of electrofishing and ichthyocide application it is likely that this this population can be eradicated in much the same way as the Brookfield Estate Goldfish populations.

Yabbies have been recorded in four catchments in the Cape to Cape region (see Figure 38). Illegally stocked private dams were the likely source of escapees into these systems. Ideally, these illegal dam populations should be eradicated to prevent further escapes, but this may prove impossible due to the likely unwillingness of landholders to empty their dams for conservation purposes. Yabbies are also extremely hardy and capable of withstanding habitat de-watering. Therefore, the most realistic course of action will be to undertake annual removal operations at known sites and attempt to limit the spread of the species this way.

Common Carp have not been re-sighted in either of their previous collection sites (i.e. Margaret River main channel and Yallingup Brook) and it is likely that self-maintaining populations have not established. This assumption can be tested during a recommended follow-up survey of Yallingup Brook (see section 5.2 above) and potentially a visual census survey of the Margaret River site, however this is a lower priority.

Estimated costs

$5,000 - $10,000 /year	(Goldfish control in Darch Bk)
$10,000 - $15,000	(Goldfish eradication in Duggans Dam, Wilyabrup Bk)
$15,000 - $20,000 /year	(Yabby control throughout the region)
$15,000 - $20,000	(Carp survey in Margaret River main channel)

5.4 Community education program

Education programs (i.e. public lectures, community workshops, school presentations) can be used to raise awareness of environmental threats, and is the most effective means available to slow down the rate of exotic species introductions. In the development of this strategic action plan, a brochure and poster highlighting the threats to the native aquatic macrofauna of the Cape to Cape region were produced (see Appendix II and III). Additionally, a public lecture was given by the authors of this report and staff from CCG visited schools throughout the Cape to Cape region to present information contained in this report. We recommend the development of a regional educational campaign with expanded coverage of the current and potential future threats to the native aquatic biodiversity, with emphasis on the impacts of introduced species. This could potentially involve the production of a short documentary film.

Estimated costs

$10,000 - $15,000	(Production and roll-out of educational materials)
$15,000 - $25,000	(Production of short documentary film)

5.5 Monitoring of conservation priority areas

The changing nature of the threatening processes identified in this report ensures that the conservation landscape in catchments of the region will also change. Adaptive and ongoing management will be required to protect aquatic biodiversity, particularly those species that are listed as threatened or endangered. It is therefore recommended that sites housing threatened species are monitored at least annually to monitor abundances and habitat condition in order to identify issues that may be impacting the species (e.g. riparian zone degradation, water quality issues, increased abundance of introduced species, incursion of new exotic species). This action has already been covered specifically for *E. pseudoreducta* under the recommendation in section 5.1, but annual monitoring of five other conservation priority areas in the Cape to Cape region are also recommended. These sites include: Wilyabrup Brook (tributary housing Western Mud Minnow); middle reaches of Margaret River (Pouched Lamprey spawning grounds/ammocoete beds); upper Margaret River (Rapids Conservation Park housing Hairy Marron, Balston's Pygmy Perch, and Western Mud Minnow); lower Margaret River (main channel around the confluence with Yalgardup Brook housing Western Mud Minnow), and; Boodjidup Brook (tributary housing Western Mud Minnow) (Figure 42).

Estimated costs

$25,000 - $50,000 /year

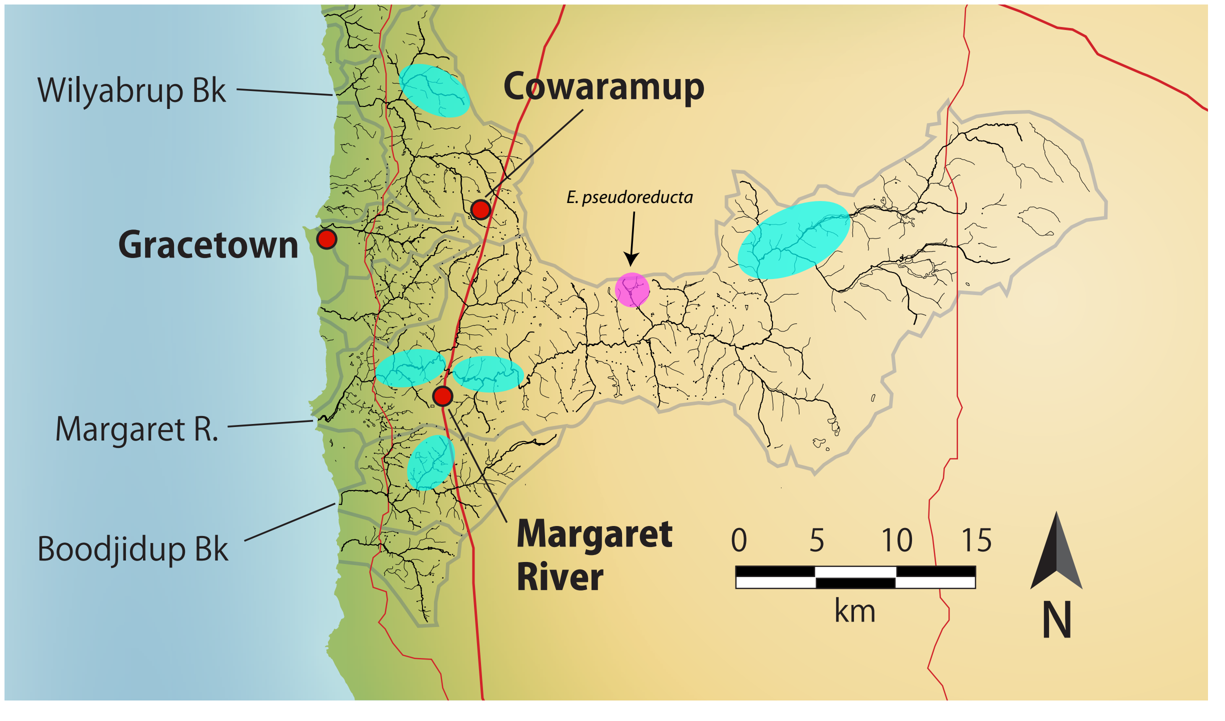

Figure 42. Conservation priority areas in the Cape to Cape region housing threatened, endangered and priority species (i.e. Hairy Marron, Margaret River Burrowing Crayfish, Balston's Pygmy Perch, Western Mud Minnow, and Pouched Lamprey).

5.6 Riparian zone fencing and revegetation

We advocate for the continuation of land care initiatives including riparian fencing and revegetation projects in accordance with the recommendations contained in the numerous regional River Action Plans. The highest priority for this work, from an aquatic biodiversity conservation perspective, includes the conservation priority sites outlined above (refer to Figure 42) that house threatened species. Any degraded riparian sections located upstream of these sites should also be considered for rehabilitation and fencing.

Estimated costs

$10,000 /ha of riparian revegetation

$9,000 /km of riparian fencing

5.7 Hairy Marron conservation

The Department of Fisheries is actively involved in a range of projects aimed at conserving the Critically Endangered Hairy Marron including a captive breeding program for supplementation of wild stocks. We recommend the continuation of this project. A recent study in the USA of supplementation of wild populations of Rainbow Trout with captive-bred fish determined that reproductive fitness was compromised in descendant generations (Araki *et al.* 2009). Consideration should be given to undertaking a similar study on reproductive fitness of wild born Hairy Marron in the upper Margaret River to ensure the captive breeding and restocking programs are achieving the desired benefits for the conservation of the species.

Until recent years the Department was involved in the controlled removal of Smooth Marron and hybrid individuals from the upper Margaret River. However, due to the difficulty of distinguishing hybrids from pure-strain Hairy Marron in the field, the project was put on hold until a more reliable method of field identification is developed (R. Duffy, pers. comm.). We recommend the resumption of the removal program once these methods are perfected.

NB - information on costing and time frame of Hairy Marron initiatives is not available.

5.8 Regional review of instream barriers

A process for identifying and prioritising instream barriers for removal to restore natural hydrology and increase stream connectivity is currently being developed for southern Australia. The primary objective of this research is the development of a protocol for cataloguing barriers, and assessing their current level of utility/redundancy and the potential ecological benefit of remedial works (i.e. removal or modification of barrier; installation of a fishway structure).

In south-western Australia, this project relies heavily on a GIS database of instream barriers maintained by the Department of Water, however ground truthing of the protocol will also be required to ensure the accuracy of desktop assessment. The process that is developed is planned to be applied in catchments that house threatened species throughout southern Australia, including the Cape to Cape region (e.g. Margaret River, Wilyabrup Brook, and Boodjidup Brook). Part of this work will involve validating GIS information on instream barrier locations by aerial survey. Current knowledge of aquatic fauna inhabiting these catchments will then be used to help prioritise barriers for further investigation as to their level of redundancy. This will facilitate the compilation of a prioritised list of barriers for which remedial action (including removal) will best improve ecological function and conservation outcomes.

At this stage, the exact costs of running the process (including aerial and/or ground-truthing) are specuative, pending the results of a cost-benefit analysis.

Estimated costs (NB - total costs, not per catchment)

$50,000 - $80,000	(assessment of Cape to Cape catchments with conservation priority sites)
$50,000 - $75,000	(additional major catchments in the Cape to Cape region)

5.9 Aquatic refuge mapping and assessment

A thorough review of remote imagery, data and expert input from the Department of Water, and on-ground/aerial validation is recommended to map and assess permanent refuge pool habitats. It is imperative that permanent water habitats (both natural and artificial) are mapped and hydrologically assessed to ascertain whether they will provide adequate refuge habitat for sustaining native fauna populations under a range of future climate scenarios. This will allow for planning of potential methods of human intervention (e.g. creation of artificial refuge pools, captive breeding programs) for ensuring the conservation of native species in some catchments. This work is important given climate change predictions in south-western Australia.

Catchments housing listed threatened species (including Margaret River) are the top priority for assessment. As these catchments are also prioritised for instream barrier assessment (see above recommendation), the two projects could overlap considerably in terms of timing and execution of validation activities. This project will contribute towards achieving the eventual aim of compiling a comprehensive database of dry season refuges for all catchments in the broader south-west region.

Assessing only the Cape to Cape region, the time frame for completion of the initial phase of this project (i.e. refuge pools in Margaret River, Wilyabrup Brook, and Boodjidup Brook), would be 18 months with an estimated budget of around $80,000. An expanded coverage of all catchments in the Cape to Cape region would require the allocation of time and funding to be at least doubled.

Estimated costs (NB - total costs, not per catchment)

$70,000 - $90,000	(assessment of Cape to Cape catchments with conservation priority sites)
$40,000 - $50,000	(additional major catchments in the Cape to Cape region)

5.10 Hairy Marron refuge 'arks'

Lawrence *et al.* (2010) proposed that that dams should be investigated for their potential utilisation as refuge 'arks' for maintaining Hairy Marron stocks in isolation from Smooth Marron. The recent project carried out by CCG and Department of Fisheries that located what appeared to be a pure-strain Hairy Marron specimen in a private farm dam that was in fact a hybrid highlights the need for strict quarantine measures to be imposed in any such project. A scoping study including feasibility trials could explore the conservation merit of this proposal. It is recommended that Department of Fisheries oversee any such project with the possibility of involving CCG or other groups in the education of participating land holders on maintenance of populations, and the carrying out of monitoring activities.

Estimated costs

$25,000 - $50,000 (Scoping study of the use of dams as refuge 'arks')

5.11 Fish Habitat Protection Area (FHPA) nominations for critical habitats

There is a provision in State Legislation under the *Fish Resources Management Act 1994* for the creation of fish habitat protection areas (FHPAs). Section 115 of the Act states FHPAs can be created for various purposes including "...the conservation and protection of fish, fish breeding areas, fish fossils or the aquatic eco-system." We recommend the designation of two such areas in the Cape to Cape region: 1) upper Margaret River, upstream and inclusive of Canebrake Pool (Figure 43), and; 2) the ephemeral headwaters of the unnamed tributary of Margaret River that arises in Treeton Forest Block.

The former is the only known location of the Critically Endangered Hairy Marron, and also houses the Vulnerable Balston's Pygmy Perch and Western Mud Minnow thus representing an ideal FHPA for the purpose of conservation and protection of listed threatened aquatic species. Note, this part of the Margaret River catchment already lies within the DEC managed Rapids Conservation Park, however, fish (including decapod crustaceans) and aquatic ecosystems fall under the jurisdiction of the Department of Fisheries, therefore the creation of an FHPA in this stretch of river is entirely appropriate and justified. The latter site (i.e. Treeton Block drainage line) houses the only extant populations of the Critically Endangered Margaret River Burrowing Crayfish in the Cape to Cape region and is also a worthy area for designation as an FHPA, especially considering that it is not presently located inside an official Conservation Estate.

While it might be argued that the creation of an FHPA in the upper Margaret River is a form of conservation redundancy, we argue that it is worthwhile as it will raise awareness of the conservation significance of this site and, hopefully, facilitate greater funding opportunities to carry out the recommendations outlined in this action plan. Furthermore, if the creation of FHPAs at these sites is granted by the Minister they will, significantly, be the first freshwater FHPAs in Western Australia.

Estimated Costs

$3,000 - $5,000

Figure 43. Upper Margaret River near Canebrake Pool. This stretch of river houses a number of threatened and endangered aquatic species including the Hairy Marron. We recommend that it be nominated for listing as a Fish Habitat Protection Area. (photo: R. Jurjevich).

5.12 River action plans

CCG has published nine separate river action plan reports in the past 13 years and a tenth covering Quinninup Brook is currently in preparation. However, there are a number of drainage basins in the region that are not covered. The riparian foreshore assessment surveys that form the basis of these documents are vital in providing a snapshot of overall catchment health as well as involving private land holders in land care initiatives and, at the same time, educating them about the issues affecting their streams. The recommendations for on-ground works contained in these action plans provide the necessary focus to most efficiently utilise time, funding and volunteer resources to best tackle the most crucial issues identified.

The catchments requiring a river action plan in order of priority are Turner Brook, Calgardup Brook, and Wyadup Brook. Note, these are mostly the same catchments that have not yet been surveyed for aquatic macrofauna (see 5.2 above). Information contained in aquatic macrofauna survey reports will provide valuable scientific input to complement these river action plans.

River action plans typically require between 6-12 months to complete (from planning and initial landholder approach to publication of final report) and a budget of between $15,000 - $35,000 per catchment depending on size.

Estimated costs (NB - total costs, not per action plan)

$60,000 - $70,000 (development of action plans for Turner Bk, Calgardup Bk, and Wyadup Bk).

5.13 Captive breeding of *Engaewa*

This is a project that was recommended in the *Engaewa* Recovery Plan (DEC 2008) and could be investigated further into the future if the concept outlined in recommendation 5.1 for providing supplemental groundwater to habitats is found to be impracticable. The Perth Zoo, working in collaboration with university researchers has a proven history of running successful captive breeding programs for threatened species, both terrestrial (e.g. Numbat) and aquatic (e.g. Western Swamp Turtle). Recently, another program involving captive breeding of Critically Endangered frogs of the genus *Geocrinia* has proven successful as well.

Due to the Critically Endangered status of *E. pseudoreducta*, captive maintenance and husbandry techniques should first be trialled using a more common but closely related species such as *E. similis*. This species shares the same habitat as *Geocrinia*, so an *Engaewa* captive breeding program could stand to benefit from the knowledge already gained in maintaining these frogs in captivity. If successful the methods could then be used to maintain a captive stock of *E. pseudoreducta*, as a safeguard measure against a catastrophic loss of wild populations.

A captive breeding project would require a large commitment of finances and human resources. Such a project would likely need to be ongoing as it is likely that the conservation status will become more precarious in the future with climate change. Maintenance of a captive stock may be the only means by which the extinction of this species is prevented.

NB - Annual costing estimates are not available.

5.14 Regional surveys of seasonal wetlands

There are few records of burrowing decapod crustaceans in recent aquatic macrofauna surveys as seasonal wetlands, their preferred habitat, are not typically sampled. There are at least four *Cherax* species that utilise ephemeral habitats: *C. quinquecarinatus*, *C. crassimanus*; *C. preissii*, and; *C. glaber*. Targeted surveys in seasonally inundated habitats would address the shortfall in our knowledge of the distributions of these species, facilitating a more accurate appraisal of their conservation status.

Estimated costs

$25,000 - $50,000

5.15 Impacts of fire on aquatic ecosystems

Considering the prevalence of fire in the south-western Australian landscape it is odd that its impact on aquatic ecosystems has remained unresearched. Fire, and particularly prescribed burning, is a highly relevant topic in the Cape to Cape region following the devastating 2011 Margaret River bushfire. Additionally, climate change forecasts are for drier and hotter weather conditions conducive to more frequent and intense fires. It is recommended therefore that research on this topic commences.

The focus of research should quantify the impact on water quality of ash fall and run-off following fire, and determine any post-fire changes in aquatic communities (both invertebrates and vertebrates). Ecotoxicity of fire retardant chemicals on native aquatic fauna is also worthy of investigation. This is a particular concern where the use of these chemicals occurs in areas known to house threatened aquatic species.

A secondary focus of research that overlaps with the recommendation for refuge mapping and assessment (section 5.9 above) is an investigation of the efficacy of human-made water points as dry season fish refuges as there is evidence that native aquatic fauna, including listed threatened species, readily utilise such habitats. In a drying climate, it seems likely that water for fire management activities will come under increasing demand. The creation of additional artificial water points may be one way of meeting this increased demand. If expert scientific advice is used to guide the design and geographical placement of new water points for the optimal benefit of aquatic fauna (as dry season refuges), this could provide a positive outcome for both biodiversity conservation and fire management in the region.

This project would require the support and collaboration of the Department of Environment and Conservation, Government of Western Australia. The time frame for completion would be 12-18 months.

Estimated costs

$40,000 - $80,000

5.16 Impacts of sedimentation and summer pumping on river pools

Sedimentation has been consistently raised as an issue of concern in the River Action Plan documents produced for catchments in the Cape to Cape region. Additionally, the pumping of water during the summer/autumn months in catchments such as the Margaret River is another issue that has been raised as potentially having an impact on refuge pools. Research into these two issues are having would be prudent in firstly assessing the extent of the problem, and secondly, determining measures that need to be taken to mitigate the impacts.

Estimated costs

$40,000 - $60,000

5.17 Baseline assessment of freshwater mussels in upper Margaret River

This stretch of river houses the highest known densities of Carter's Freshwater Mussel (M. Klunzinger pers. comm.). As part of a research project on the conservation status of the species, it would be valuable to conduct a detailed survey and demographic analysis of this robust population to use as a surrogate baseline for a distribution-wide study where many populations have been found to be in severe decline or are highly skewed demographically.

Estimated costs

$15,000 - $20,000

5.18 Wardandi language names and cultural significance of aquatic biodiversity

Although ranked as a low priority from a biodiversity conservation perspective, a collaborative project between linguists and Wardandi traditional owners to record indigenous names and stories of the native aquatic biodiversity would have significant cultural and social value. Similar studies have been undertaken by Morgan *et al*. (2004b, 2006) in the Kimberley and Pilbara regions of Western Australia.

Estimated cost

$2,000 - $5,000

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Appendix I - List of recommended conservation actions

Code	Action	Approximate cost	Time required for completion
Comm	Development of "*Engaewa* chimney watch" website	$2K + $500 /yr	2 months + ongoing upkeep
Comm	Production of introduced species materials and regional education campaign	$10-15K	6-12 months
Comm	Production of short documentary film (threats and feral species)	$15-25k	6-12 months
Comm	Traditional Nyoongar names for aquatic biodiversity project	$10-20K	12-18 months
Man Act	Goldfish control in Darch Brook and confluence with Margaret River	$5-10K /year	1 week /year (ongoing)
Man Act	Goldfish eradication in Duggans Dam (Cowaramup)	$10-15K	1 month
Man Act	Yabby control at known sites	$15-20K /year	1 week /year (ongoing)
Man Act	Fencing and rehabilitation of riparian zones in priority conservation areas	to be determined	12-18 months
Man Act	Fencing and rehabilitation of riparian zones elsewhere (as prioritised in RAPs)	to be determined	several years
Man Act	* Resumption of Smooth/hybrid Marron removal from upper Margaret River	---	ongoing
Man Act	* Captive breeding/restocking of Hairy Marron (DoF)	---	ongoing
Man Act	Fish Habitat Protection Area nomination for highest conservation value areas	$3-5K	1-2 months
Man Act	Aquatic macrofauna survey of Turner Brook	$20-25K	1 month
Mon	*Engaewa pseudoreducta* surveys and habitat monitoring	$25-50K /year	1-2 weeks /year (ongoing)
Mon	Aquatic macrofauna survey of Turner Brook	$20-25K	1 month
Mon	Expanded aquatic macrofauna survey of Wilyabrup Brook	$20-25K	1 month
Mon	Annual monitoring of conservation priority areas	$25-50K /year	1-2 weeks /year (ongoing)
Mon	Aquatic macrofauna survey of Quinninup, Wyadup & Yallingup Bk	$25-35K	1 month
Mon	Aquatic macrofauna survey of Calgardup Brook	$10-15K	1 month
Mon	Carp survey of Margaret River (near town)	$15-20K	1 month
Mon	Regional surveys of seasonal wetland habitats	$25-50K	4 months

Continued on next page....

Appendix I (cont.) - List of recommended conservation actions

Code	Action	Approximate cost	Time required for completion
Planning	Action plan assessment of Turner Brook	$30-$35K	6-12 months
Planning	Action plan assessment of Calgardup Brook	$15-20K	6-12 months
Planning	Action plan assessment of Wyadup Brook	$15K	6-12 months
Research	Barrier assessment (high priority catchments - MR, WB, BB)	$50-80K	12-18 months
Research	Aquatic refuge assessment (high priority catchments - MR, WB, BB)	$70-90K	12-18 months
Research	Hairy Marron dam surveys and scoping study of establishment of refuge 'arks'	$25-50K	6-12 months
Research	Scoping study of supplementing water to *Engaewa pseudoreducta* habitats	$40-60K	12-36 months
Research	Investigate captive breeding of *Engaewa*	unknown	12-24 months
Research	Barrier assessment (remaining regional catchments)	$50-75K	12-18 months
Research	Aquatic refuge assessment (remaining regional catchments)	$40-50K	12-18 months
Research	Research on the impact of fire on aquatic ecosystems	$40-80K	12-18 months
Research	Assessment of population demographics of mussels in upper Margaret R.	$15-20K	1 month
Research	Assessment of the impact of sedimentation and summer pumping on river pools	$40-60K	18-36 months

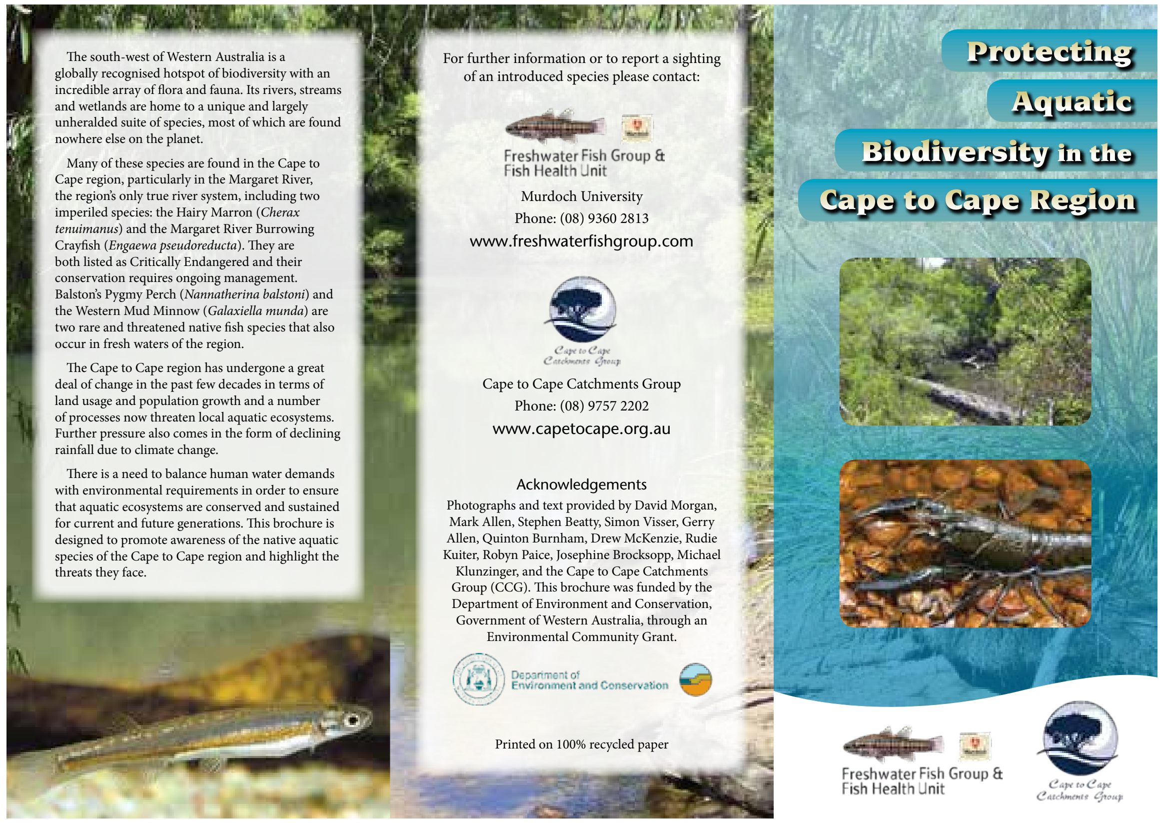
* Hairy Marron conservation actions are already underway, under the stewardship of Department of Fisheries (information on costing and time frame of these projects was not available).

Action Codes

Comm - Community engagement or Awareness raising activity
Man Act - Implementation of on ground management action
Mon - Monitoring or specific survey work generally following on from previous studies
Planning- Preparation of plans to guide future on ground actions
Research - Research or broad study

DISCLAIMER - All costing estimates are based on standard consulting rates as of October 2012. The presented costs may vary depending on a range of factors including inflation, source of funding, project specific in-kind contributions, etc.

Appendix II - Protecting aquatic biodiversity in the Cape to Cape region brochure



The south-west of Western Australia is a globally recognised hotspot of biodiversity with an incredible array of flora and fauna. Its rivers, streams and wetlands are home to a unique and largely unheralded suite of species, most of which are found nowhere else on the planet.

Many of these species are found in the Cape to Cape region, particularly in the Margaret River, the region's only true river system, including two imperiled species: the Hairy Marron (*Cherax tenuimanus*) and the Margaret River Burrowing Crayfish (*Engaewa pseudoreducta*). They are both listed as Critically Endangered and their conservation requires ongoing management. Balston's Pygmy Perch (*Nannatherina balstoni*) and the Western Mud Minnow (*Galaxiella munda*) are two rare and threatened native fish species that also occur in fresh waters of the region.

The Cape to Cape region has undergone a great deal of change in the past few decades in terms of land usage and population growth and a number of processes now threaten local aquatic ecosystems. Further pressure also comes in the form of declining rainfall due to climate change.

There is a need to balance human water demands with environmental requirements in order to ensure that aquatic ecosystems are conserved and sustained for current and future generations. This brochure is designed to promote awareness of the native aquatic species of the Cape to Cape region and highlight the threats they face.

For further information or to report a sighting of an introduced species please contact:

Freshwater Fish Group & Fish Health Unit
Murdoch University
Phone: (08) 9360 2813
www.freshwaterfishgroup.com

Cape to Cape Catchments Group
Phone: (08) 9757 2202
www.capetocape.org.au

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Department of Environment and Conservation

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Protecting Aquatic Biodiversity in the Cape to Cape Region

Freshwater Fish Group & Fish Health Unit

Cape to Cape Catchments Group

THREATS TO THE AQUATIC FAUNA OF THE CAPE TO CAPE REGION

Introduced species compete with (and consume) native species, they harbour introduced parasites and diseases, and contribute to declining habitat and water quality. Releasing exotic species into the wild is illegal and any sightings or captures should be reported to the Freshwater Fish Group (see back page of brochure for contact details) or FishWatch: 1800 815 507.

Instream barriers and water extraction cause reductions and delays in stream flows which are vital triggers for breeding, and also prevent access to suitable feeding and spawning habitats for migrating species. Fishways are staircase-like structures that can be installed to allow some aquatic species to bypass barriers. There are three fishways in the Cape to Cape region (two are pictured above).

Concept drawing of a bypass channel fishway design around an instream dam (CCG)

Poaching threatens the critically endangered Hairy Marron (above left) as does the widespread introduction of **Smooth Marron** (above right) which competes for food and habitat and is responsible for the genetic dilution of Hairy Marron stocks through hybridisation.

Degradation and destruction of riparian vegetation reduces food supply, instream habitat, and shading of waterways. Healthy riparian vegetation is vital in maintaining aquatic ecosystem health, preventing erosion and providing a buffer zone for capturing nutrients that can pollute waterways. A highly effective way of protecting or enhancing the recovery of riparian vegetation is by fencing off streams from livestock.

Climate change has already been felt in the form of declining rainfall throughout the region since the mid-1970s. This trend is predicted to continue which is likely to result in streams becoming more seasonal. Aquatic fauna will be more vulnerable to localised extinctions as a result.

CAPE TO CAPE CATCHMENTS

Appendix III - Aquatic Fauna of the Cape to Cape Region poster