Conserving freshwater fish in south-west Western Australia

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Conserving freshwater fish in south-west Western Australia

Over the last few decades, there has been a growing body of evidence that has suggested that the inland fish fauna of the Southwestern Province of Western Australia is declining.

Since the turn of the Century, two of the region's freshwater fish species have been listed under the Federal Government's Environment and Biodiversity Conservation Act (EPBC Act 1999); one laying claim to being Australia's first *CRITICALLY ENDANGERED* freshwater fish, the Western Trout Minnow (*Galaxias truttaceus hesperius*), which was listed in 2006. The other species, also listed in 2006 as *VULNERABLE*, is Balston's Pygmy Perch (*Nannatherina balstoni*), a rare species with a restricted distribution.

Surprisingly, in 2013, the significant discovery of a previously undetected fish species was made. , the Little Pygmy Perch (*Nannoperca pygmaea*). This species was only known from a single river system and, at the time of its discovery, was regarded as one of Australia's rarest freshwater fishes.

The Southwestern Province has the highest proportion of endemic fishes on the continent, and in 2012 as an initiative of the Western Australian Government's State Natural Resource Manangement Program, with joint funding from the Western Australian and Austalian Governments, a project arose that aimed to gather the information required to conserve these unique species.

The project partners include the Department of Fisheries, Murdoch University (Freshwater Fish Group & Fish Health Unit), University of Western Ausralia (Centre of Excellence in Natural Resource Management), Department of Water, Department of Parks and Wildlife, South West Catchments Council, South Coast NRM, Blackwood Basin Group, Denmark Environment Centre and the communities of south west Western Australia.

Conserving freshwater fish in south-west Western Australia:

A summary of distribution, migration, critical habitats and threats to the region's most endangered freshwater fishes

A report for the State Natural Resource Management Office, Western Australia.

Project No. 12035

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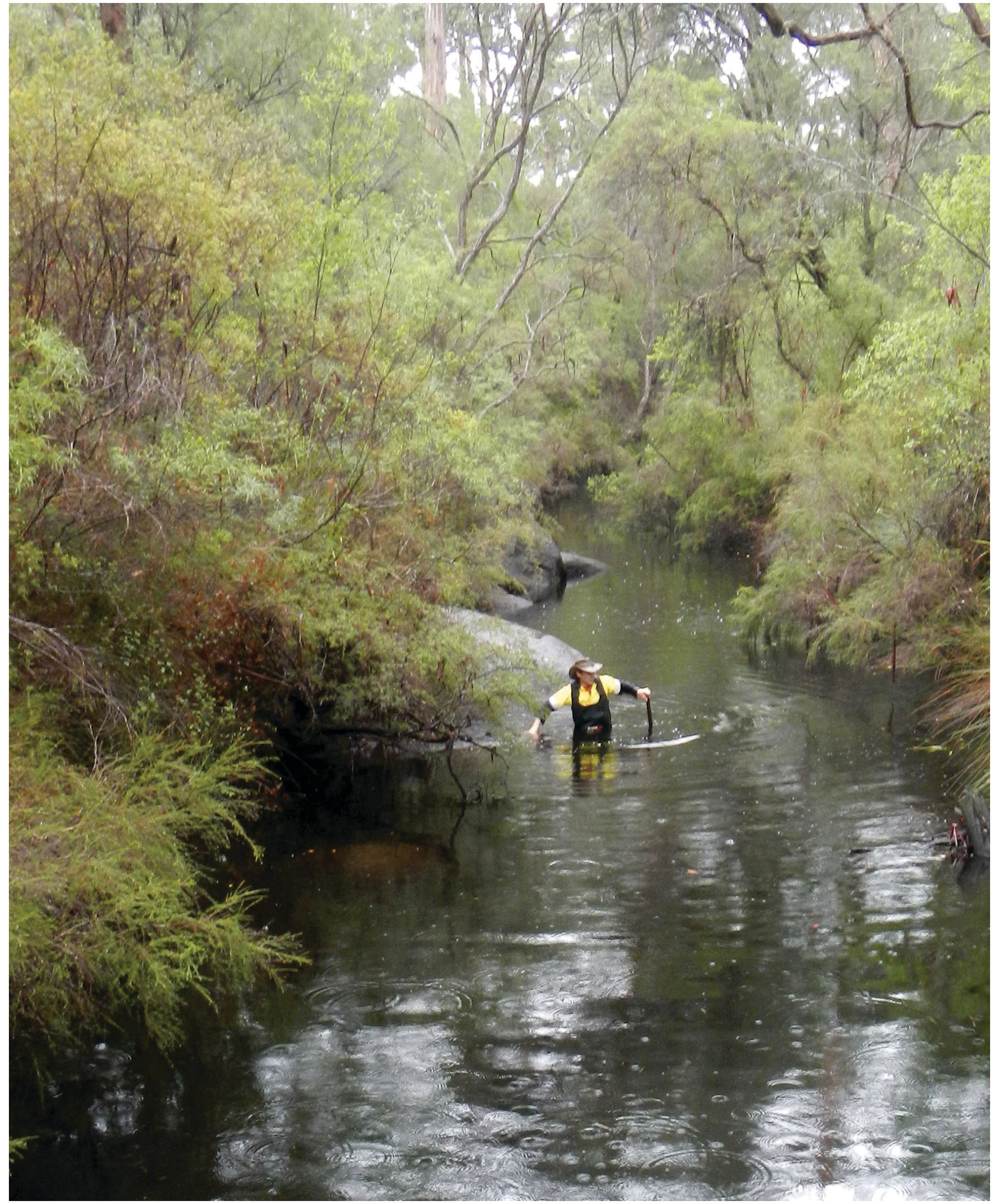

Foreword

The south-west of Western Australia has the highest proportion of endemic freshwater fishes in the continent, with over 80% found nowhere else. The need to conserve these unique species has driven this project, which represents one of the largest ever undertaken on freshwater fishes in this region. Based on newly established and existing collaborations between researchers, managers and community, this three year project has provided exciting new information and knowledge relating to the distribution and ecology of three of the regions most endangered freshwater fishes: Western Trout Minnow, Balston's Pygmy Perch and Little Pygmy Perch.

This report presents the key findings of the research including up-to-date species distributions and new knowledge of the critical processes and requirements that support viable populations, such as migration, critical habitat, spawning and recruitment.

The south-west faces a number of future challenges, including climate and land use changes that directly impact on river ecosystems and their fauna. The compilation of knowledge presented here, provides new opportunities to manage and prepare for these challenges. It also highlights the value and need for continued monitoring, research and management of freshwater ecosystems in this unique corner of Australia.

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THE UNIVERSITY OF WESTERN AUSTRALIA

Fishes of Australia's Southwestern Province

The Southwestern Province of Australia encompasses all of the inland water bodies between the Arrowsmith River (south of Dongara) and the Thomas River (to the east of Esperance). It is one of Western Australia's five ichthyological provinces and is one of the most unique on the continent. Over 80% of the freshwater fish species in this region are found nowhere else in the world, and the fauna includes some species of global significance.

The Salamanderfish is one of the world's most unusual fishes and is the sole representative of an early divergent lineage within teleost evolution, with estimates putting its mean age of divergence at about 230 million years ago. Recent studies have also suggested that Freshwater Cobbler, the largest native freshwater fish in the south west, has been incorrectly placed in the genus *Tandanus*, and actually represents an undescribed genus which is one of the earliest branching lineages of the freshwater eel-tailed catfishes. These two species represent unusual and ancient lineages that have persisted in the Southwestern Province and represent legacies in the evolution of Australia's unique freshwater fauna (see Unmack 2013; Morgan *et al*. 2014).

Most of the other species in the Southwestern Province have very old relationships with the eastern Australian fauna that were severed following the formation of the Nullarbor Plain and through increasing aridity of the continent. These include seven endemic species of the Percichthyidae (including *Bostockia* and *Nannatherina*), some of which represent undescribed species, as well as five species of the Galaxiidae, three of which are endemic to the region.

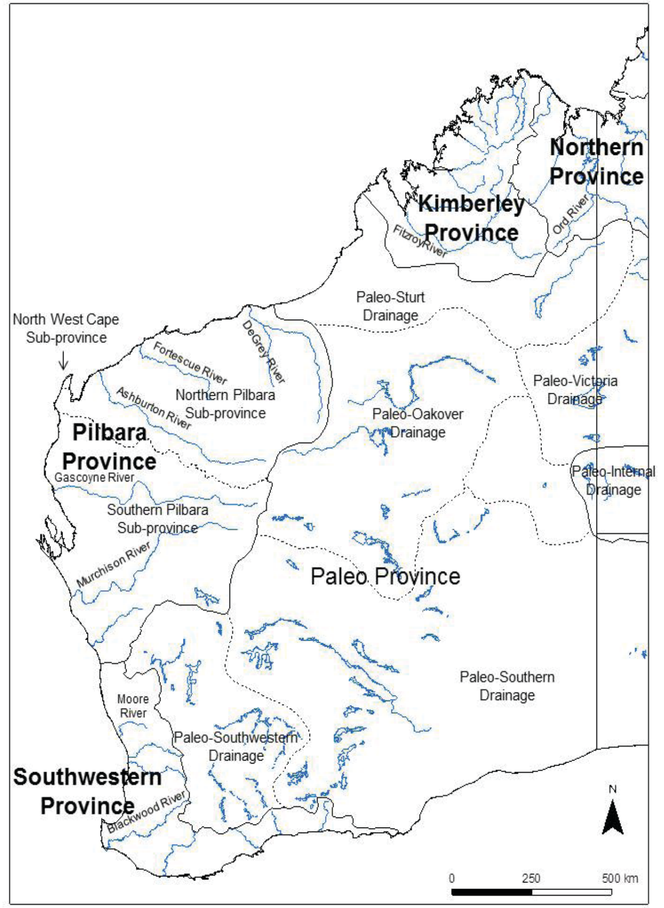
Unfortunately, a number of these species are now threatened and populations are declining in both abundance and distribution, principally due to declining water quality (particularly secondary salinisation), loss of habitat (large scale land clearing), water extraction, river regulation and threats from introduced species. More recently, climate change has become a significant threat to the aquatic fauna of south-west Western Australia with significant declines in rainfall, surface flow and fresh groundwater occuring across the region since the mid-1970s.

The need for conservation

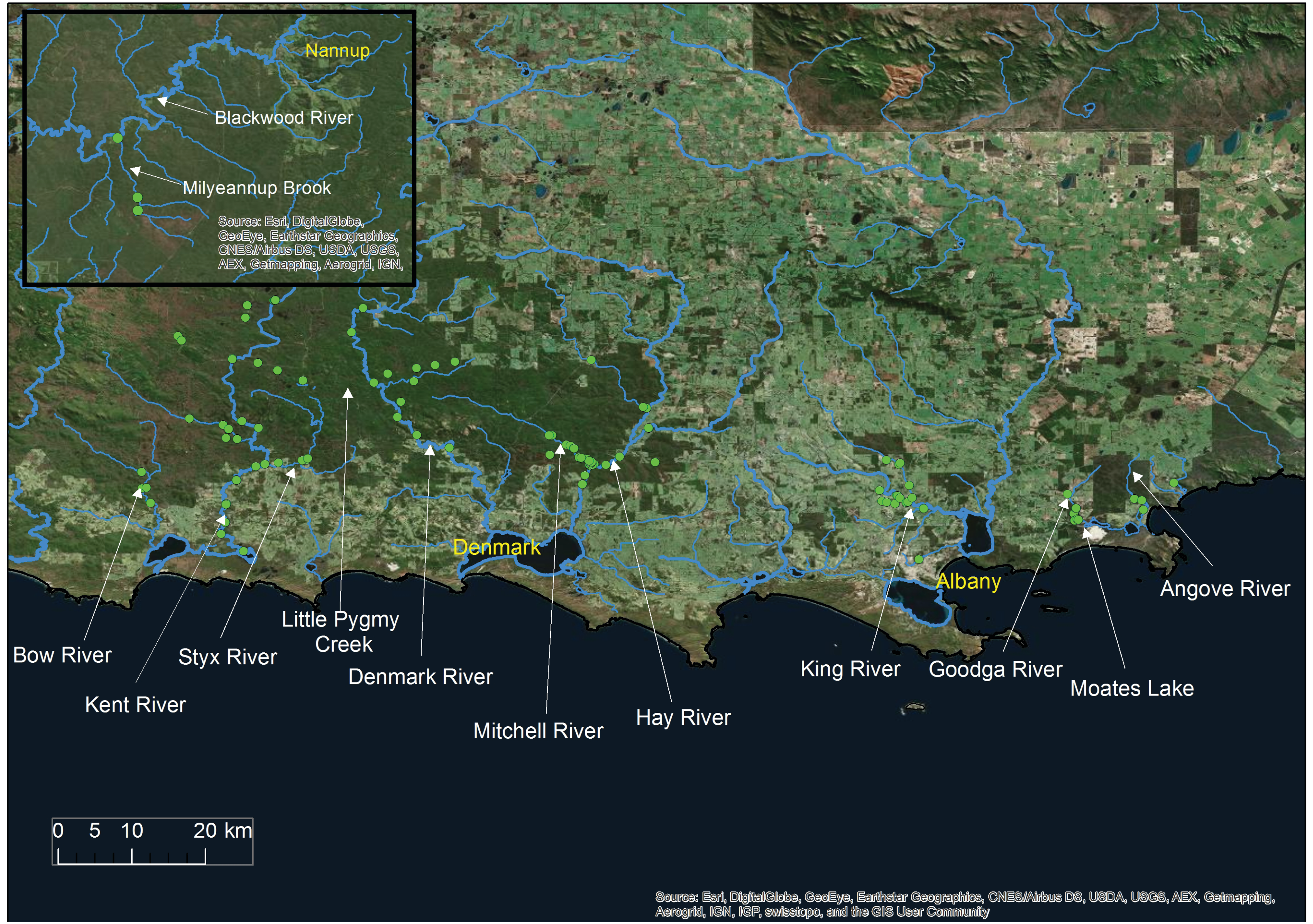
While there has been an increase in our understanding of the ecology and threats faced by this unique fauna, critical knowledge gaps remain. This has hampered the development and implementation of management strategies to conserve and protect these important populations and the habitats critical for their survival.

In 2012, the Western Australian Government's State NRM funded this three year project in response to a need for field-based knowledge on the distribution and ecology of three of the region's most endangered freshwater fishes: Western Trout Minnow, Balston's Pygmy Perch and Little Pygmy Perch.

All three species are considered threatened; however, fundamental knowledge of their biology, ecology and the processes that threaten their sustainability are poorly understood. Both the Western Trout Minnow and Balston's Pygmy Perch have experienced significant declines in distribution and possibly abundance, whilst very little is known about the recently discovered Little Pygmy Perch, a species that was only formally described in 2013.



The ichthyological provinces of Western Australia (after Unmack 2013 and Morgan *et al*. 2014)



Sites (>150) and major waterbodies in which sampling was undertaken between 2013 and 2015. N.B. Numerous sites to the west were also sampled.

Major aims

This study was designed to assist in the conservation of south-west Western Australia's rarest freshwater fishes by gathering detailed ecological information on the current distribution, migration patterns, and habitats critical to the survival of each species. This information is crucial for prioritising, developing and implementing appropriate management arrangements to protect these rare species and their habitats. An example of one of the key management objectives of this study was the undertaking of a comprehensive assessment of the conservation status of the Little Pygmy Perch.

Together with new information on ecology, we aimed to identify the key risks to the sustainability of populations. This information will guide the development and prioritisation of rehabilitation, restoration and ecosystem management projects to protect, maintain or improve river and wetland habitats for fishes.

This project addresses five key objectives for each of the three threatened species:

- Determine the distribution, migration patterns, critical spawning habitats.
- Identify critical habitats that sustain populations over the summer period.
- Assess the risks to the ongoing sustainability of populations.
- Implement management arrangements for the protection of populations and preservation of critical habitats.
- Increase community engagement and awareness.

The study area

The fieldwork component of this study surveyed fishes across the south-west and south coast regions of Western Australia. Sampling was undertaken throughout a large proportion of the known historical range of the species, extending from catchments immediately south of Perth to Two Peoples Bay, near Albany. More intensive fieldwork, designed to gather new ecological knowledge for each species, was undertaken in specific catchments including the Kent, Goodga and Angove rivers for the Western Trout Minnow; Milyeannup Brook, the Blackwood, Hay and Mitchell rivers for Balston's Pygmy Perch, and; the Mitchell, Hay, Denmark and Kent rivers for the Little Pygmy Perch.

The region has a Mediterranean climate with hot, dry summers, and most rainfall occurring in winter. A strong climatic gradient exists across the region with highest rainfall occurring around the south-west corner. Rainfall decreases in both a northerly and easterly direction. The region includes rivers that drain large inland catchments, and much smaller systems that drain the coastal margin. While many rivers in south-western Australia cease to flow during the annual dry period, groundwater has a major influence upon most river systems, by i) maintaining permanent water pools in rivers that cease to flow over summer, or ii) being primarily responsible for sustaining permanent river flow during the summer.

Western Trout Minnow - Australia's first *Critically Endangered* freshwater fish

In 2006, the Western Trout Minnow (*Galaxias truttaceus hesperius*) was the first freshwater fish in Australia to be listed as Critically Endangered under the *Environmental Protection and Biodiversity Conservation* (EPBC) Act 1999. This was due to the loss of this species from the King and Kalgan Rivers between 1981-1994, with the remaining populations in Western Australia restricted to very small sections of the Goodga (4km) and Angove (2km) rivers (McDowall & Frankenberg, 1981; Morgan *et al*., 1998). In 2010 Western Trout Minnow were discovered in a small section of the Kent River (Coleman 2010).

Of the three species investigated in this study, the biology of the Western Trout Minnow is relatively well understood. It is a migratory fish; however, unlike populations in eastern Australia that migrate between fresh water and the sea, Western Australian populations are effectively landlocked as they are confined to river systems that only rarely connect to the sea. Instead, they migrate between riverine habitats and freshwater lakes located in the lower reaches of these catchments. Two out of the three known populations are impacted by human-made structures (i.e. weirs) that impede migratory pathways. Prior to the construction of a vertical-slot fishway in 2003, Western Trout Minnow were not found above the weir on the Goodga River, but have since colonised upstream habitats. On the nearby Angove River, multiple weirs exist in the mid-reaches, associated with hydrographic gauging and water resource development. Despite the successes in the Goodga River, no fishways have yet been constructed in the Angove, and consequently, Western Trout Minnow in this system are currently restricted to approximately 2km of riverine habitat between Angove Lake and the lower-most weir.

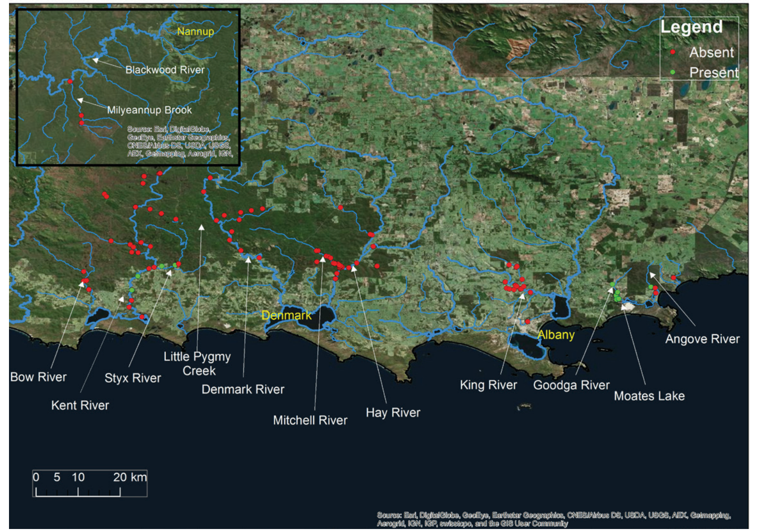
The Kent River population was only known from the collection of five individuals from the lower reaches of the catchment near Owingup Swamp. A recovery plan for this species was developed in 2008, which provided 12 recovery actions to "abate the identified threats to the Western Trout Minnow, and maintain or enhance *in situ* populations and distribution to ensure the long-term preservation of the subspecies in the wild". Of these 12 recovery actions, this project specifically addressed the following eight:

1. Define and map critical habitat and survey for additional populations.
2. Implement a monitoring program for the known populations.
3. Research the cause of the deaths of the fish from the drop-off of the Goodga River Gauging Station.
4. Investigate and implement measures to facilitate upstream movement of the Angove suite population.
5. Obtain biological and ecological information for the separate populations.
6. Investigate the potential for *ex situ* populations.
7. Investigate tolerances to factors such as water temperature, salinity, turbidity and nutrients.
8. Promote awareness of threatened species.

The Goodga River Fishway (above), and the Angove Weir (below)

Distribution

Historically, the Western Trout Minnow has been recorded from the King, Kalgan and Goodga Rivers near Albany in south west Western Australia (Morgan *et al*. 1998). Currently, populations are known from three locations: the Goodga River extending into Moates Lake (Goodga suite), the Angove River extending into Angove Lake (Angove suite), and the Kent River extending into Owingup Swamp. The Goodga population is restricted to a 4 km stretch (~0.008 km^2) of the Goodga River, Moates Lake and Black Cat Creek. The Angove population is found along a 2km stretch of Angove River downstream of a gauging station (weir), and in Angove Lake, an area of approximately 0.004 km^2. The population in the Kent River is only known from the opportunistic collection of five specimens in 2005 from a private property in the lower Kent River (Coleman 2010). The available habitat for this population has been estimated to be 0.001 km^2.



Current known distribution of the Western Trout Minnow (green) based on the sampling of >150 sites during the study

This project has confirmed the existing known distribution of Western Trout Minnow in both the Goodga and Angove rivers and expanded the distribution in the Kent River to cover an area between Owingup Swamp and the Styx River, including both main channel and tributary habitats. Despite substantial survey effort in neighbouring catchments including the Bow, Denmark, Mitchell/Hay, King and Normans rivers, no additional populations of the species were discovered.

The distribution and abundance of Western Trout Minnow in the Goodga and Angove rivers was monitored at weekly or fortnightly intervals during the spring of 2013 and 2014 and the summer and autumn of 2014-15. Abundance in each catchment increased during spring and autumn, attributable to the recruitment of juvenile fish and increased activity of adults (and therefore catchability) respectively. A distinct peak in abundance of adult fish was recorded in the lower reaches of the Goodga River and in the site located in the lower reaches of the Angove River catchment during the 2015 spawning season (May-June).

Migration patterns

In Western Australia, the Western Trout Minnow is landlocked and completes its life-cycle by moving between the river and its associated coastal lake at various stages throughout its life. For example, within the Goodga River, adults reside in river habitats and spawn during autumn. Larvae subsequently drift downstream to the freshwater Moates Lake where they grow for approximately four months before undertaking an upstream recruitment migration in spring and early-summer.

The current knowledge of migration was derived from the initial work of Morgan (2003) on the Goodga River population. This component of the project aimed to determine: i) whether the coastal lakes also provided critical nursery habitats for the Western Trout Minnow populations in the Angove and Kent rivers, and; ii) to determine if specific environmental conditions could be identified as cues for both the downstream drift of larvae and the upstream migration of juveniles.

Plankton sampling was undertaken during May-June 2014 in both Angove Lake (Angove River) and Owingup Swamp (Kent River) for the presence of larvae. Both waterbodies are large and difficult to access; plankton samples were collected by towing a plankton net behind a small canoe. While sampling did not detect larvae of Western Trout Minnow in Angove Lake, one specimen was collected from Owingup Swamp.

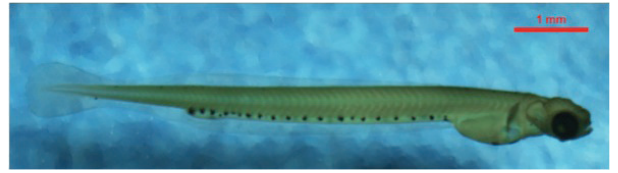
High-resolution information on the dynamics of both larval and juvenile stage migrations was collected from both the Goodga and Angove rivers over a period of two years (2013-2015). Juveniles were sampled at weekly/bi-weekly intervals in the Goodga (Lower, Upper and Tributary sites) and

and Angove rivers over spring and summer using small single-winged Fyke nets. Larvae were collected at weekly/sub-weekly intervals during autumn and early-winter, at night, using fine mesh plankton nets from sites located in the lower and upper reaches of the catchment, as well as from the weir and fishway.

For the first time on record, larvae were collected upstream of the Goodga weir and fishway, demonstrating that adult fish had successfully navigated the fishway to spawn in the upper reaches of the catchment. The role of the fishway in providing safe passage for drifting larvae appears minor; 99% of larvae collected from immediately upstream of the weir and fishway were transported directly over the weir. New evidence shows that larvae in the Goodga River drift predominantly at night and during elevated river flows during autumn and early winter.

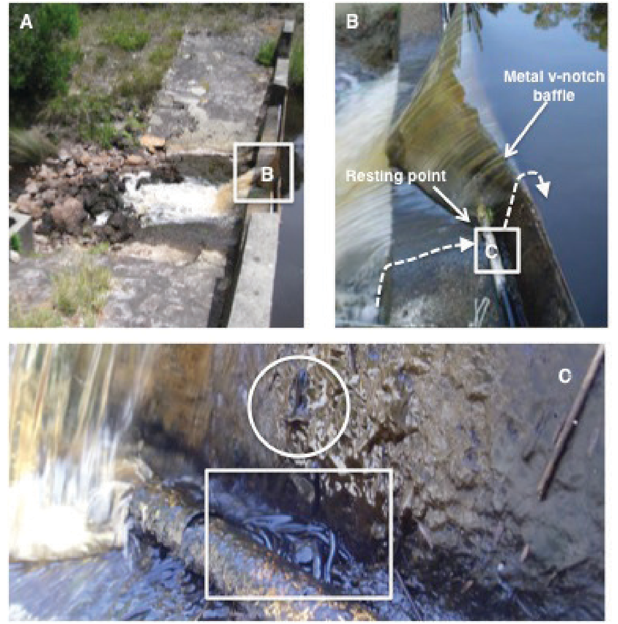
In 2014, the entire cohort of newly-hatched fish were transported to downstream nursery habitats over just a few days during a single high flow event. Contrastingly, in 2015, larvae drifted downstream during elevated river flows that occurred over a more protracted period between mid-June and late-July following two major spawning events.

New data on the migration of juvenile stages demonstrates that they migrate upstream during spring and early-summer. Juveniles moved upstream into their adult riverine habitats in a distinct migration beginning in September - October 2013, whereas the 2014 migration was slightly later,



starting in October - November. In the Goodga River in 2013-14, the upstream migration of juvenile stages started after the cessation of winter high-flows. Despite the low-rainfall and river flows recorded in the Goodga River in 2014-15, upstream migration of juvenile stages occurred a month later, starting in early-October. The relative abundance of juvenile stages varied among catchments and years. In 2013-14, the timing of juvenile recruitment and the relative abundance of juvenile stages was similar at both the lower Goodga and Angove river sites: both sites are located in similar positions in the catchment. In contrast, during 2014-15, the timing of recruitment was later (~one month) and the relative abundance of juvenile stages was lower in Angove River compared to that recorded in the lower Goodga River. While the reasons behind these variations in recruitment among years between two geographically- close catchments remains unclear, the potential influence of variable river flows, either natural or due to water resource development (i.e. Angove River) on the timing of recruitment and relative abundance of juvenile stages requires further investigation.

For the first time, this study recorded the ability of Western Trout Minnows to climb and jump over the Goodga Weir (Close *et al*. 2014). This ability is ecologically advantageous for recolonisation of upstream habitats by juvenile stages that typically migrate during seasonally low river discharge when hydraulic (e.g. cascades) and physical (e.g. rock bars) barriers may be common. This ability is thought to be limited to few native Australian freshwater fishes. These observations are novel, but also important for improved habitat management. Clearly they will lead to improved fishway design and assist in the prioritisation of mitigation works on instream barriers. In the case of Western Trout Minnow, specific fish passage criteria may be less complicated than previously thought.



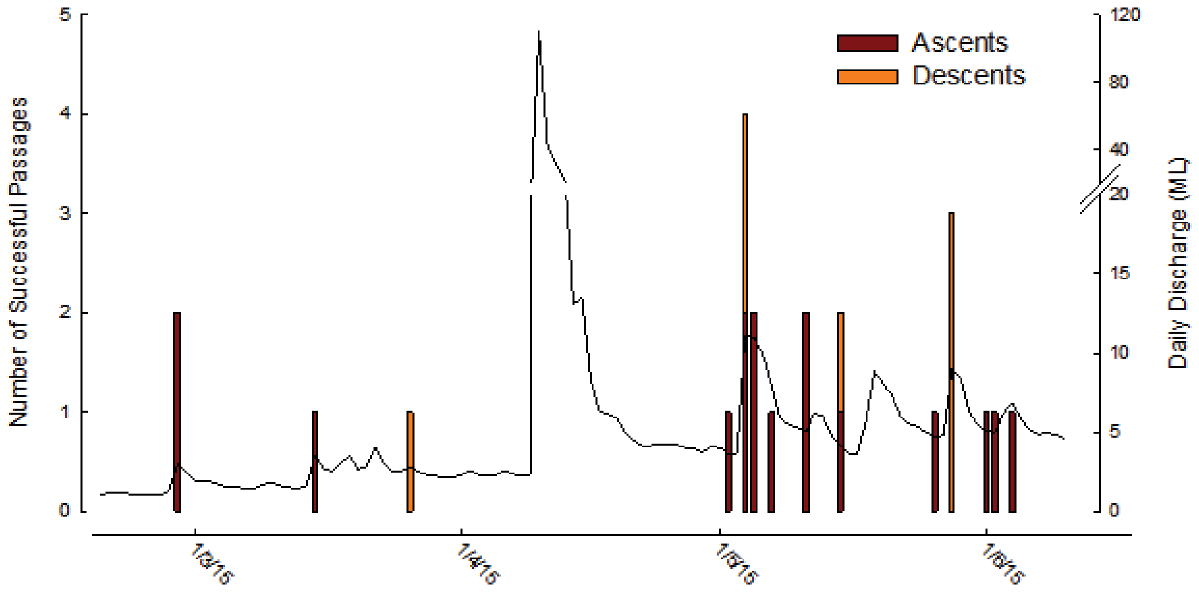
Images illustrating the ability of Western Trout Minnow to climb and jump over the Goodga River Weir (A). This includes the ability to climb the near-vertical weir wall, jump over the vertical weir baffle (B) and tolerate shorts periods of exposure to air (C). Rectangles labeled "B" and "C" identified enlarged images in photos B and C, respectively

This study also undertook the first ever field application of passive inducer transponder (PIT) technology to study movement of Western Trout Minnow through the Goodga Weir Fishway. In total, 115 mature (i.e. >80 mm TL) individuals were tagged with PIT tags and then released so that their movements through the entrance and exit of the fishway could be detected and logged remotely. A total of 25 individuals (~16% of tagged fish), were detected at least once during the study which encompassed the autumn breeding period of 2015.

Of these, 16 individuals successfully passed through the fishway at least once, with some individuals ascending and descending on multiple occasions. The lag period between consecutive passage events for individual fish ranged from 1 to 116 days. The mean duration of fishway ascent (57.44 ± 11.50 min) was substantially longer than the mean duration of descent (22.70 ± 3.04 min) and fish were detected in the fishway much more frequently during the night (74.6%) compared to the day (25.4%).

A proportion of the nine fish that were detected at the fishway that did not pass through were regular visitors to the fishway entrance over a period of days to weeks. It is unlikely that these fish were physically incapable of passaging the fishway, as the structure was specifically designed for this purpose, rather this observation may represent evidence of home-ranging behaviour in this species. It is unclear why these fish were repeatedly detected at the entrance to the fishway. They may have been attracted to the well-oxygenated water at the foot of the weir near the fishway entrance, or perhaps they were using the fishway as habitat in which to seek shelter and/or ambush prey.

Successful passage through the fishway tended to coincide with flow pulses, although no passage events were recorded during a significant flood pulse (approximately an order of magnitude larger than the second highest flow pulse recorded during the study) that occurred on April 10th.



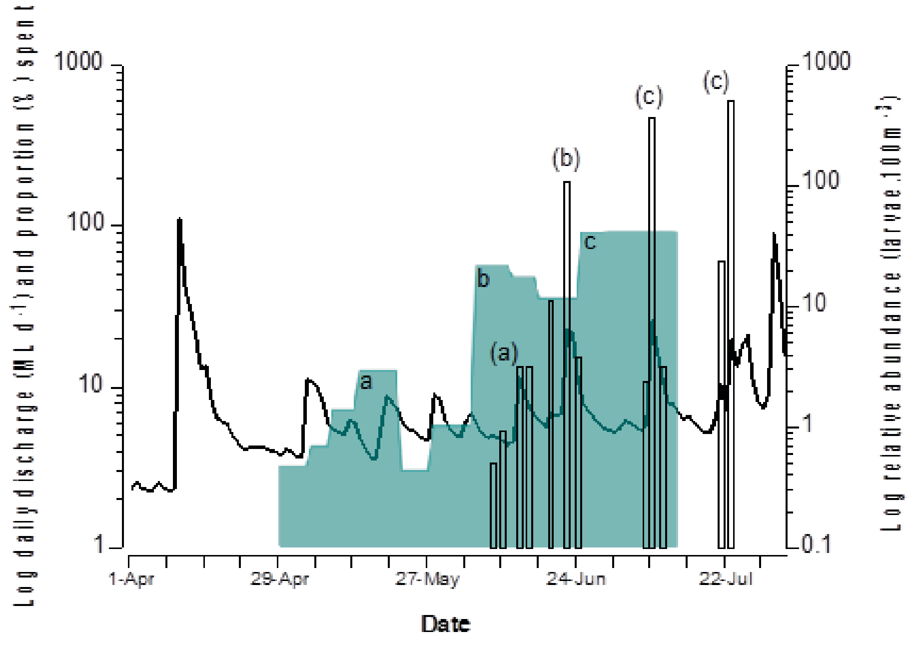
Successful fishway passage events (bars) overlayed with total daily discharge (ML) in the Goodga River, Western Australia

Critical spawning habitats

Previous data collected from the Goodga River population showed that Western Trout Minnow undertake an upstream migration to tributary habitats where they spawn in May (Morgan 2003). This coincided with a seasonal decrease in water temperature and day length. In this study we aimed to identify specific spawning cues, particularly hydrology, and to identify the critical spawning habitat for the Goodga River population.

Reproductive state of the population was monitored at weekly / biweekly intervals around the known spawning period (April – May) in 2015. Fish were collected using fyke nets from the downstream and upstream reaches of the catchment and the reproductive state of a subsample (up to ~100 individuals) was determined by visual assessment of the gonads and classified as: immature and early development (stage 1-3); maturing (stage 4-5); ripe (stage 6), and; spent (stage 7).

Reproductive state of adult Western Trout Minnow developed rapidly during April. By late-April, the entire adult population was 'running ripe' and the first 'spent' individuals were recorded in early-May. Two major spawning events occurred during June. The first of these events occurred in early-June, when the proportion of spent animals increased from 5% to 60% and the second spawning event occurred in late-June after which the proportion of 'spent animals' was approximately 90%. All remaining 'ripe' animals were approximately 60 mm in length, presumably the previous years recruits, and most were male. Seven flow pulses occurred during the spawning period ranging in magnitude from 6 Ml.day^{-1} to 25 Ml.day^{-1}. Increases in the proportion of 'spent' animals was recorded on, or shortly after five of these flow events. The two major spawning events in June were record on or shortly after flows of 8 Ml.day^{-1} (early-June) and 25 Ml.day^{-1} (end-June).

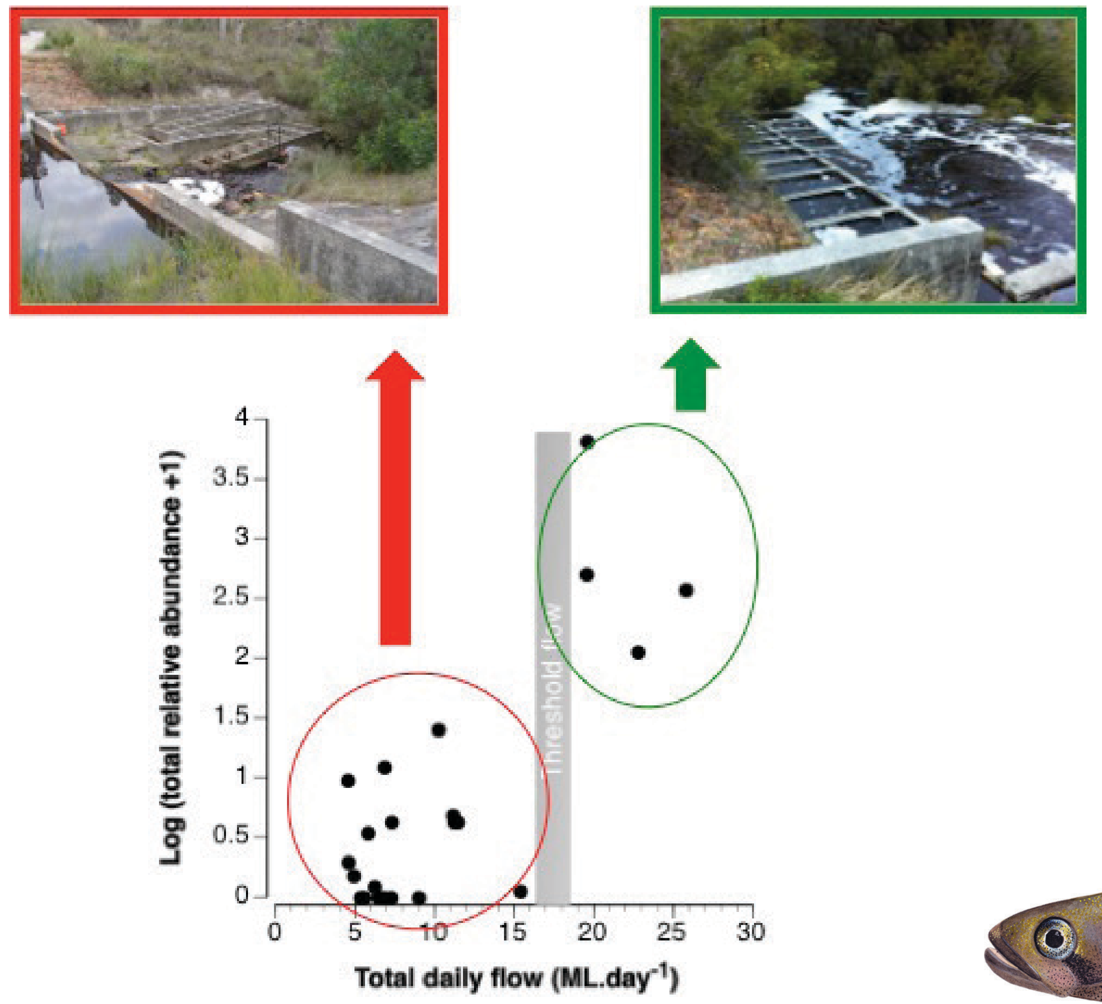


Total daily disharge (black line), proportion of spent adults (blue) and relative abundance of larvae collected in the drift (columns) at Goodga Lower between April and August 2015. Letters link spawning events with subsequent larval drift (in parentheses).

Following the main spawning event, searches for eggs on both natural and artificial spawning substrates were undertaken in the downstream, upstream and tributary reaches of the Goodga River. Searches were made of a variety of natural spawning substrates available in the catchment, including woody debris, aquatic vegetation, overhanging terrestrial vegetation, root-masses and the stream-bed. River pools were sampled using oblique hauls of a small 250µm plankton net. Artificial spawning substrates deployed one month prior to the spawning event, including bundles of sticks sourced from fallen riparian timber and string-type mop heads were also searched.

A total of ~500 m of river length (numerous sites ~5 m in river length) was searched for the presence of eggs over a period of 10 days after the main spawning event in May. Only 15 eggs were collected by dip netting; no eggs were found adhered to either natural or artificial spawning substrates. Despite the significant attempt to collect eggs, the critical spawning habitat for Western Trout Minnow remains unclear.

This study has identified the apparent importance of seasonal and daily flows as a trigger for spawning and in supporting processes at various life-stages critical to the preservation of Western Trout Minnow populations. In the Goodga River during 2015, both spawning and larval drift occurred on elevated river flows. The timing and relative abundance of drifting larvae was strongly correlated to elevated river flows and corresponded to the spawning phenology recorded in the preceding months. Approximately 10% of adult fish had spawned between late-April and early-June and low abundances of larvae (<5 larvae.100 m^{-3}) were recorded during early-mid June. The timing of spawning and larval drift indicates this cohort may have remained in the system for a period of up to approximately 40 days before they were collected in drift samples. The peak in larval abundance recorded in late-June (50 larvae.100 m^{-3}) occurred approximately 15 days following the first of two major spawning events during which approximately 50% of the adult population had spawned. The two remaining periods during which larvae were collected in drift samples occurred following the second of these spawning events after which 90% of the adult population had spawned. Maximum abundances of larvae were recorded 15 days (160 larvae.100 m^{-3}) and 30 days (230 larvae.100 m^{-3}) following this final spawning event. During both 2014 and 2015 substantially greater abundances of larvae were recorded at flows greater than 20 Ml.day^{-1}.



Total relative abundance of larvae collected in the drift at Goodga Lower during individual sampling events in 2014 and 2015 versus total daily discharge on the day of sampling. Photos illustrate typical flows below (left) and above (right) a flow threshold above which most larvae drift downstream

Western Trout Minnow (*Galaxias truttaceus hesperius*)
(artwork Lindsay Marshall)

Balston's Pygmy Perch - one of our rarest fish

Balston's Pygmy Perch was discovered in 1906 in the King River near Albany, and was originally known as the King River Perchlet. Exactly 100 years later, it was added to the Australian Government's endangered species list as *Vulnerable*. The largest of our pygmy perches, growing to 90 mm total length, the species breeds at the end of its first year of life, and lives on insects and arachnids. It is an extremely rare species that was once much more widespread, but is now restricted to south-west and southern coastal streams and lakes.

Prior to this study the only comprehensive survey of the distribution of Balston's Pygmy Perch took place in the early 1990s and established that the species ranged between Margaret River and the Goodga River (Morgan *et al*. 1998). However several individuals have since been recorded tot he east of the Goodga River, in the Angove River. It is a migratory species with a low salinity tolerance and its movements are restricted to riverine reaches and ephemeral streams and wetlands. The species is relatively short-lived (individuals in some populations live < 2 years) and adults consume a high proportion of terrestrial invertebrates, even leaping from the water to knock their prey from low, overhanging vegetation.

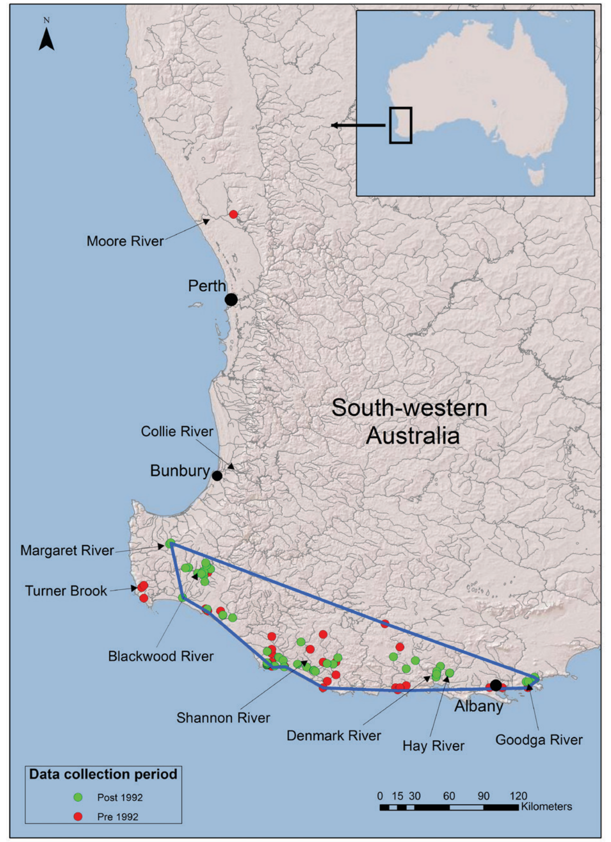
The distribution of this species has not been accurately established since 1998, making it difficult to determine whether its range is declining. Moreover, the most abundant population is restricted to a solitary tributary of the Blackwood River (Milyeannup Brook), yet the specific spawning sites in that catchment have not been determined, nor have additional refuge habitats upstream of the Yarragadee Aquifer discharge zone been identified.

Addressing these key knowledge gaps is important for tailoring management recommendations to help ensure the long-term viability of this population, particularly in light of ongoing reductions in surface flow and groundwater within the region.

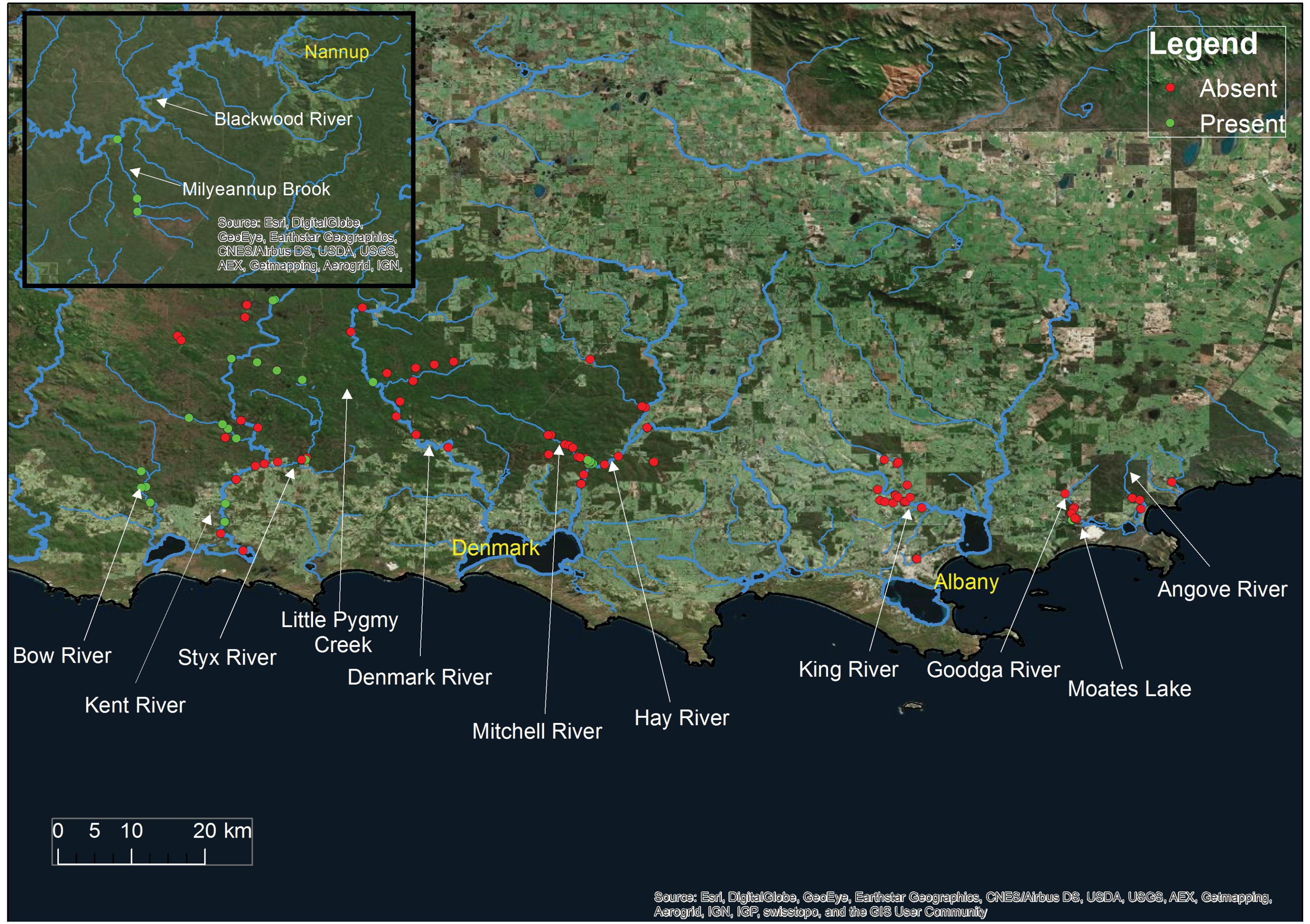
Distribution

This study has shown that the Extent of Occurrence (EOO) of Balston's Pygmy Perch has now been reduced by 31%, mostly due to the loss of this species from Moore River and Turner Brook at the extreme north and west of its former range. Unfortunately, the species also appears to have been lost from the King River, the species' type locality.

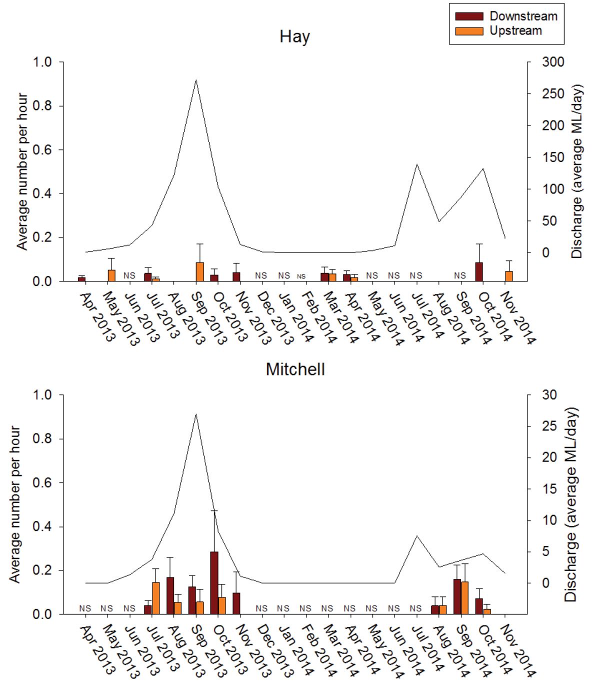
The intensive sampling that occurred in the Kent, Denmark, and Hay Rivers revealed the species to be most widespread in the Kent River but highly restricted in distribution in the Denmark and Hay river systems. The species represented only ~2.5% of all native fishes captured in the southern-most rivers (i.e. between the Bow and Hay rivers) highlighting its rarity. Relative abundance varied greatly among rivers with it representing 12, 10, 6.4, and just 0.7% of all native fishes captured in the Bow, Kent, Denmark and Hay River systems, respectively. This contrasts sharply with its relative abundance in Milyeannup Brook (~64% of all fishes captured), highlighting the dominance of the species in this groundwater maintained system. The maximum-recorded density of the species was 2.9 fish/m^2 in a newly discovered refuge pool in a tributary of the Denmark River.



The known location points of Balston's Pygmy Perch. The area of occupancy of Balston's Pygmy Perch is based on the distribution locations excluding the presumed extirpated populations in the Moore River and Turner Brook. These data are based on the collections by the authors and those deposited in the various museums prior to 1992



Presence and absence of Balston's Pygmy Perch from the major systems surveyed in the current project



Upstream and downstream movement patterns of Balston's Pygmy Perch in the Hay/Mitchell system. Note the NS in the Mitchell River corresponded to non-flow periods and that the species was completely absent from this system during those periods

Migration patterns

The movement patterns of Balston's Pygmy Perch (and all sympatric fishes, including the Little Pygmy Perch) were determined in the Hay/Mitchell river systems by sampling six sites on 14 occasions using two directional fyke nets at each site on each occasion. This enabled the upstream and downstream movements of species to be determined during the major flow period in both the main channel and tributary. The first mark-recapture study of small-sized native southwestern Australian fishes in a natural river system was undertaken using Visual Implant Elastomer Tags (VIE). The VIE mark-recapture program enabled the marking of Balston's Pygmy Perch, Little Pygmy Perch (and for comparison the common Western Pygmy Perch) during baseflow 2014 to provide information on species movement patterns (during the fyke netting program) and population estimates of each species. The mark-recapture program was undertaken in the key refuge pools that were identified during the aerial/ground-truthing surveys of refuge habitats across the systems.

Balston's Pygmy Perch moved into the Mitchell River from the Hay River. This movement occurred slightly earlier compared with the other species and suggests an earlier spawning period (May-July) compared with most other south-western Australian freshwater fishes that generally breed between winter and spring. The common Western Pygmy Perch also utilised the Mitchell River during winter-spring; however, large numbers were also recorded in the Hay River during that period.

The spawning migration into Mitchell River was greater in 2013 compared with 2014; an average of 0.15 ±0.04 fish/hr and 0.098 fish/hr ±0.03 for Balston's Pygmy Perch was recorded in 2013 and 2014, respectively, and 0.79 ±0.16 fish/hr and 0.57 ±0.09 fish/hr in those years, respectively, for Western Pygmy Perch. This difference was also evident for the Western Minnow, which had an average of 2.80 ±0.08 fish/hr captured in the Mitchell River between August and October during 2013, compared with 1.48 ±0.41 fish/hr captured in that period in 2014.

The greater CPUE of the species during higher discharge in 2013 compared with 2014 in the Mitchell River supports the findings of Beatty *et al.* (2014) who demonstrated that the strength of spawning migrations of south-western Australian fishes was positively associated with the amount of discharge in rivers. Therefore, under the projected major reductions in surface discharge, it is expected that spawning migrations will be reduced, which will negatively impact recruitment into the populations and the future sustainability of these species.

Critical habitats

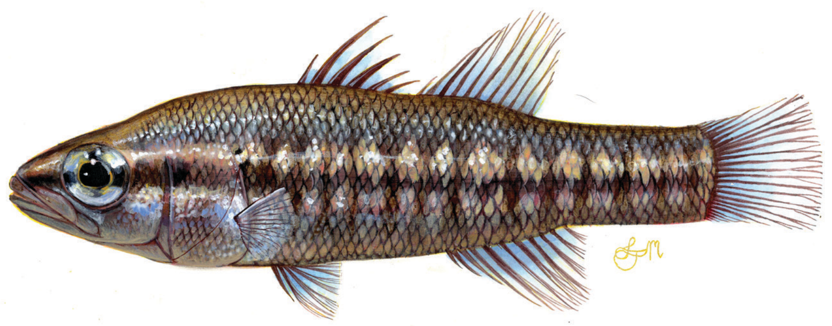
Milyeannup Brook in the Blackwood River houses the most viable and abundant known population of Balston's Pygmy Perch. The species is known to utilise the main channel of the Blackwood River within the major zone of Yarragadee Aquifer discharge during baseflow (Beatty *et al.* 2009, 2014) and also an annually variable reach of the perennial, aquifer fed Milyeannup Brook. The current study expanded that refuge habitat by discovering two refuge pools in the middle reaches of Milyeannup Brook.

In the Hay River, Balston's Pygmy Perch utilised two refuge pools located near the Mitchell River confluence. These were the same critical baseflow refuges utilised by Little Pygmy Perch in this system. Similarly in the Denmark River, the species was found in the same refuge pools as the Little Pygmy Perch in 'Little Pygmy Creek' where it was recorded in relatively high abundance (i.e. 2.9 fish/m^2) in a remote natural refuge pool. While Balston's Pygmy Perch was not detected in the main channel of the Denmark River during baseflow, it may utilise some permanent habitat in the middle reaches. It is quite widely distributed in the Kent River system, and was found in reasonable abundance at some sites. It was also widespread in the permanent main channel of the Bow River.

The study used several approaches in order to ascertain the breeding period and spawning locations for Balston's Pygmy Perch. Particular attention was focused on the Mitchell/Hay given the existence of some data for this species in that system. The fyke netting program enabled the temporal analysis of fish lengths. Moreover, a non-destructive approach was used to establish whether individuals were in breeding condition (stage VI – 'ripe') on each sampling occasion by gently applying pressure to the abdomen to detect exudence of sperm or eggs.

In order to determine the spawning period, the proportion of 'spawning' individuals was determined on each sampling occasion and plotted over time. Finally, larval light-trapping was conducted in all of the main rivers surveyed for Balston's Pygmy Perch (i.e. Milyeannup Brook, Kent, Denmark and Hay/Mitchell rivers) to determine the key spawning habitats (including larval associations with instream variables such as flow, shade, depth, substrate, and location in the channel).

Balston's Pygmy Perch undertook spawning migrations, with winter/spring sampling in the Hay/Mitchell system revealing that the critical spawning habitat for this population was flooded riparian vegetation located in the lower section of the Mitchell River (within ~3 km of the Mitchell/Hay confluence). Similarly, the critical breeding/nursery habitats for the Denmark River population, appeared to be restricted to a solitary tributary in the upper catchment that features extensive areas of seasonally inundated sedgelands that may provide critical spawning/nursery habitat. The precise breeding habitat of the species in the Kent River is yet to be determined but several tributaries were surveyed and were not found to be spawning sites. In Milyeannup Brook, larval light trapping in the headwaters of the system revealed the presence of both larvae and juveniles in ephemeral floodwaters (roadside ditches adjoining a creek/wetland complex). In this system, as well as the Hay/Mitchell, Balston's Pygmy Perch was the first of the percichthyids to breed, with spawning completed by the commencement of spring.



Balston's Pygmy Perch (*Nannatherina blastoni*)
(artwork Lindsay Marshall)

Little Pygmy Perch - one of Australia's newest freshwater fishes

The Little Pygmy Perch (*Nannoperca pygmaea*) is one of the newest freshwater fish species to be described in Australia (Morgan *et al*. 2013). This highlights, that even in the relatively well-researched south-west bioregion, our knowledge of endemic freshwater fishes is extremely limited and new discoveries are still out there waiting to be made.

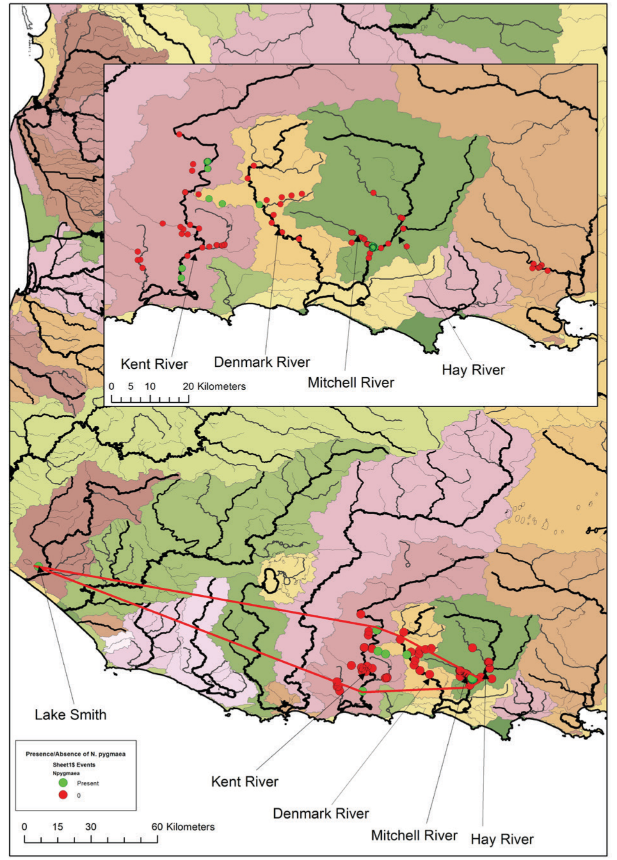
Prior to this study, the species was known from a single population in a small section (1.2 km) of the Hay River system near Denmark, and was thought to contract to a single permanent pool during baseflow, making its ongoing viability doubtful (Morgan *et al*. 2013). Research was urgently required to determine if other populations existed in the region and to elucidate important life-history traits of this species including relative abundance, movement patterns, and reproductive strategies, along with comparing these traits with sympatric freshwater species. This information will enable the identification of key threats to its sustainability, and allow for an accurate assessment of the conservation status of the species. Given its rarity, the study deliberately used a non-destructive approach that aimed to gather as much information as possible, while having the least amount of impact on this species.

Distribution

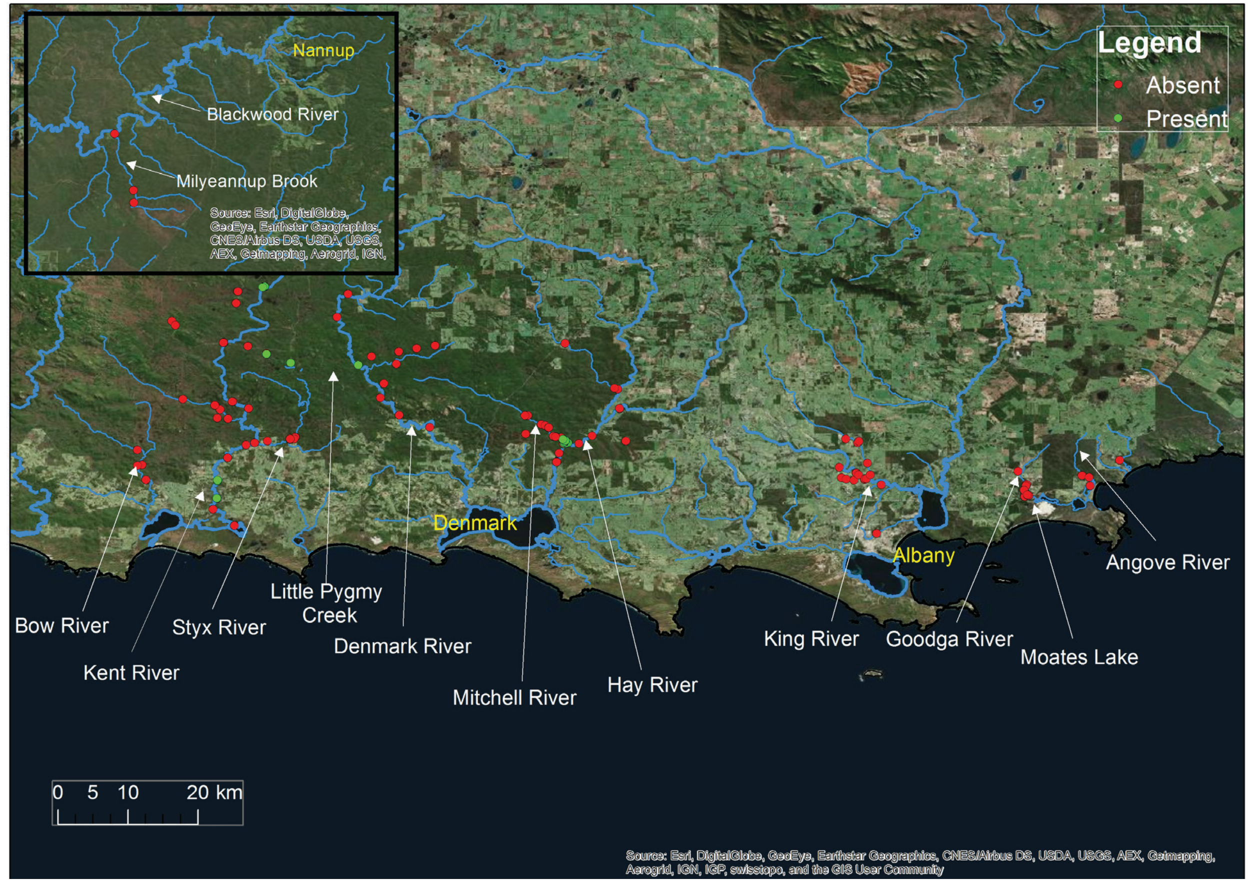
This study discovered three new populations of the Little Pygmy Perch. This has significant implications for its conservation and management. We confirmed that it is highly restricted in the Hay/Mitchell (occupying just 3 km). It was also found in ~30 km of the Denmark River, ~50 km of the Kent River and also in Lake Smith, over 200 km from the nearest known population. While these data significantly increased its range, it also highlighted the fragmentation of populations of this rare species.

The EOO of the species was calculated to be 3420 km^2, but due to the fragmentation of populations the area of occupancy (AOO; in 1 km^2 grids) is only 10 km^2. The Little Pygmy Perch species was assessed as *Endangered* under the IUCN Redlist criteria, because this study showed that it i) has a small population size, ii) has a severely fragmented range, iii) is only known from four locations, iv) has likely suffered reductions in its EOO and AOO (similar to other species), and v) has extreme fluctuations in seasonal range and abundance. A formal nomination for listing of the species as *Endangered* under the Western Australian Government's Wildlife Conservation Act 1950 has been prepared and submitted as part of the current project.

Due to the discovery of new populations, the sampling plan in the current project for this species was expanded to include additional sites and catchments in order to gather as much information about the new populations as possible. This included sampling sites on multiple occasions in the Kent and Denmark rivers that helped determine the critical habitats used by the species. The Lake Smith population was only discovered towards the end of the sampling period of the project (i.e. November 2014). It is crucial that more information is gathered on this apparently outlying population to determine its viability and distribution. Because the species is morphologically similar to the sympatric Western Pygmy Perch, additional surveys between the Kent and Donnelly rivers may also discover new populations that may have previously been misidentified.



Current known distribution (including EOO polygon) of the Little Pygmy Perch



Presence and absence of Little Pygmy Perch from the major systems surveyed in the current project

Biology and migration patterns

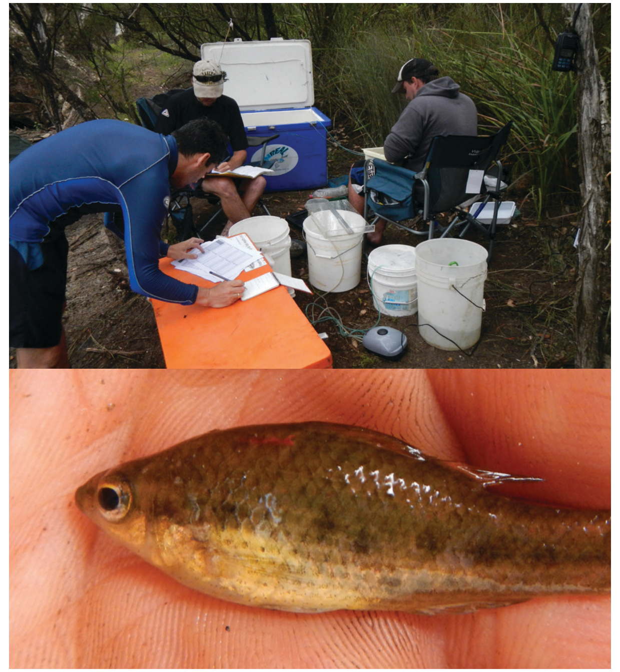
Based on its length-frequency distribution, the Little Pygmy Perch appears to have a maximum life expectancy of four years and grows to a maximum size of 65 mm TL. An analysis of the length-frequency data shows that the species reaches a length of around 30-40 mm TL at the end of its first year of life.

Little Pygmy Perch, Balston's Pygmy Perch and Western Pygmy had staggered breeding periods in the Mitchell River. Balston's Pygmy Perch bred in early-May (and peaked in that month in 2013), prior to the onset of winter flows and had finished breeding by September. Little Pygmy Perch commenced breeding in July and was finished by September (peaking in August in 2013, and July in 2014), whereas Western Pygmy Perch had a protracted breeding period extending from July to November (peaking in October 2013 and September 2014).

The Little Pygmy Perch was found to be a batch spawner, likely spawning on multiple occasions during the breeding period. This study also established that Little Pygmy Perch is potamodromous, much like other south-western Australian fishes (Beatty *et al.* 2014); meaning that it migrates within freshwaters for the purpose of breeding. It migrated upstream in winter to breed, moving from two refuge pools in the Hay River, into the Mitchell River. The Mitchell River dries during baseflow, aside from a handful of refuge pools. Importantly, neither Little Pygmy Perch nor Balston's Pygmy Perch were found to utilise the refuge pools in the Mitchell River, preferring the main-channel pools despite it being slightly salinised; noting that elevated salinities may in the longer term be deleterious to these species.

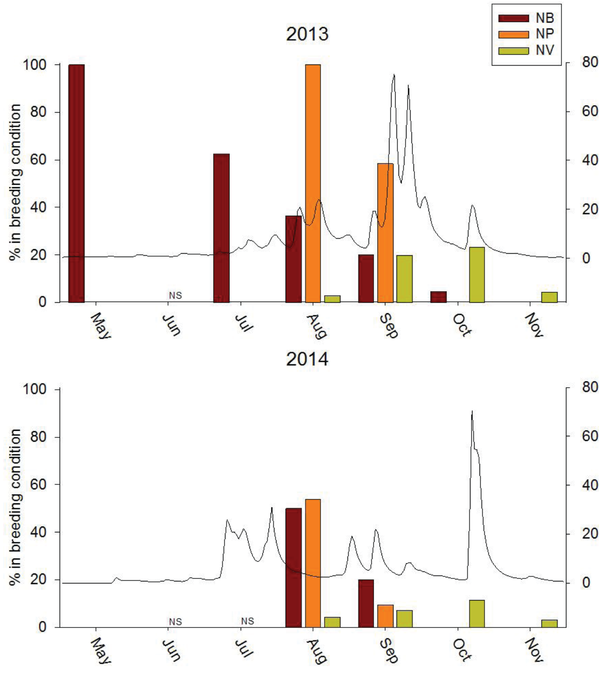
VIE tagging also supported the potamodromous migration strategies of the native fishes as all marked species in the Hay were subsequently detected in the Mitchell River during the flow period. This is the first time that the migration of the small south-west Western Australian freshwater fishes have been demonstrated using mark-recapture.

The Little Pygmy Perch undertook similar movement patterns in the neighbouring Denmark and Kent rivers, where it contracts to refuge pools during summer. In the Denmark River, it was found to move upstream in a key tributary (named 'Little Pygmy Creek' during the study) during winter and also utilised four refuge pools in that system during baseflow; with the main channel of the Denmark River being dry near the confluence of the breeding tributary. Ryan *et al.* (2015) also detected the species some ~10 rkm downstream in permanent habitat in the main channel.

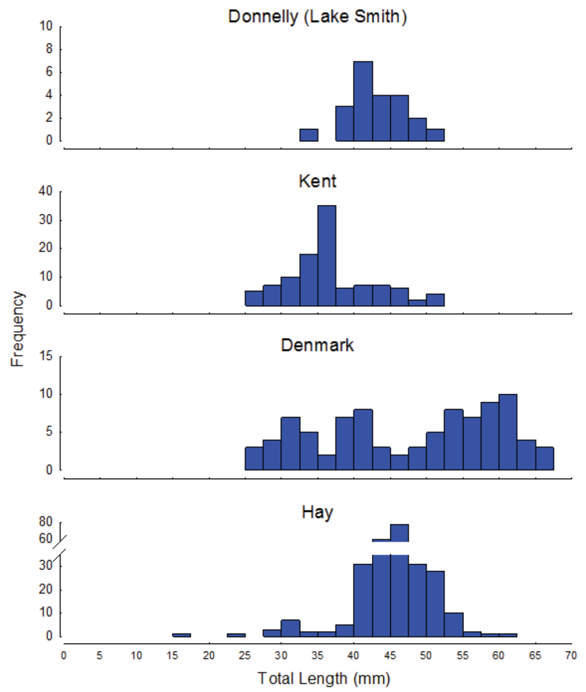


VIE tagging Little Pygmy Perch

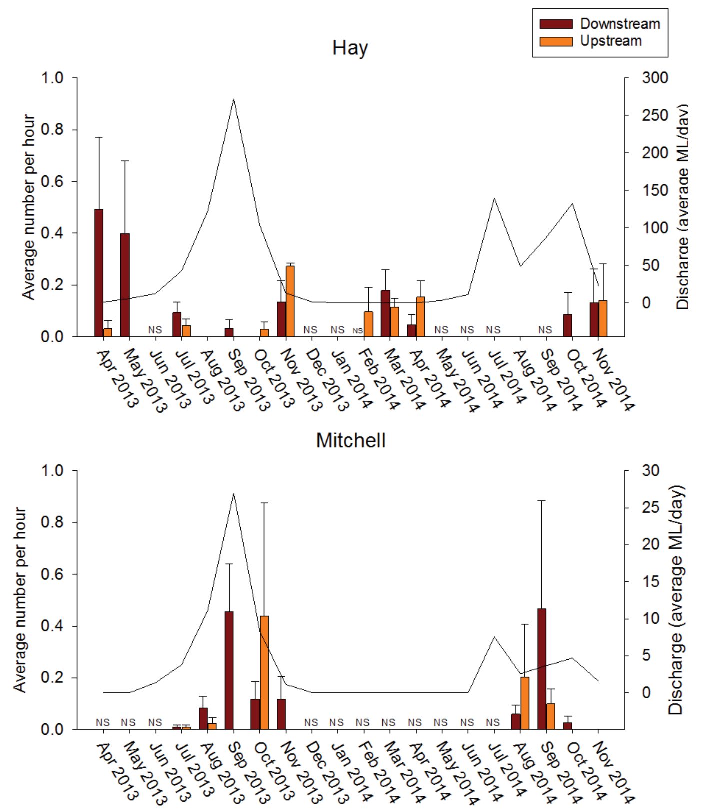
Discharge in 2013 was much higher than 2014 for all systems, including the Mitchell River where total discharge between August and October was ~2.5 times greater in 2013 compared with 2014. There was also a slightly greater relative abundance of Little Pygmy Perch recorded in the Mitchell River during the major flow and breeding period (August – October) in 2013 compared with 2014. These results provide further evidence that the annual level of recruitment to populations may be greater in years of higher discharge for these species. This has major implications for future recruitment rates and population abundances of these species under the projected drying climatic scenarios.



Percentage of the population of Balston's Pygmy Perch (NB), Little Pygmy Perch (NP), and Western Pygmy Perch (NV) that were in breeding condition (i.e. stage VI 'ripe') in the Hay/Mitchell system during the study. Note the higher proportion of breeding fish and the higher discharge (Mitchell River shown) in 2013 compared with 2014



Length-frequency for the Little Pygmy Perch in each of the systems in which it occurs, pooled over the entire study period



Upstream and downstream movement patterns of Little Pygmy Perch in the Hay/Mitchell system. Note the NS in the Mitchell River corresponded to non-flow periods and that the species was completely absent from this system during those periods; moving back into the refuge pools in the Hay River

Critical habitats

The Little Pygmy Perch represented just 2.2% of native fish captured in the rivers it occupied during the study. The relative abundance of Little Pygmy Perch was greater in the newly discovered populations (representing ~18%, ~4% and ~8% of native fishes captured in Lake Smith, and the Kent and Denmark rivers, respectively) compared with the Hay/Mitchell rivers (where it represented only 1.5 % of all native fishes captured). The Hay River population has a highly restricted baseflow distribution and low population size and is currently at a higher risk of extinction compared to other known populations.

The comprehensive baseflow surveys (aerial and ground-truthing) in the Hay/Mitchell rivers revealed that the population is restricted to just two major refuge pools in the Hay River during baseflow. The VIE mark-recapture program conducted in those baseflow refuge pools revealed that the number of Little Pygmy Perch was ~ 90 fish in one pool compared with ~8117 Western Pygmy Perch and just ~26 Balston's Pygmy Perch. This highlights the precarious conservation status of the species in the Hay/Mitchell system, particularly during baseflow.

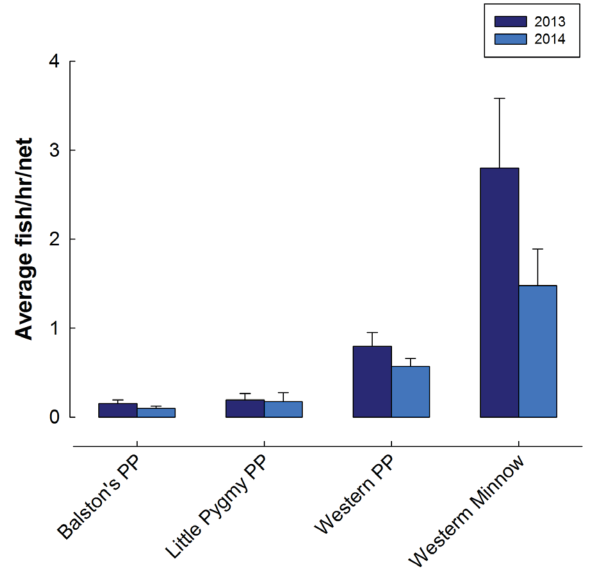
In the Denmark catchment, the species is known from four refuge pools (two are artificial waterpoints) in 'Little Pygmy Creek'. A recent study (Ryan *et al*., 2015) has also found the species in the middle reaches of the Denmark River (~10 km downstream of 'Little Pygmy Creek') and, therefore, it is also likely to occupy additional remote main channel refuge pools between those two sites.

The species is most widespread (~50 rkm) in the Kent River and utilises the middle reaches as baseflow refuge. It is in high abundance in at least two pools and it likely occupies other similar habitats that could not be sampled owing to the limited river access in this section of the catchment. Less is known about the Lake Smith population; however, it undoubtedly utilises the permanent lake as a major refuge habitat. A priority recommendation arising from this study is to conduct a thorough aquatic survey between Lake Smith and the Kent River in order to determine if the species is perhaps more widespread than currently thought.

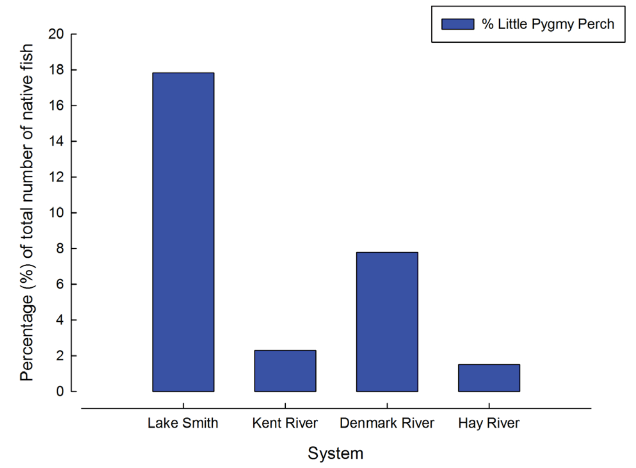
Another important discovery during the sampling was finding the Black-stripe Minnow (*Galaxiella nigrostriata*) in a refuge pool in the Mitchell River in September 2013. This represents a major finding and a range extension for the species which was recently found to have undergone a 57% and 58% reduction in its EOO and Area of Occupancy (AOO), respectively (Ogston 2015).

As described earlier in the spawning migration section, key spawning sites confirmed during this study for the Little Pygmy Perch included the lower 3 rkm of the Mitchell River and 'Little Pygmy Creek' in the Denmark catchment. While the critical breeding sites in the Kent River remain unknown, we narrowed down the likely spawning region to a remote part of the mid-catchment.

Two major refuge pools were identified in the Kent River during the study that had very high abundances of Little Pygmy Perch, however, given the species is relatively widespread in the system, there are undoubtedly other main channel pools that are also utilised.

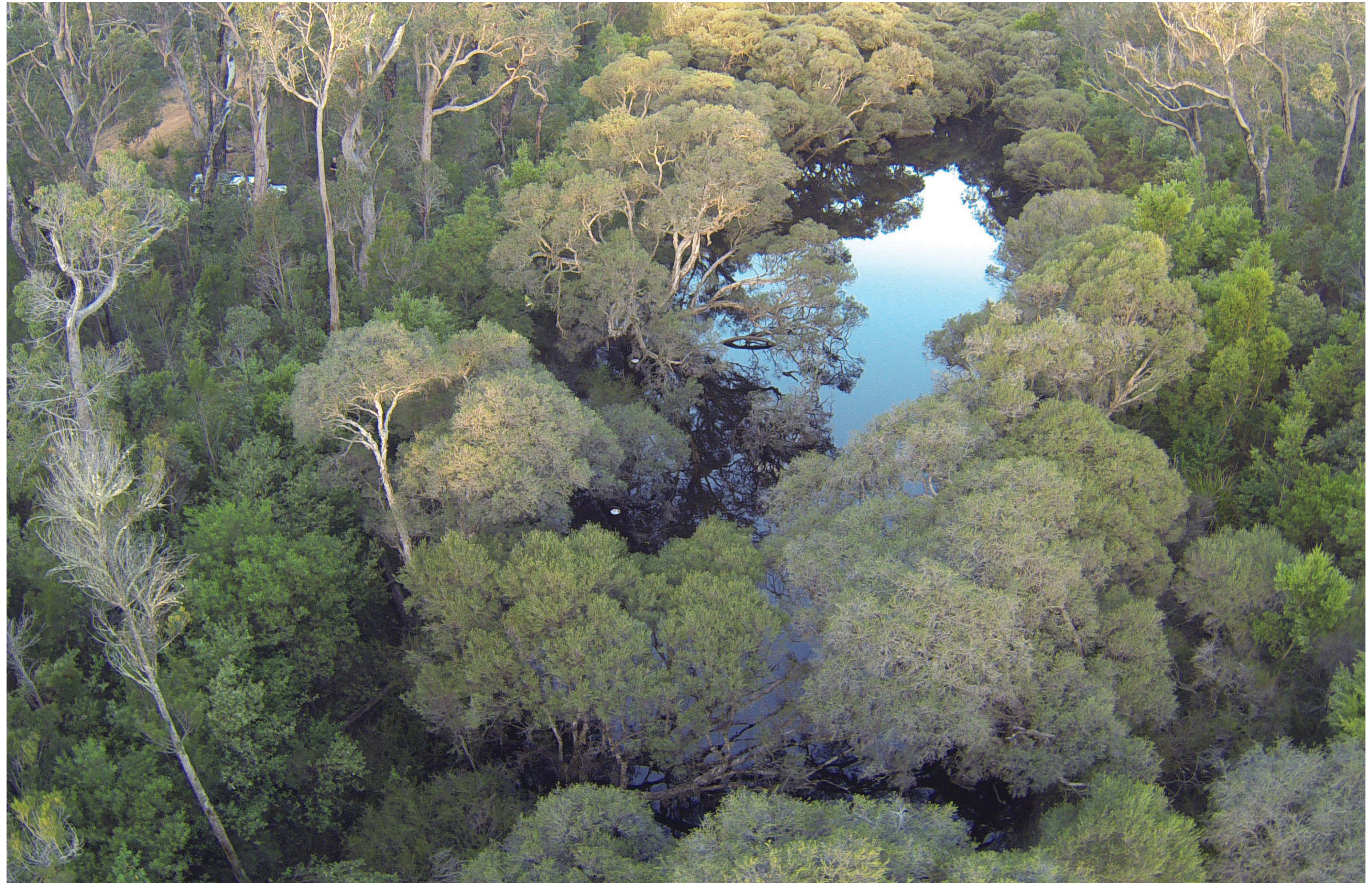


Mean abundance of the different species captured in the Mitchell River in fyke nets during the major flow period



Relative abundance (proportion of all native fish) of Little Pygmy Perch in the different catchments from which it is known


Little Pygmy Perch (*Nannoperca pygmaea*)
(artwork Roger Swainston)



Risks and key strategies for the conservation of our threatened fishes

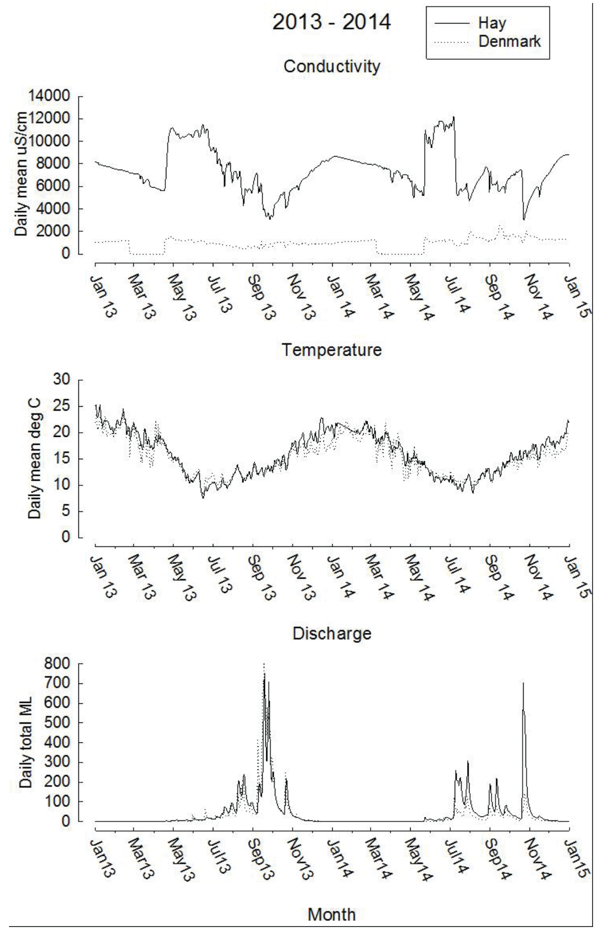
The key threats that were identified in this project are summarised in Table 1, along with their potential impacts and proposed mitigation strategies. Key issues affecting each species are broadly outlined below.

Although Western Trout Minnow may be locally abundant (e.g. Goodga and Angove rivers), their restricted distribution to three isolated catchments means the threats and conservation strategies should be considered in the context of each individual population. Within each catchment, recovery from any significant and wide spread disturbance will rely on recolonisation from sources within that catchment. Because the species relies on natural flow variability (high flows in autumn-winter and low flows in spring-summer) and habitat connectivity (river-lake) to complete its life-history cycle, any change in river flows and habitat connectivity, either due to climate or water resource development, represents a significant risk. Similarly, the apparent preference for complex structural habitat, relatively low water temperatures and terrestrial insect prey means that clearing or modification to native stream-side vegetation will represent a potential risk to the future viability of populations. Increased salinity also represents a significant risk based on their present occurrence in low salinity habitats. Key conservation strategies for this species should therefore focus on the maintenance of natural flow variability and habitat connections, management of secondary salinisation and protection of natural stream-side vegetation.

The relatively restricted EOO and small AOO (10 km^2) of Little Pygmy Perch results in it being susceptible to catastrophic losses from current and future stressors. A key threat is the ongoing reduction in rainfall causing reduced surface flow and groundwater levels resulting in the drying of critical baseflow refuges and reductions in spawning migrations and associated population recruitment. Increased secondary salinisation (i.e. in the Hay and Kent) may also exceed the physiological tolerance of the species (which has not yet been determined) resulting in increased mortality during baseflow. The impacts of existing (i.e. Eastern Gambusia) and potential novel alien species introductions could also be catastrophic for the species. Currently, the species is sympatric with Eastern Gambusia during baseflow in the Hay River, but the two are not sympatric in its known breeding habitats in the Mitchell River. The assessment of refuge pools should continue, given the importance of artificial fire fighting waterpoints revealed in the current study.

Balston's Pygmy Perch is the most widespread of the three species but has suffered a major decline in its EOO. Moreover, it occurs in very low abundance and many populations have a one year life-cycle, predisposing them to catastrophic losses in the case of a potential failure of a single breeding period. The Milyeannup Brook population (the most abundant) is reliant on the Yarragadee Aquifer to maintain much of its refuge habitat and also to dilute the salinity of habitats in the adjoining section of the Blackwood River to which the majority of the population retreats during baseflow. Key threats to the species include ongoing declines in rainfall and groundwater impacting spawning migrations and viability of refuge habitats, increased salinisation of main channels of rivers throughout its range, and the impact of introduced species.

Given the recent declines of these and other species in the south-west, it is crucial that the key threats to their survival are addressed and that ongoing monitoring of these fishes and their habitats continues.



Conductivity, temperature and discharge in the Hay and Denmark rivers. N.B. the much higher conductivity in the Hay River. Increasing salinity in the Hay and Kent rivers are a major threat to its freshwater fishes

Summary of the key threats for the three target threatened freshwater fishes that were the focus of this research

Threat	Causes	Impacts	Western Trout Minnow		Balston's Pygmy Perch		Little Pygmy Perch		Solutions
			Likelihood	Conseq.	Likelihood	Conseq.	Likelihood	Conseq.	
Flow reductions	Rainfall reductions (climate change), water abstraction (e.g. irrigation, potable), landuse	Migratory pathways, nursery habitat, resources = less recruitment	High	High	High	High	High	High	Ensure sustainable water abstractions (e.g. Angove), landuse (hydrology), captive breeding
Refuge loss	Rainfall and groundwater reductions (climate change), water abstraction (e.g. fire points, water supply dams)	Reduction in baseflow populations, concentration effects = reduced range, pop size	High	High	High	High	High	High	Creation of new strategic waterpoints, management of existing refuge, captive breeding
Water quality decline	Salinisation, climate change (e.g. increased temperature)	Exceeding physiological tolerances, baseflow populations most affected (salinity) = reduced range, pop size	High	High	High	High	High	High	Determine env. tolerances to model viability, address salinity in Hay, Kent (e.g. Denmark)
Riparian degradation	Land clearing, grazing	Reduced shelter, food, instream stability = reduced pop size	High	High	Low	Medium	Low	Medium	Fencing, revegetation
Introduced species	Current and future freshwater fish introductions.	Competition, predation, aggression, disease. *Gambusia holbrooki* in main channel of most rivers	Med-high	Med-high	High	Low-High	Medium	Low-High	Impact dependent on species. Education, monitoring, rapid response to control novel introductions
Instream barriers	Existing weirs, dams	Impedes migration = increased mortality, reduced recruitment	High	High	Low	Low	Low	Low	Prioritisation of fishways (e.g. Angove), barrier removal

Further Reading

BOOKS

Beatty, S., Allen, M., Lymbery, A., Storer, T., White, G., Morgan, D. & Ryan, T. (2013). *Novel methods for managing freshwater refuges against climate change in southern Australia: Evaluating small barrier removal to improve refuge connectivity: A global review of barrier decommissioning and a process for southern Australia in a drying climate*. National Climate Change Adaptation Research Facility, Gold Coast, 73 pp. ISBN: 978-1-925039-54-2

Morgan, D.L., Allen, M.G., Beatty, S.J., Ebner, B.C. & Keleher, J.J. (2014). *A field guide to the freshwater fishes of Western Australia's Pilbara Province*. Freshwater Fish Group & Fish Health Unit, Murdoch University, Murdoch, W.A.

OTHER PUBLICATIONS

Allen, M.G., Beatty, S.J. & Morgan, D.L. (2015). *Resurvey of historical collection sites for Balston's Pygmy Perch in the South West Linkages Target Area*. Report to the South West Catchments Council. Freshwater Fish Group & Fish Health Unit, Centre for Fish & Fisheries Research, Murdoch University, Perth, Western Australia.

Allen, M.G., Beatty, S.J. & Morgan, D.L. (2015). *Baseline survey of key fish refuge habitats in the Margaret River*. Report to the Cape to Cape Catchments Group and South West Catchments Council. Freshwater Fish Group & Fish Health Unit, Centre for Fish & Fisheries Research, Murdoch University, Perth, Western Australia.

Beatty, S.J. & Morgan, D.L. (2013). Introduced freshwater fishes in a global endemic hotspot and implications of habitat and climatic change. *BioInvasions Records* 2: 1-9.

Beatty, S.J., Morgan, D.L. & Lymbery, A.J. (2014). Implications of climate change for potamodromous fishes. *Global Change Biology* 20: 1794-1807.

Beatty, S.J., Morgan, D.L., McAleer, F.J. & Ramsay, A.R. (2010). Groundwater contribution to baseflow maintains habitat connectivity for *Tandanus bostocki* (Teleostei: Plotosidae) in a south-western Australian river. *Ecology of Freshwater Fish* 19: 595-608.

Beatty, S.J., Morgan, D.L., Rashnavadi, M. & Lymbery, A.J. (2011). Salinity tolerances of endemic freshwater fishes of south-western Australia: implications for conservation in a biodiversity hotspot. *Marine & Freshwater Research* 62: 91-100.

Beatty, S.J., Seewraj, K., Allen, M.G & Keleher, J.J. (2014). Enhancing fish passage over large on-stream dams in south-western Australia: a case study. *Journal of the Royal Society of Western Australia* 97: 313-330.

Close, P.C., Ryan, T.J., Morgan, D.L., Beatty, S.J. & Lawrence, C.S. (2014). First record of 'climbing' and 'jumping' by juvenile *Galaxias truttaceus* (Valenciennes, 1846) (Galaxiidae) from south-western Australia. *Australian Journal of Zoology*.

Morgan, D.L. (2003). Distribution and biology of *Galaxias truttaceus* (Galaxiidae) in south-western Australia, including first evidence of parasitism of fishes in Western Australia by *Ligula intestinalis. Environmental Biology of Fishes* 66: 155-167.

Morgan, D.L. & Beatty, S.J. (2006). Use of a vertical-slot fishway by galaxiids in Western Australia. *Ecology of Freshwater Fish* 15: 500-509.

Morgan, D.L., Beatty, S.J. & Adams, M. (2013). *Nannoperca pygmaea*, a new species of pygmy perch (Teleostei: Percichthyidae) from Western Australia. *Zootaxa* 3637: 401-411. Morgan, D.L., Beatty, S.J., Allen, M.G., Keleher, J. & Moore, G. (2014). Long live the King River Perchlet (*Nannatherina balstoni*). *Journal of the Royal Society of Western Australia* 97: 307-312.

Morgan, D.L., Beatty, S.J. & Allen, M.G. (2013). *Fishes and crayfishes of Turner Brook: Past and Present*. Report to the Cape to Cape Catchments Group. Freshwater Fish Group & Fish Health Unit, Murdoch University, 15 pp.

Morgan, D.L., Gill, H.S. & Potter, I.C. (1995). Life cycle, growth and diet of Balston's pygmy perch in its natural habitat of acidic pools. *Journal of Fish Biology* 47: 808-825.

Morgan, D.L., Gill, H.S. & Potter, I.C. (1998). Distribution, identification and biology of freshwater fishes in south-western Australia. *Records of the Western Australian Museum Supplement* No. 56: 1-97.

Morgan, D.L., Unmack, P.J, Beatty, S.J., Ebner, B.C., Allen, M.G., Keleher, J.J., Donaldson, J.A. & Murphy, J. (2014). An overview of the 'freshwater fishes' of Western Australia. *Journal of the Royal Society of Western Australia* 97: 263-278.

CONFERENCE ABSTRACTS

Beatty, S. & Morgan, D. (2014). Vulnerability of Western Australian fishes to changing flow. In Special Session Fish responses to environmental flows: moving beyond patterns to understand process. *Australian Society for Fish Biology and Australian Society for Limnology Congress, Darwin, June 2014*.

Beatty, S., Morgan, D., Allen, M., Keleher, J. & Lymbery, A. (2013). Vulnerability of south-western Australian fishes to climate change: canaries in the coal mine. *Inaugural Western Australian Freshwater Fish Symposium, Naturaliste Marine Discovery Centre, Hillarys Boat Harbour, Western Australia, November 2013*.

Beatty, S., Morgan, D., Close, P., Allen, M., Lymbery, A., Davies, R., Ryan, T. & Lawrence, C. (2013). Enhancing the prospects for south-western Australia's rarest and most threatened freshwater fishes. *Inaugural Western Australian Freshwater Fish Symposium, Naturaliste Marine Discovery Centre, Hillarys Boat Harbour, Western Australia, November 2013.*.

Morgan, D. & Beatty, S. (2013). Western Australia's extreme freshwater fishes. *9th Indo-Pacific Fish Conference, Okinawa, Japan.*

Morgan, D., Beatty, S., Allen, M., Ebner, B. & Keleher, J. (2013). Fishes in freshwaters of Western Australia: an overview. *Inaugural Western Australian Freshwater Fish Symposium, Naturaliste Marine Discovery Centre, Hillarys Boat Harbour, Western Australia, November 2013.*

Murphy, J., Lymbery A., Beatty, S. & Morgan, D. (2013) Population genetic structure and cryptic speciation within five species of freshwater fish from the south-west of Western Australia. *Inaugural Western Australian Freshwater Fish Symposium, Naturaliste Marine Discovery Centre, Hillarys Boat Harbour, Western Australia, November 2013.*

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Short communication

First record of 'climbing' and 'jumping' by juvenile *Galaxias truttaceus* Valenciennes, 1846 (Galaxiidae) from south-western Australia

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Abstract. Upstream migration of juvenile stages of temperate Australian amphidromous fish typically coincides with seasonally low river discharge when hydraulic (e.g. cascades) and physical (e.g. rock bars) barriers may be common. The ability to 'climb' or 'jump' may be expected to assist in negotiating low-flow barriers; however, it is presumed to be limited to a few native Australian freshwater fishes. Juvenile stages of *Galaxias truttaceus* Valenciennes, 1846 were observed 'climbing' and 'jumping' to successfully negotiate a low, vertical weir wall during their upstream recruitment migrations in south-western Australia. Based on this observation, we propose initial definitions for 'climbing' and 'jumping' to describe locomotory strategies employed by fishes to negotiate obstacles that would otherwise prevent free passage

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An overview of the 'freshwater fishes' of Western Australia

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Western Australia's non-tidal waters provide refuges to many unique fishes. Here we provide an overview to synthesise contemporary knowledge on these species with the aim of providing readers with an understanding of their biological, ecological and conservation significance. Western Australian inland aquatic ecosystems provide critical habitats for many obligate freshwater fishes as well as diadromous species that rely on fresh water to complete their life-cycle. Five of Australia's 10 ichthyological provinces are found within the State, three in their entirety. Notable species from evolutionary and biogeographic perspectives include the enigmatic Gondwanan relic *Lepidogalaxias salamandroides* (Salamanderfish) and the ancient jawless fish, the anadromous *Geotria*

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Long live the King River Perchlet (*Nannatherina balstoni*)

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Exactly 100 years following the discovery of Balston's Pygmy Perch (*Nannatherina balstoni*) and its subsequent description from south-western Australia, it was added to the Australian Government's endangered species list due to a contraction of the species range and its low abundance relative to sympatric species. The current study aimed to determine the historical and contemporary geographical range of the species, to quantify its range reduction and prioritise areas for ongoing monitoring and management. The original common name of this species, the King River Perchlet, was derived from the type locality of the two syntypes deposited at the British Museum of Natural History. Only one syntype remains. Based on a review of published information and unpublished data held by the authors, the apparent contemporary area of occurrence of *N. balstoni* is now ~69% of its historical distribution. The remaining syntype from

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