ACTION PLAN FOR SOUTH AUSTRALIAN

FRESHWATER FISHES

Native Fish Australia (SA) Inc.

2009

Native Fish Australia SA Incorporated

Australian Government

Government of South Australia
Department for Environment and Heritage

Nature Foundation SA

Threatened Species Network

WWF

Action Plan for South Australian Freshwater Fishes

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Cover: Southern Purple-Spotted Gudgeon.

Foreword

With South Australia experiencing prolonged drought, the release of an Action Plan for South Australian Freshwater Fish has never seemed timelier, yet ironically its production was delayed significantly so those involved could divert effort to rescue populations of freshwater fish stranded by the dry conditions.

Despite, or perhaps exaggerated by, their relatively low profile, freshwater fish are a group under threat worldwide. Australia is no exception, with 40 of its 300 known species currently listed in the higher extinction risk categories nationally, while over 50 per cent of South Australia's described species are identified in this document as worthy of listing, as guided by IUCN criteria.

A severe impediment to the conservation of native freshwater fishes in South Australia has been an historic lack of information and it took until the mid-1980s before the first indications of concern were recognised.

Only now are we starting to recognise that freshwater systems and water-reliant ecosystems require integrated management at a much greater scale than attempted in the past. The fluid nature of water means that freshwater habitats are often connected within broader networks and with terrestrial habitat. Local changes to habitat and species introductions can be transmitted elsewhere and often become interlinked with other threats. The main impacts recognised in this document are altered hydrology, habitat loss and disturbance, lowering water quality, introduced or alien species, exploitation, population decline and climate change.

The South Australian plan complements the broad framework for protecting fishes provided by the national "Action Plan for Australian Freshwater Fishes", and is State-specific and far more up to date.

The South Australian plan provides information that will help managers and the community alike to better understand the diversity of South Australia's freshwater fish and contribute to the protection of those species at risk. It does this by providing useful overviews of the status and recovery objectives for each fish species identified at risk, outlining current and potential threats to South Australia's freshwater fish and options for conservation and management.

Although the plan contains the most up to date biological information on freshwater fish in South Australia it was never intended to be anything other than a useful guide to facilitate and support freshwater fish management at its most practical level.

The Action Plan is useful to a broad audience of interested individuals, community groups and government organisations including those involved with on ground habitat restoration, natural resource management, biodiversity protection and landscape or hydrological planning, development and policy.

It has been released at a time when scientific, community and land manager interest in freshwater fish is growing, particularly within the Murray-Darling Basin. The introduction of South Australia's Natural Resource Management (NRM) Act 2004 and, under its auspices, the establishment of regional NRM boards with responsibilities in both water allocation planning and biodiversity conservation provide new opportunities for integrated planning and funding. The Action Plan is an invaluable tool for these groups to determine priorities for both.

Native Fish Australia (SA) members Michael Hammer and Scotte Wedderburn, and Jason van Weenen from the South Australian Department for Environment and Heritage prepared the Action Plan with support from society members. Considerable financial and in-kind assistance was provided from organisations such as the South Australian Museum, Nature Foundation South Australia, Wildlife Conservation Fund and WWF-Australia's Threatened Species Network Community Grants. I would like to warmly commend the primary authors for the quality of the document and recognise the important contribution of the supporting organisations.

South Australia's freshwater fish are precious and diverse. This Action Plan will play a key role in highlighting their plight and value and I am confident it will provide a valuable guide to managers working at all levels in their efforts to better manage the State's water-reliant ecosystems and the unique and incredible wildlife they sustain.

Vicki-Jo Russell AM
Senior Coordinator, Threatened Species Network (South Australia)

Summary of threatened freshwater fishes in South Australia with 2009 Action Plan status

Species	Scientific name	Status
Flathead Galaxias	*Galaxias rostratus*	Extinct
Macquarie Perch	*Macquaria australasica*	Extinct
Trout Cod	*Maccullochella macquariensis*	Extinct
Australian Mudfish	*Neochanna cleaveri*	Critically Endangered
Murray Hardyhead	*Craterocephalus fluviatilis*	Critically Endangered
Agassiz's Glassfish	*Ambassis agassizii*	Critically Endangered
Variegated Pygmy Perch	*Nannoperca variegata*	Critically Endangered
Yarra Pygmy Perch	*Nannoperca obscura*	Critically Endangered
Southern Purple-spotted Gudgeon	*Mogurnda adspersa*	Critically Endangered
Flinders Ranges Purple- spotted Gudgeon	*Mogurnda clivicola*	Critically Endangered
Pouched Lamprey	*Geotria australis*	Endangered
Shortheaded Lamprey	*Mordacia mordax*	Endangered
Freshwater Catfish	*Tandanus tandanus*	Endangered
Australian Grayling	*Prototroctes maraena*	Endangered
Spotted Galaxias	*Galaxias truttaceus*	Endangered
River Blackfish	*Gadopsis marmoratus*	Endangered
Murray Cod	*Maccullochella peelii peelii*	Endangered
Estuary Perch	*Macquaria colonorum*	Endangered
Southern Pygmy Perch	*Nannoperca australis*	Endangered
Silver Perch	*Bidyanus bidyanus*	Endangered
Dalhousie Catfish	*Neosilurus gloveri*	Vulnerable
Dwarf Galaxias	*Galaxiella pusilla*	Vulnerable
Mountain Galaxias	*Galaxias olidus*	Vulnerable
Dalhousie Hardyhead	*Craterocephalus dalhousiensis*	Vulnerable
Flyspecked Hardyhead	*Craterocephalus stercusmuscarum stercusmuscarum*	Vulnerable
Glover's Hardyhead	*Craterocephalus gloveri*	Vulnerable
Congolli	*Pseudaphritis urvilii*	Vulnerable
Dalhousie Purple-spotted Gudgeon	*Mogurnda thermophila*	Vulnerable
Dalhousie Goby	*Chlamydogobius gloveri*	Vulnerable
Shortfinned Eel	*Anguilla australis australis*	Rare
Cooper Catfish	*Neosiluroides cooperensis*	Rare
Climbing Galaxias	*Galaxias brevipinnis*	Rare

Executive summary

The Action Plan for South Australian freshwater fishes is the first document of its kind and provides a comprehensive overview of issues and actions to protect and restore populations of threatened species and ecological communities. Freshwater fish are an important part of biodiversity and good indicators of environmental health.

South Australia spanning multiple climatic, geological and biogeographical regions has a surprising diversity of aquatic habitats and corresponding richness of freshwater fishes - most places with permanent water have fish. Some species even colonise some temporary or seasonal habitats. Available distributional and biological information has been collated to provide a knowledge base for assessing the risk of extinction or conservation status for South Australian freshwater fishes. The overall picture is alarming, with over half of the State's species considered threatened (32 of 58).

The listings may even be an underestimate as many species are still so poorly known that their extinction risk is masked, and yet others occur in habitats which could undergo change thus rapidly elevating species to higher categories. The current state and projected condition of the River Murray in particular, experiencing a severe and prolonged water shortage, ensures that no species could be considered secure in this region, with the status of the many already threatened species likely to move quickly to higher extinction risk categories or to local extinction.

A reliance on water for survival places fishes in direct conflict with human water use of a scarce natural resource, in what is renowned as the driest State on the driest inhabited continent on earth. Hence hydrological alteration is seen as the primary threat to the sustainability of many species and habitats. As with other groups of threatened animals and plants, habitat loss and alteration has and is taking its toll, but has a subtly different form in aquatic habitats due to broad connectivity within catchments, requirements for linear movement, and a submerged water landscape. Other potential threats include deteriorating water quality such as salinity and pollutants, the impacts of alien (introduced) species and disease, exploitation or use, chance population factors, and a significant lack of awareness regarding the status and requirements of native fishes. The looming impacts of climate change is likely to exacerbate many of these threats.

This Action Plan presents a way forward to halt declines and increase native fish populations. Recovery Outlines are presented for each threatened species, and summarised at an ecosystem level in 'threats' and 'action' sections. Such information must inform conservation management and stakeholder involvement, and in many cases significant information exists but needs to be incorporated into an encouragingly wide body of legislation and existing plans, and to the activities and responsibility of the varied stakeholders.

Targeted stakeholders or users of this document include organisations and individuals involved with threatened species and ecological communities, alien species, natural resource management especially concerning water, habitat protection, and restoration. These stakeholders will be involved in different ways from being decision makers, providing funding and those involved in implementing or undertaking actions (the doers). They will also have diverse affiliations such as government departments (federal and State), research organisations, educators, funding bodies (government and private sector), non-government organisations, community groups and concerned individuals on the land, in business or involved with fish at some level.

A series of 20 key recommendations provide a first step for more detailed information and awareness on the conservation management of South Australia's freshwater fishes. The major recommendations across three broad categories include:

Securing and restoring habitat and populations:

- **Water:** develop water allocation plans that protect and restore water requirements for sensitive aquatic ecosystems and fish across all regions of South Australia. This will require a strong commitment by stakeholders to ensure freshwater fishes and their habitats remain for future generations.
- **Habitat:** improve riparian and instream condition, vegetation buffers, water quality, and fish passage (past artificial barriers) through well planned and monitored habitat protection and rehabilitation.

- **Protected areas:** improve our understanding of protected areas to provide greater capacity to cater for the conservation requirements of freshwater fishes, including inventory and planning within the existing State Reserve system and investigation of gaps in species or community coverage for future reserve planning.
- **Urgent conservation measures:** undertake actions for high priority species and populations, to protect against existing and potential threats. Implement species recovery plans and regional action plans, encouraging their incorporation into regional Natural Resource Management frameworks.
- **Water quality:** encourage councils, landholders and industry to improve point source and diffuse pollution problems within aquatic habitats (including stormwater).
- **Alien species:** undertake targeted control of alien species to facilitate recovery and improve resilience of impacted native fish populations.
- **Climate change:** plan for the impacts of climate change, especially potential reductions in available surface water during dry periods.

Improving knowledge and awareness:

- **Biodiversity:** develop a sound systematic framework for all freshwater fish species in South Australia, even for 'common' species that may actually have more complex genetic patterns. This work also needs to be supported by taxonomic studies.
- **Accessible data:** build a detailed database of freshwater fish distribution which incorporates existing data and identifies data gaps or areas without recent inventories.
- **Meaningful research:** incorporate research priorities into NRM and funding programs to underpin effective implementation of on ground works, flow restoration programs and conservation biology.
- **Let people know:** develop a broader education and communication strategy to improve stakeholder and community awareness; undertake targeted awareness raising programs to improve the profile of key threatened species and the level of awareness of key threatening processes.
- **Review:** the Action Plan information should be reviewed every five years, and status assessment and Recovery Outlines updated every two years.

Policy and management:

- **Collaboration:** initiate engagement of stakeholders through a coordinated body or working group to drive policy, awareness raising and to connect people, agencies and states. Develop recovery teams for threatened fishes.
- **Protection:** work to enhance the legislative framework for protecting species, ecological communities and habitats in South Australia through review, development and strengthening of existing Acts and policy. This process should explicitly consider the conservation requirements of fishes and remove perverse incentives.
- **Status:** review federally listed species and ecological communities to incorporate new information.
- **On the front foot:** Develop a coordinated strategy for proactive protection of flows and habitats with high natural value or minimal disturbance, especially in the Lake Eyre Basin.
- **Biosecurity:** Formulate a 'fish introduction, translocation and stocking strategy' to provide proactive measures to address the problem of existing and potential alien fish and disease.
- **Use:** further promote ecosystem based fisheries which recognise the intrinsic value of all native species, sustainable practice and the protection of wild habitats.
- **The triple bottom line:** initiate significant improvement in the recognition and incorporation of fishes into ecologically sustainable development (e.g. planning).
- **Capacity:** address the need for increased capacity to undertake action in South Australia.

Acronyms used in this document

Regions		Organisations	
SA	South Australia	NFA(SA)	Native Fish Australia (SA)
MDB	Murray-Darling Basin	DEH	SA Department for Environment & Heritage
MLR	Mount Lofty Ranges	TSSS	Threatened Species Schedule Subcommittee (SA)
EMLR	Eastern MLR	TSN	Threatened Species Network
WMLR	Western MLR	CCSA	Conservation Council of SA
AMLR	Adelaide & MLR	DWLBC	Department of Water, Land and Biodiversity Conservation
SE	South East	PIRSA	Primary Industries and Resources SA
KI	Kangaroo Island	SARDI	SA Research & Development Institute
LEB	Lake Eyre Basin	NRM	Natural Resources Management (Board)
SAAL	South Australian Arid Lands	EPA	Environment Protection Authority (SA)
NY	Northern & Yorke Peninsula	LAP	Local Action Planning Association
EP	Eyre Peninsula	SEWCDB	SE Water Conservation and Drainage Board
NP	National Park	USE Program	Upper South East Dryland Salinity and Flood Management Program
CP	Conservation Park	MDBA	Murray-Darling Basin Authority
RP	Recreation Park	DEWHA	Department of the Environment, Water, Heritage and the Arts Formerly Federal Department of the Environment and Heritage
GR	Game Reserve	IUCN	World Conservation Union
WPA	Wilderness Protection Area	SAMA	South Australian Museum, Adelaide
		AWQC	Australian Water Quality Centre
Other		**Conservation status**	
ESD	Ecologically sustainable development	EX	Extinct in SA
WAP	Water Allocation Planning	CR	Critically endangered
EWR	Environmental Water Requirements	EN / E	Endangered
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*	VU / V	Vulnerable
EHNV	Epizootic Haematopoietic Necrosis Virus	R / RA	Rare
SMART	Specific, measurable, achievable, realistic and time-bound	NL	Not Listed

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The data employed in mapping combined information from multiple sources, kindly provided with permission for restricted use by NFA(SA), Aquasave, SARDI, SA Water Quality Centre, AMLR & SAMDB NRM Boards, DEH (SE region), DWLBC, University of Adelaide, SA Museum, Victorian Museum, and Australian Museum. The following individuals were most helpful in data provision or other tips and information on species distribution: Darren Hicks, Tarmo Raadik, Ralph Foster, Qifeng Ye, Dale McNeil, Ben Smith, Peter Schultz, Dianne Bray, Mark McGrouther, Peter Unmack and Rudie Kuiter. Ruan Gannon and Roman Urban provided technical support for data verification and GIS mapping. Numerous NFA(SA) members or associates were involved with surveying significant regional data gaps identified at the inception of the program including: Ruan Gannon, Simon Westergaard, Troy Ristic, Scott Slater, Tom Barnes, Sam Eastley, Justin Rowntree, Dylan Sortino and Michael Roberts.

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Section 1 Introduction

The 'Action Plan for South Australian Freshwater Fishes' aims to provide information that will help managers and the community alike to better understand the diversity of South Australian freshwater fishes and provide specific information for the protection of threatened species and their habitats. This involves raising awareness of the sorts of things required to improve the status of South Australia's freshwater fish at broad and local scales, to spark ideas of how important actions might be achieved, and importantly identify opportunities for groups or individuals to get involved and make a difference.

The overall objective is to improve the collective status of freshwater fishes in South Australia. This should involve documenting a positive response to actions combined with improved information to enable a downgrading in species status. Specific objectives are to:

- Raise awareness of the presence and plight of freshwater fishes and the need for action.
- Comment on the current state of knowledge and information gaps for threatened fish species.
- Identify priority actions for improving the status of freshwater fishes in South Australia.
- Provide information and options for stakeholders on how they can contribute to conservation.

The targeted users or stakeholders for this document are broad and includes organisations and individuals involved with threatened species, threatened ecological communities, alien species, natural resource management (especially concerning water), habitat protection, and restoration. These stakeholders will be involved in different ways ranging from being decision makers, providing funding and being involved in implementing or undertaking actions (the doers). They will have diverse affiliations ranging from government departments (federal and State), local government, research organisations, educators, funding bodies (government and private sector), non government organisations, community groups and concerned individuals on the land, in business or involved with fish at some level.

The general layout of the document is to firstly provide background information (Section 1), specific reviews of the status and recovery objectives for threatened fishes (Section 2) and an overview of potential threats (Section 3). Section 4 provides a summary and strategic direction for conservation and management options with general supporting information in Section 5.

A "freshwater" fish is defined here as those that spend some or all of their life within inland aquatic habitats (freshwater) as opposed to estuarine or marine environments[1]. It is important to note however, that 'fresh water' is often slightly or moderately saline in South Australia. Freshwater fish include species that complete their life cycle inland (obligate freshwater species), diadromous species which move between freshwater and estuarine/marine habitats for one or more lifecycle stages, and select euryhaline species (comfortable in either fresh or salt water) known to complete their lifecycle inland. The correct biological term when referring to more than a few individuals of one fish species or for two or more species, is fishes. However in common use fish and fishes are often used interchangeably. The term 'alien' species is a collective term used to describe species exotic to Australia (SA *Fisheries Management Act 2007*) and Australian native species translocated outside their natural range (can also be referred to as introduced species). A summary of acronyms appearing throughout the text is contained at the start of the document.

1.1. **Why be concerned about freshwater fish?**

Fishes are one of the most diverse groups of animals on earth and are a key part of aquatic biodiversity. They make up over half the world's vertebrates, and have a huge variation in basic body forms and biology[2]. Around 10,000 known species occur in freshwater which is about 40% of all fishes, a staggering number considering their habitat makes up only a tiny area of the earth's surface (less than 0.01%).

In addition to being species rich, freshwater fish have high levels of genetic diversity[3]. Most freshwater systems are trapped within small sections of the landscape isolated by physical barriers such as the sea, mountains, waterfalls, and dry areas like deserts. Other biological barriers such as predators and unsuitable habitat also isolate populations to particular areas. Populations isolated for long periods begin to diverge from one another and can become genetically and biologically distinct. Outlying populations at the edge of a species range or in unusual habitat can be quite different (and not easily replaced) and may have accumulated characteristics to help the species adapt to changing conditions in the future.

Being so well represented in aquatic environments, freshwater fishes also have a variety of intrinsic and human related values. For example they are a critical part of conserving aquatic biodiversity, and of complex ecosystems and food chains. Being reliant on underwater habitat for survival they can be indicators of the condition or health of waterways. Some of their roles in the environment are important to humans (e.g. mosquito control) and there is significant cultural value at basic levels such as for food, and more complex interactions (e.g. recreation, mythology). These values combine to make fishes icons for the sustainable use and protection of aquatic habitats.

In addition to their diversity and ecology, a major reason why we should be concerned about freshwater fishes is that they are a group under threat. Around the world they are disappearing at a rapid rate and high numbers are threatened with extinction[4,5,6,7]. Australia is no exception, with 33 of around 300 species currently listed at risk of extinction under national legislation (*EPBC Act 1999*).

No known species has been recorded as extinct in Australia, but some species may well have disappeared since European settlement without being noticed. There have also been some close calls and many species are now clearly on the verge of extinction. For example the Lake Eacham Rainbowfish disappeared in the 1980s from Lake Eacham on the Atherton Tablelands Queensland (its only know habitat at the time), following the introduction of alien fishes[8]. It was rediscovered in nearby streams but the distinctive lake population has been lost. In Tasmania the Pedder Galaxias rapidly disappeared from its only known habitat of Lake Pedder following threats relating to damming for hydroelectric development and introduced fishes, and is now extinct in the wild[9,10]. Fortunately the decline was noted in time and a small number of fish were transferred to a habitat outside its natural range where the species does seem to have become established. The Trout Cod, once widespread throughout the southern Murray-Darling Basin, now has only one small natural population remaining on the Murray River near Yarrawonga Victoria[11]. There are many examples of species clinging to small pockets of ever dwindling habitat especially Barred Galaxias, Redfinned Blue-eye, Oxleyan Pygmy Perch and Mary River Cod[12].

1.2. **A South Australian perspective**

In South Australia many of the concerns relating to freshwater fishes are even more heightened. The region is reputed to be the driest State on the driest inhabited continent on earth, and thus freshwater habitat is very limited and different systems are quite isolated. At the same time there is a surprising diversity of freshwater fishes and consequently the few aquatic habitats are vital for their survival, particularly during dry periods.

Around 60 freshwater fish species have so far been recorded in South Australia (Table 1)[1]. They range in size from the mighty Murray Cod which can reach over one metre in length, to the tiny Dwarf Galaxias which has an adult size of 2-3cm (the majority of native species grow no larger than 10cm). Ongoing genetic research at the SA Museum indicates that additional cryptic species are likely to be uncovered and that distinct genetic populations occur in isolated sections of the State[13,14,15,16].

The main interest in freshwater fishes in South Australia has traditionally focused on those species with recreational or commercial value in fisheries. Some smaller species have attracted interest in regard to their natural history (e.g. Southern Purple-spotted Gudgeon[17,18]) but overall this has been minimal. Efforts to understand and conserve native species have fallen behind that of other animal groups. Much recent energy has gone towards highlighting exotic species, especially Carp[19,20], such that this species is perhaps better known by the public and researchers than the majority of native species.

Fortunately a new interest in natural resource management has seen native fish become an increasing focus of conservation and management concern. Community and government organisations are taking more holistic approaches to biodiversity conservation and the sustainability of local waterways, to now include underwater components such as fishes. The notion of biodiversity protection and habitat restoration is also becoming more widely accepted and practiced at a State and national level (e.g. Landcare and Catchment groups, 'SA no species loss strategy', national conservation lists and legislation).

Some native fish species have risen to prominence within local management in South Australia. The Flinders Ranges Purple-spotted Gudgeon occurs only in a small section of stream in the rocky north Gammon Ranges. Its home recently came under threat from a proposal for an open cut mine within a National Park, but the conservation of the gudgeon was one of the factors used to lobby for continued protection of the unique local habitat (Figure 1). The Murray Cod (or Ponde) is without doubt our best known fish, being a long term focus of fishing and indeed culture in South Australia. Its significant decline and recent national listing helps to bring home the message regarding the decline in health of the River Murray system, and the urgent need to improve the situation. A much smaller relative of the Murray Cod, the Southern Pygmy Perch, is becoming an icon for restoration and awareness of fishes and aquatic habitat in the Mount Lofty Ranges[21,22].

Size extremes of South Australian freshwater fishes - the tiny Dwarf Galaxias and mighty Murray Cod

Tiny fish blocks park mine

EXCLUSIVE

By Political Reporter
HUW MORGAN

A TINY fish and a wallaby have sunk a plan to mine in the Gammon Ranges National Park in the state's Far North.

Concern for the habitats of the purple-spotted gudgeon and the yellow-footed rock wallaby have resulted in the State Government refusing access to a company wanting to mine magnesium from the park.

Environment Minister Iain Evans, who visited the park yesterday, has refused the transfer of a mining lease which lies 1.5km along either side of the environmentally sensitive Weetootla Gorge in the remote park, about 700km north of Adelaide.

Adelaide-based company Manna Hill Resources had applied to have the lease transferred from the current holders, BHP. It wanted to mine the area over a 50-year period.

The company had planned to completely excavate two large hills rich in magnesite, which is used in the production of magnesium.

The company believed there was a 20 million tonne deposit in the area.

Manna Hill Resources had also planned to use Weetootla Gorge as an access road for trucks to haul the magnesite to processing plants.

The gorge is home to a range of aquatic life – including the Flinders Ranges subspecies of the purple-spotted gudgeon which grows to about 90mm in length.

● Continued Page 2

Tiny fish ends park mining plans

● From Page 1

The fish is listed as a vulnerable species.

The yellow-footed rock wallaby is also found in the area and is listed as a vulnerable species at state and national levels.

Mr Evans has power over the lease transfer and was required to have an environmental statement prepared.

He said his decision to block the lease transfer was based on "major environmental concerns" presented by the Department for Environment and Heritage and the Wilderness Advisory Committee.

"I am advised that disruption of the natural drainage pattern by removing large portions of nearby hills and construction of an access road along the creeks would represent an unacceptably high impact, with a real risk that the gudgeon would become locally extinct," Mr Evans said.

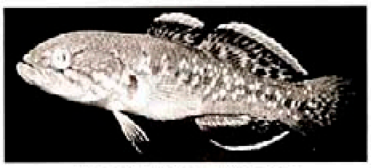
"Likewise, a mine would remove habitat and cause disturbance through noise and activity and may have an impact on the quality and quantity of the water source for the yellow-footed rock wallaby, which would be detrimental to its continued existence.

"If you look at all of the environmental values, whether it be the native animal species or the native vegetation, or just the sheer beauty of the place, in my mind there is no way you can allow mining there."

The news was greeted with elation yesterday by walkers in Weetootla Gorge. One of the walkers, Sue Barker, was director of the South Australian National Parks and Wildlife Service when Weetootla was added to the park in 1982.

"It's tremendous," Ms Barker said. "South Australia would have been a laughing stock if this mine had been allowed to go ahead."

The 128,000ha park attracts more than 20,000 visitors a year.



The purple-spotted gudgeon.

The yellow-footed rock wallaby.

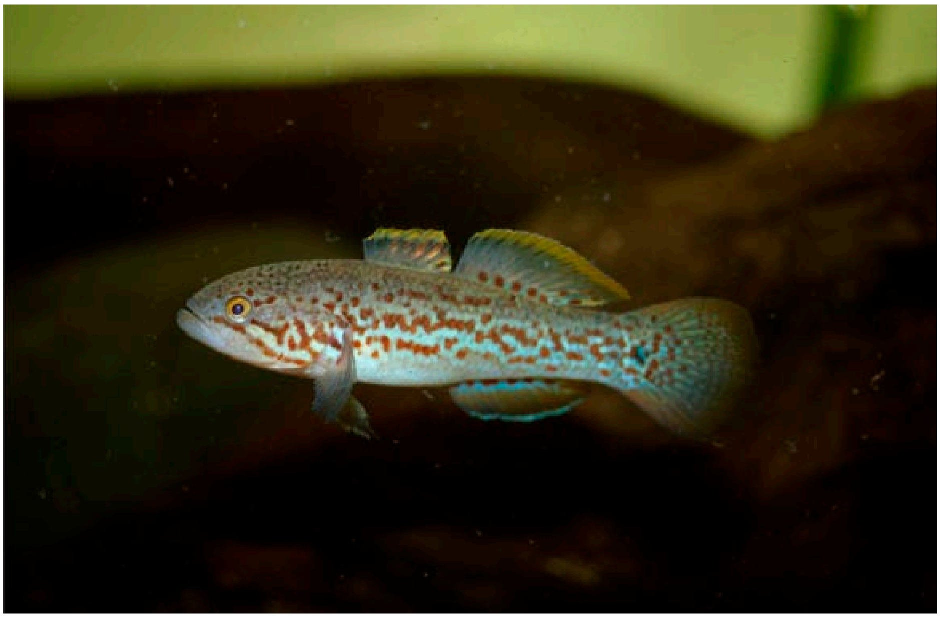
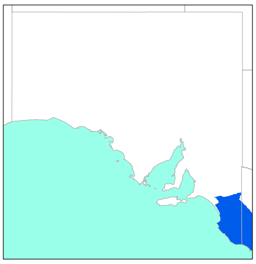


Figure 1. Freshwater fish as icons for sustainable development and ecosystem protection. Newspaper cutting from "the Advertiser" 30th August 2000, with added colour photograph of the Flinders Ranges Purple-spotted Gudgeon.

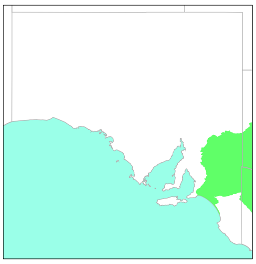
1.3. **Fish habitat in South Australia**

South Australia is an expansive area (close to one million km^2) with considerable variation in climate, geology, hydrology (processes involving water) and human landuse across different sections of the State. For the most part, surface water is generally rare due to low rainfall and a lack of significant mountains (see Figure 2), so any habitats present are important refuge. In fact many people are surprised to learn of the presence of native fish in their local waterway and of the highly varied places native fishes can be found. From tiny mound springs in flat, hot desert landscapes, to small local streams or wetlands, through to urban rivers flowing through Adelaide like the Torrens - most places with permanent water have fish. Some species are even able to colonise some temporary or seasonal habitats.

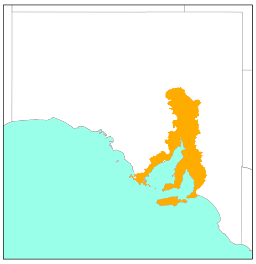
The principal organisation of aquatic habitats in SA is defined by five major Drainage Divisions, each containing different habitats and fishes (Appendix 1 and Appendix 2):



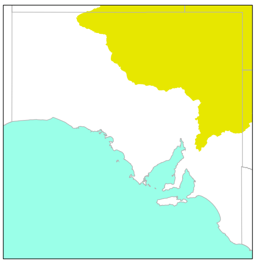
South East Coast - a naturally wetter region of the State containing a diversity of habitats[23]. The most significant is spring pools and creeks of the Lower South East especially Ewens Ponds. Mosquito Creek and Henry Creek are important stream refuges. The majority of natural wetland habitat in the region has been drained since European settlement; however remaining habitats include Bool Lagoon, coastal wetlands, and the Dismal Swamp corridor. Drains, while artificial, are the only alternate habitat in many areas (e.g. Drain L and Millicent area) and thus have refuge value.



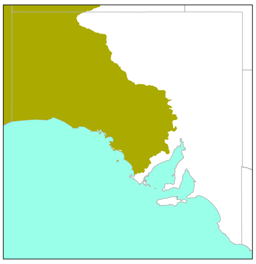
Murray-Darling Basin – the iconic River Murray flows across a third of Australia and ends its journey through South Australia. The main channel itself provides habitat for many species, and is interlinked with wetland and anabranch habitat, including the Chowilla system. Wetland areas of the Lower Lakes are particularly important with high species diversity and many threatened species[24]. The Eastern Mount Lofty Ranges draining into the Murray and Lower Lakes also contains a variety of streams between Currency Creek to Burra Creek which are important refuges[22,25].



South Australian Gulf – a region with several distinct subsections including (a) coastal streams on Kangaroo Island[26], (b) the southern Fleurieu Peninsula[27], (c) the western Mount Lofty Ranges including larger streams such as the Onkaparinga, Torrens, Gawler and Broughton rivers[28], (d) Lake Torrens catchment including Willochra Creek and the western Flinders Ranges and (e) Yorke and Eyre peninsulas (e.g. Tod River, coastal lakes).



Lake Eyre Basin - the desert region in the northeast of the State contain highly unpredictable but unregulated inland waterways such as the Cooper Creek, Diamantina River and Neales River feeding to the core of Lake Eyre, with a surprising variety of fish species for such a harsh environment[1,29]. Artesian mound springs serve as oases in otherwise desolate landscapes and are hot spots for uniquely adapted fauna, especially Dalhousie Springs[30,31]. The rugged north Flinders Ranges also has pockets of permanent habitat[32].



Western Plateau – very little permanent water exists in the expansive region, nevertheless some coastal lakes contain fishes and there are odd reports from more inland areas[1,33].

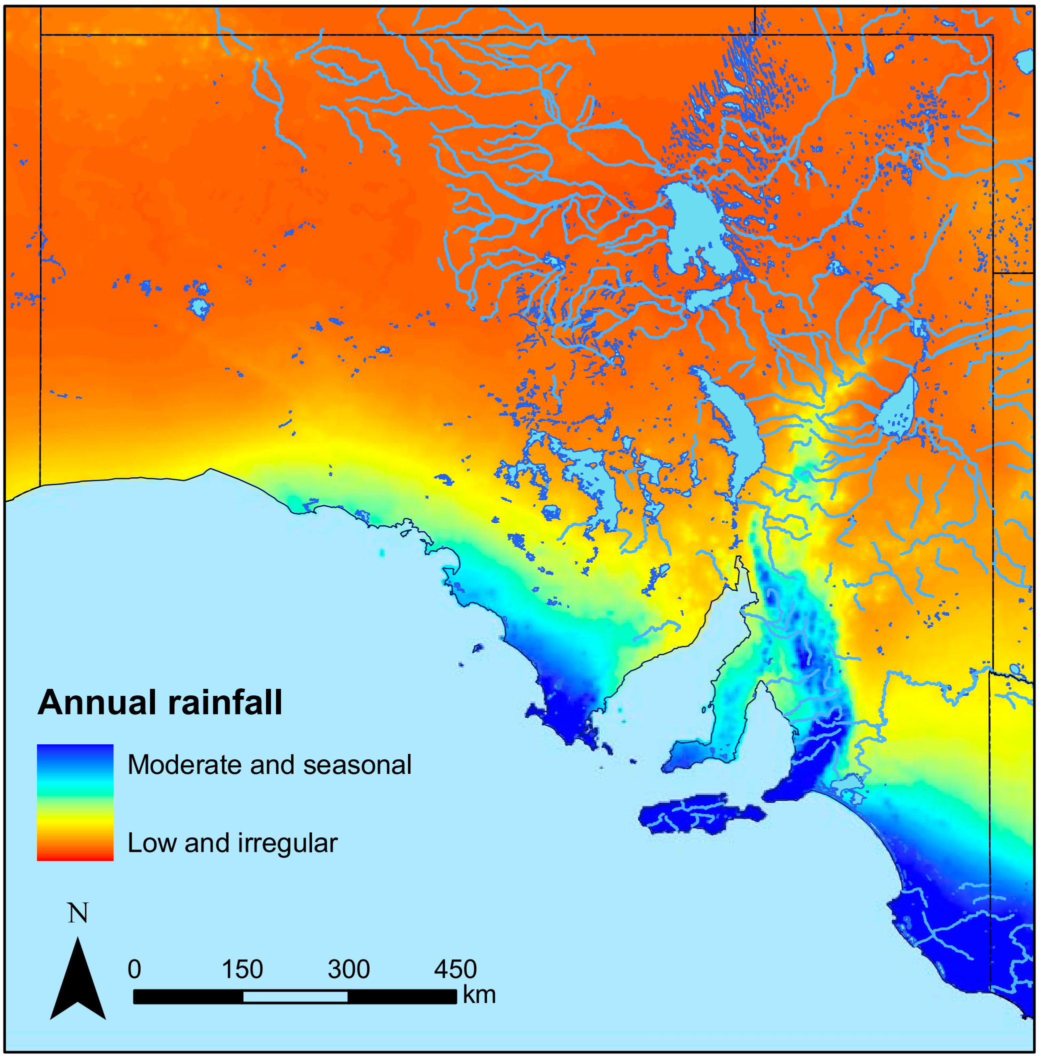


Figure 2. Map showing annual rainfall patterns in South Australia.

Extremes of aquatic habitat in South Australia (Drought and Flood)

1.4. **Recognising South Australia's threatened fishes**

Threatened species lists are useful in explaining the importance of recovery or loss of species, and can provide a clear social and political mandate for action. Lists can span different levels of management and are normally applied on political boundaries, but should come with particular background information and instructions or cautions on their use (see below). There is an increasing focus on conservation of ecological communities and bioregions rather than isolated species, however broadly-focused projects can overlook more specialised requirements of rare and threatened species and a combined top down and bottom-up approach will likely work best. Species are also more recognisable units within conservation and recovery planning, particularly for the broader community.

There has been an historic lack of information regarding the plight of native freshwater fishes in South Australia which has acted as a severe impediment to their conservation. Species without direct commercial (fishery) value have essentially been left unmanaged. The first indications of concern for some species appeared in the mid-1980s[34,35], later followed by a list of eight State 'endangered' species, including several species already presumed locally extinct[36]. The endangered eight received the official status of 'protected' under State based fisheries legislation (*Fisheries Management Act 2007*). However, no formal plans for action were ever designed or implemented, with the exception of a local recovery outline recently developed for the threatened Southern Pygmy Perch in the Mount Lofty Ranges[22]. Freshwater and marine fishes are the only vertebrates that do not currently have official conservation status in South Australia. This Action Plan and a separate review for marine species[37] aim to address this deficiency.

At a national level a broad framework for protecting fishes is provided in the "Action Plan for Australian Freshwater Fishes[12]". This serves as a useful information source and recovery document for some species which occur wholly or partially within South Australia (although it is now a bit dated). More recently a handful of species have been listed under national legislation (*EPBC Act 1999*) with national recovery plans developed or in progress. Species that are considered common across broader ranges in south eastern Australia, but which are threatened in South Australia, are not considered in national recovery, and regional populations of those species nationally listed may not receive adequate attention to prevent local disappearance from the State.

The first attempt to provide an official State list of threatened freshwater fishes, based on defined criteria, was undertaken from available information at the time (2002) by a panel of experts guided by the Threatened Species Schedule Subcommittee (TSSS) with the intent of listing under the threatened species legislation of the *National Parks and Wildlife Act 1972*[12,38]. The Draft of this document provided a 2007 update of this list and included extensive supporting material on species status and ways for protecting and conserving South Australia's freshwater fishes. The 2009 final version of the Action Plan includes review to incorporate the latest information on status updates.

1.5. **Development of the Action Plan**

The initial list of South Australian threatened freshwater fishes revealed that over half the State's native species were threatened. In addition, a large proportion of the listed species were considered highly threatened, requiring urgent attention to prevent their loss from the State. The seriousness of the situation resulted in the TSSS investigating strategies to increase awareness about the plight of freshwater fish in SA. The preparation of an Action Plan was considered one of the most appropriate ways to address the varied and often specific issues relating to freshwater fish conservation, particularly as such a plan would provide valuable background information and also strategies for the recovery of each taxon. Native Fish Australia (SA) has prepared this Action Plan with considerable financial and in-kind support from a number of organisations.

Phase 1 in development of this Action Plan, initiated in 2002, was designed to collect distributional information and literature as background to compiling the 'Action Plan' document. A large component of this involved a review of South Australian Museum specimens to verify identification and any other specimen details to provide an accurate database for faunal mapping and reference. This stage of the review also highlighted some important field survey requirements for gaps in distributional coverage and these were targeted as part of NFA(SA)'s 'Fish Inventory' program[23,25,27,28]. Phase 1 was undertaken with financial grants from the Nature Foundation (SA) and the Wildlife Conservation Fund, with support of DEH and the SA Museum. Phase 2, completed in 2006, drew on the previous work by collating and interpreting species information (distribution and literature) within the production of species based Recovery Outlines, and an overarching structure (e.g. background to fish and aquatic habitats, threatening processes, regional and species priorities). Funding was obtained through a Threatened Species Network Community Grant from WWF Australia, with GIS and document support provided by DEH. A third phase involving review and production of this document to the 2009 final version involved funding from Department of the Environment, Heritage and the Arts along with numerous parties who are mentioned in the acknowledgements.

1.6. **Data sources**

The process for obtaining information for assessing species status and informing Recovery Outlines involved three key steps to provide the necessary information:

- A review of historic fish specimens housed in Museums, including a detailed examination of those at the South Australian Museum, Adelaide.
- A literature review to collate survey locations, past and present species distribution records, and biological or management information (with a focus on local sources).
- Mapping the records obtained using GIS software to firstly verify the spatial location of points, and to then map past and present distributions.

Historic records are defined as those before 1990. The main source of historic records for South Australia is with specimens lodged at museums, with a few published studies and other miscellaneous literature reports.

Example of an historic record from the South Australian Museum

Museum data

the majority of records are maintained in the South Australian Museum with smaller but useful data sets at the Australian Museum, Sydney and Victorian Museum, Melbourne, and with a few records from overseas institutions (e.g. Staatliches Museum für Naturkunde, Stuttgart Germany). Databases of museums were searched by direct enquiries with the three main museums mentioned, and by searching online internet catalogues for other records. Museum specimens have the advantage of being able to be inspected to verify identification in the majority of cases.

For the South Australian Museum, a more in-depth examination was made through the physical examination of historic specimens applying current taxonomic keys and checking specimen details. This process generated a wealth of information such as (a) the identification of two new species for South Australia, (b) over 200 updates in identification including for threatened species previously confused with more common ones, (c) lodgement of previously unregistered material to provide additional records, and (d) the addition of information on location, date and insightful notes from original collection details.

Generally museum records are patchy in space and time and are not reliable as a fine scale assessment of distribution and species status. For example, fish specimens deposited at the South Australian Museum often overlook local areas for more exotic locations, or favour unusual or interesting finds rather than being representative for a site or from systematic sampling. They also tend to be biased against larger angling species (these apparently tended to be eaten rather than deposited!). That said the overall coverage is extremely valuable with almost 3000 records extending from as early as the 1860s (Appendix 3). Thus museum records are best used as comparison data for recent surveys, and can help provide indication of fish declines when used in such a way.

Literature reports

records from literature sources need to be carefully assessed as to the reliability of identification (e.g. if voucher specimens or photographs were retained for certain species). Very few published articles with a suitable level of information appeared prior to 1990, and these covered only certain areas of South Australia. A seminal study investigated the distribution of small fishes of the River Murray region in the early 1980s[35,39], and a small investigation was undertaken on the Marcollat Watercourse of the South East40. Some more extensive and representative sampling for areas around Lake Eyre, Kangaroo Island and the South East between the 1970s and mid-1980s, form part of the collection at the SA Museum. Other information sources include articles mentioning specific locations for species of interest for aquarists in the early 1900s[41,42], general accounts of species or regions[29,32,43,44,45,46,47,48], carefully scrutinised oral history records in more recent surveys[25], and long-term data from commercial fisheries (see later). Although not mapped here, fine scale data has been collected for fishes at Dalhousie Springs in the North East of the State[30,49].

Current records include museum records after the start of 1990 (presence only) and records from a hive of activity on the research front, mostly since 2000 covering around 1400 sites. Research data was included as a specific data subset for mapping (i.e. survey sites) to provide a basic assessment of presence and absence of a species from a site. However, this may not necessarily be reliable as it depends on the objectives of the research, types of sampling equipment used, skills of the researchers and time period of investigations, and should be considered as a guide only. Only records that could be validated were included (e.g. where vouchers or photographs provided proof of identify for certain species groups or outlying records). The data sources used for mapping are described below.

Native Fish Australia (SA) has undertaken a series of surveys in the State since 1999 providing baseline information at close to 1000 sites for many regions including: the South East[23], Hindmarsh Island and Lower Lakes[24,50], Eastern Mount Lofty Ranges[25,51,52], Kangaroo Island[26], Adelaide Hills (Torrens and Patawalonga catchments)[28,53], parts of the Southern Fleurieu Peninsula[27,54] and miscellaneous locations across the State[55,56,57] (see Figure 3).

The Inland Waters branch of SARDI Aquatic Sciences has had an increasing involvement with freshwater fish research in recent times, principally associated with the River Murray region (Appendix 3).

SARDI data sources available for the Action Plan included:

- Sustainable Rivers Audit – part of a Basin wide initiative of the MDBA to monitor river health (pilot phase and first implementation period data).
- Fishway assessments – data from the vicinity of locks 1, 2 and 3.
- Drought monitoring and threatened species monitoring on Hindmarsh Island[58,59].
- Wetland baseline survey (see below).
- Commercial Fisheries data – summary catch data for 32 River Reaches from 1990 onwards.

Various other research projects with documented data points (Appendix 3) include:

- Students from the University of Adelaide have undertaken several studies documenting species distribution in the SAMDB[13,60,61,62,63].
- ARIDFLO – sites in the Neales, Diamantina and Cooper catchments as part of a long term ecological investigation overseen by DWLBC (2000-2003)[64].
- Mid North ecology reports – broad scale surveys of fishes in the Gawler, Wakefield, Light, and Broughton river catchments in 1998 and 1999 as part of Department for Environment and Heritage healthy rivers assessments[65,66,67,68].
- River Murray Wetlands baseline survey – surveys in wetland habitat along the River Murray (2004 & 2005) conducted for the SAMDB NRM Board[69,70].
- AWQC reports - surveys in the Western Mount Lofty region below reservoirs for stream condition assessments and environmental flows[71,72,73].

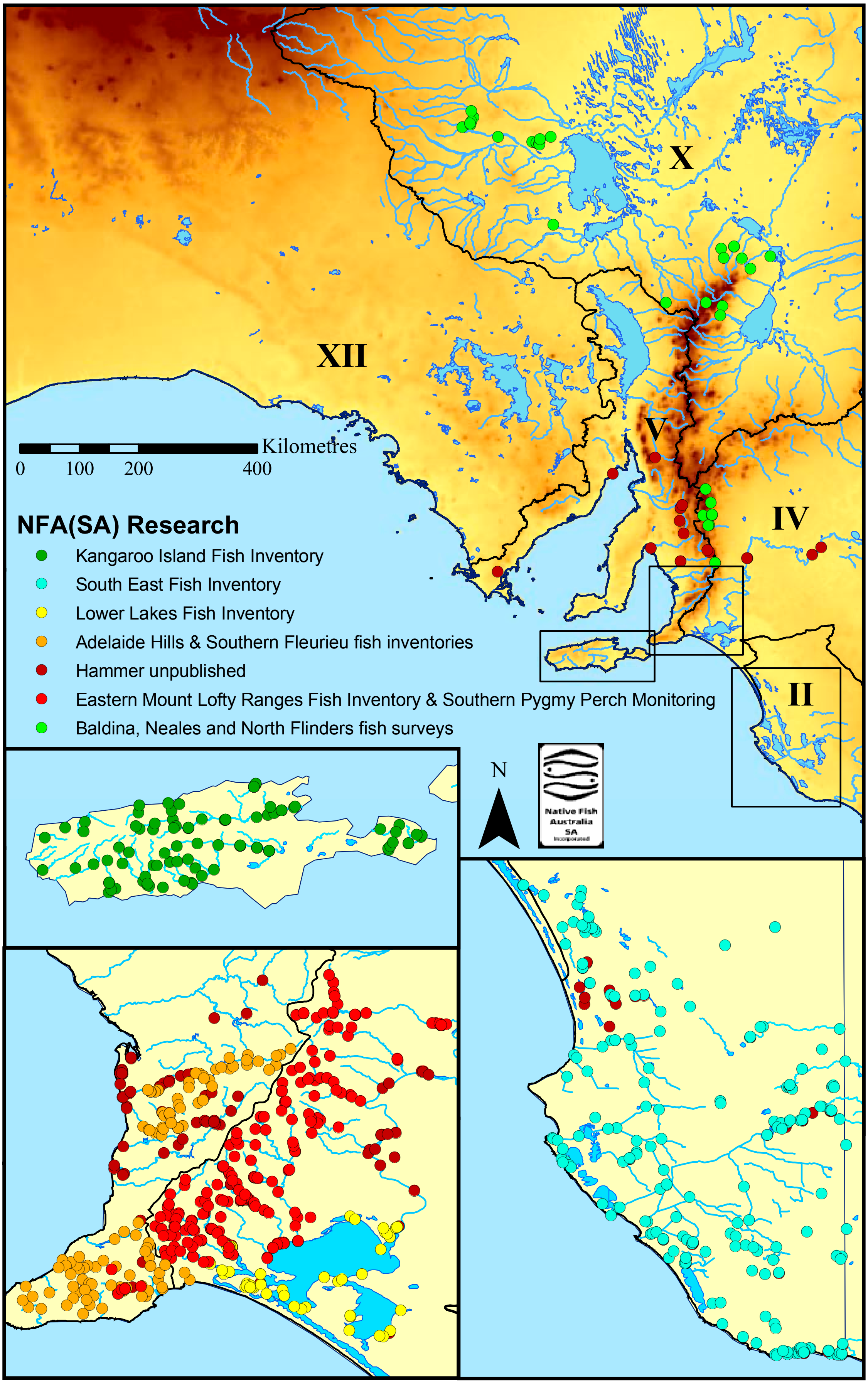


Figure 3. Location of NFA (SA) sampling sites from recent regional surveys in the State (2001-2007).

1.7. **Conservation criteria and 2009 list**

The criteria used to define threatened fish species here are the same as those applied to other animal and plant groups in South Australia[38] and are based on categories and definitions from the internationally accepted IUCN red list process[6]. There are five categories for different levels of extinction risk (listed starting with the highest): Extinct in the wild (EX), Critically Endangered (CR), Endangered (EN), Vulnerable (VU) and Rare (RA). Each category has a set of criteria that need to be met based on information such as the area of habitat the species occupies and recent or inferred declines - all are explained in Appendix 4. The emphasis in this process is on preserving all species known to occur in South Australia and can include protecting species that occasionally move into the State, but that may not necessarily have permanent or sustaining populations.

The assessment process covered the 58 known species in South Australia, 32 of which were considered threatened (Table 1). Hence 55% of the State's species are at risk, with several others close to qualification (see Section 2.4). Many species also occur in habitats which could undergo further deterioration, especially the River Murray, thus rapidly elevating species to higher categories of extinction risk. The breakdown of current risk of extinction by category is:

- Extinct in South Australia – 3 species (5%)
- Critically Endangered – 8 species (14 %)
- Endangered - 9 species (16 %)
- Vulnerable – 9 species (16%)
- Rare – 3 species (5 %)
- Not Listed – 26 species (45 %)

Examining different families, the perches (Percichthyidae) stand out as a highly threatened group having the highest number of threatened species - 8 species or 80% of the family listed (Figure 4). Galaxias (Galaxiidae) also have both high numbers (6) and a high percentage of species listed (85%), followed by hardyheads (Atherinidae) – 4 species (60%) and catfishes (Plotosidae) – 3 species 60%). Several families are represented by single threatened species (100% of State representation) – the lampreys (Geotriidae and Mordaciidae), eels (Anguillidae) and Congolli (Pseudaphritidae).

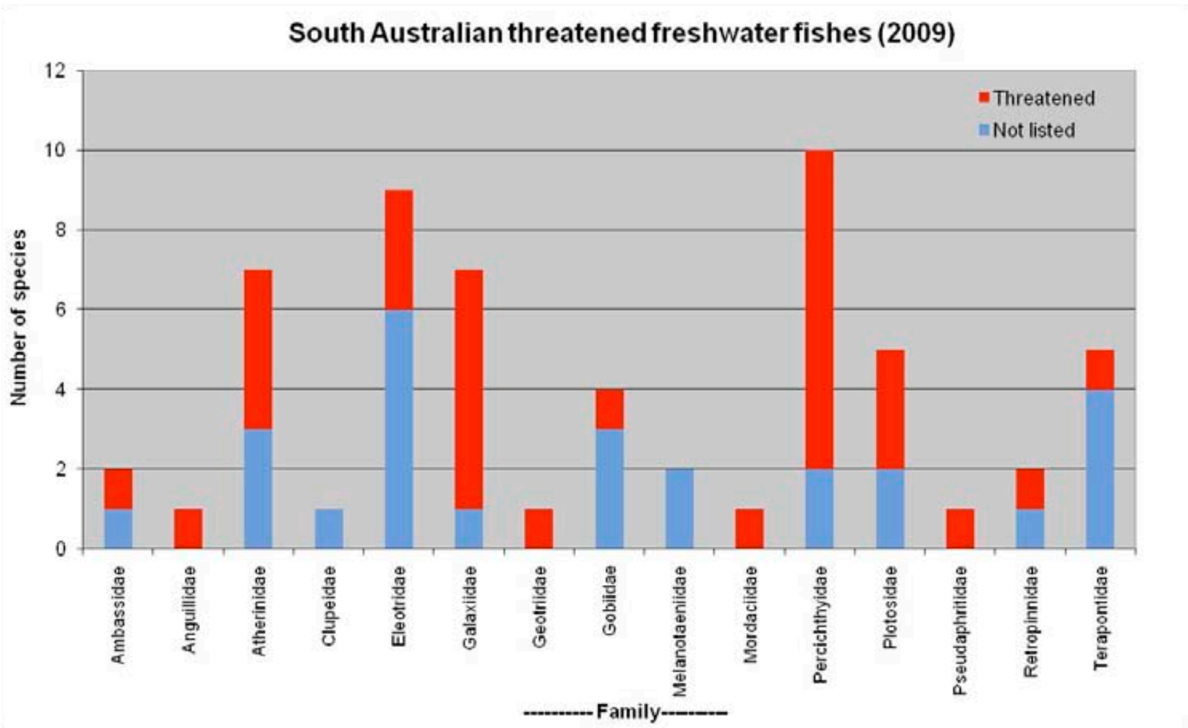


Figure 4. SA threatened fishes by family (2009 Action Plan status).

2009 Action Plan For South Australian Freshwater Fishes

Table 1. Conservation status of South Australian freshwater fishes (2009).

EX – Extinct in South Australia, CR - Critically Endangered, EN - Endangered, VU – Vulnerable, RA – Rare (IUCN criteria, Appendix 4), P – Protected (*Fisheries Management Act 2007*)
(*) = SA endemic species.

Taxon	Common name	International *IUCN Red List*	National *EPBC Act 1999*	State Fisheries *FM Act 2007*	Action Plan *2009*
Geotria australis	Pouched Lamprey				EN
Mordacia mordax	Shortheaded Lamprey				EN
Anguilla australis australis	Shortfinned Eel				RA
Neosiluroides cooperensis	Cooper Catfish				RA
Neosilurus gloveri	Dalhousie Catfish				VU
Neosilurus hyrtlii	Hyrtl's Catfish				
Porochilus argenteus	Silver Tandan				
Tandanus tandanus	Freshwater Catfish			P	EN
Nematalosa erebi	Bony Herring				
Prototroctes maraena	Australian Grayling	VU	VU		EN
Retropinna semoni	Smelt				
Galaxias brevipinnis	Climbing Galaxias				RA
Galaxias maculatus	Common Galaxias				
Galaxias olidus	Mountain Galaxias				VU
Galaxias rostratus	Flathead Galaxias	VU			EX
Galaxias truttaceus	Spotted Galaxias				EN
Galaxiella pusilla	Dwarf Galaxias	VU	VU		VU
Neochanna cleaveri	Tasmanian Mudfish				CR
Melanotaenia fluviatilis	Murray Rainbowfish				
Melanotaenia splendida tatei	Desert Rainbowfish				
Atherinosoma microstoma	Smallmouthed Hardyhead				
Craterocephalus dalhousiensis	Dalhousie Hardyhead*	VU			VU
Craterocephalus eyresii	Lake Eyre Hardyhead*				
Craterocephalus fluviatilis	Murray Hardyhead	EN	VU		CR
Craterocephalus gloveri	Glover's Hardyhead*	VU			VU

Table 1. Continued...

Craterocephalus stercusmuscarum fulvus	Unspecked Hardyhead				
Craterocephalus stercusmuscarum ?stercusmuscarum	Flyspecked Hardyhead				VU
Ambassis agassizii	Chanda Perch			P	CR
Ambassis sp.	Western Chanda Perch			P	
Gadopsis marmoratus	River Blackfish			P	EN
Maccullochella macquariensis	Trout Cod	EN	EN	P	EX
Maccullochella peelii peelii	Murray Cod		VU		EN
Macquaria ambigua ambigua	Murray-Darling Golden Perch				
Macquaria australasica	Macquarie Perch		EN		EX
Macquaria colonorum	Estuary Perch				EN
Macquaria sp.	Lake Eyre Golden Perch				
Nannoperca australis	Southern Pygmy Perch			P	EN
Nannoperca obscura	Yarra Pygmy Perch	VU	VU	P	CR
Nannoperca variegata	Variegated Pygmy Perch	VU	VU	P	CR
Amniataba percoides	Banded Grunter				
Bidyanus bidyanus	Silver Perch	VU		P	EN
Bidyanus welchi	Welch's Grunter				
Leiopotherapon unicolor	Spangled Grunter				
Scortum barcoo	Barcoo Grunter				
Pseudaphritis urvillii	Congolli				VU
Hypseleotris klunzingeri	Western Carp Gudgeon				
Hypseleotris sp. 1	Midgley's Carp Gudgeon				
Hypseleotris sp. 3	Murray-Darling Carp Gudgeon				
Hypseleotris spp.	Hybrid forms (e.g. Lake's Carp Gudgeon)				
Mogurnda adspersa	Southern Purple-spotted Gudgeon			P	CR
Mogurnda clivicola	Flinders Ranges Purple-spotted Gudgeon		VU	P	CR

Table 1. Continued...

Mogurnda thermophila	Dalhousie Purple-spotted Gudgeon*			P	VU
Philypnodon grandiceps	Flathead Gudgeon				
Philypnodon macrostomus	Dwarf Flathead Gudgeon				
Chlamydogobius eremius	Desert Goby*				
Chlamydogobius gloveri	Dalhousie Goby*	VU			VU
Pseudogobius olorum	Western Bluespot Goby				
Tasmanogobius lasti	Lagoon Goby				

Section 2 Species Recovery Outlines

A conservation status reflects a level of extinction risk for a species. In this document, extinction risk relates to the continued survival of the species in South Australia. Status is thus assigned independently of social, management and political implications (status can however, influence these and other factors depending on how such a list is used). The current list of threatened freshwater fishes was instigated by a need to raise awareness of the overall plight of freshwater native fish in South Australia and to enable comparisons across vertebrate groups of the State. The list also provides the basis for developing Recovery Outlines for threatened species which document:

- Conservation status – includes South Australia Action Plan status (criteria are in brackets and match Appendix 4), Protected species (*Fisheries Management Act 2007*), and other national and interstate listings.
- Taxonomy and identification – includes a description of the species and key characters (see Figure 5) for distinguishing between similar species (as a guide only).
- Former distribution – description of historic records (i.e. prior to 1990). Note that the historic and current distribution of many species has not been specifically assessed.
- Current distribution – records after 1990 summarising documented declines and also listing any habitats where the species may be expected to occur.
- Brief overview of species biology and habitat to outline the level of available information for aspects useful for management.
- An assessment of potential reasons for species decline and threats.
- Land tenure and conservation.
- Recovery objectives.
- Details of conservation actions already initiated.
- Required conservation actions to help meet recovery objectives.
- A list of organisations responsible for conservation of the species.
- A list of those already having some involvement with the conservation/management of the species or its habitat.

The information, recovery objectives and required conservation actions contained in Recovery Outlines should be fed into management, community activity, resource allocation and other plans. It is best to define a species as 'Threatened' and refer to recovery objectives and actions rather than prioritising purely on species status. It is also dangerous to rely solely on threatened species lists to limit the use of the natural environment (e.g. development applications). The greater value assigned to an area based on the presence of threatened species is meaningful, but should not be the only consideration as impacts to local ecosystems and genetic diversity for example may be overlooked.

Reactive conservation efforts are often complex, difficult and expensive. Preventative measure for protecting species and ecosystems before they reach a higher category of threat will often be more effective, more cost effective, and have long lived benefits. Hence while the conservation list provided here is an indication of some immediate priorities, a broader purpose of this Action Plan is to provide a holistic idea of what can be done to better protect all species of fish and their habitat in South Australia (i.e. today's common species could be tomorrow's threatened species if preventative measures are not taken).

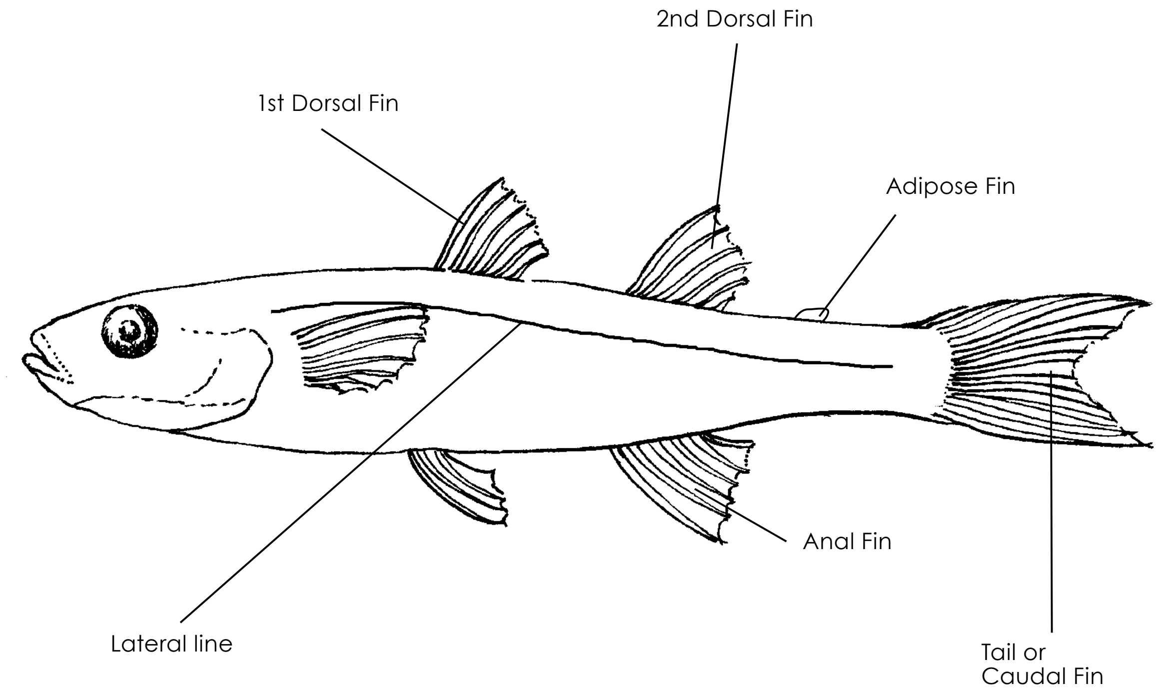


Figure 5. A generic fish with some key features used for identification.

2.1. **EXTINCT IN SA**

“no reasonable doubt that the last individual has died, following exhaustive surveys”

Flathead Galaxias *(Galaxias rostratus)*

Other common names: Murray Galaxias or Murray Jollytail

Conservation status *South Australia:* Extinct in SA (EX)
National & interstate: listed as Threatened in Victoria (Vulnerable) and recommended Vulnerable in NSW74 (also Vulnerable on IUCN Red List[6]).

Taxonomy and identification The Flathead Galaxias is a long slender fish, reaching a length of around 10cm. It is most similar to Common Galaxias, but has large eyes, a flatter head, longer snout and a mouth reaching well below the eyes (compared to the front of the eye), and is similar to some forms of Mountain Galaxias, but is more slender (v. stocky and rounded body) and the origin of both dorsal and anal fins align.

Former distribution The Flathead Galaxias is endemic to the southern MDB, and known in SA from a few early records on the lower River Murray – Frederick von Müeller (a prominent botanist) collected specimens from near Murray Bridge in 1868 and 1869 and sent them to a museum in Germany. It probably occurred more widely in floodplain, swamp and billabong habitat along the SA River Murray, but the species and its preferred habitat were not targeted in historic surveys.

Current distribution There have been no further records since the 1800s. Recent surveys in potential habitat have not recorded the species, and in general, suitable floodplain and billabong habitat has severely diminished with an altered River Murray flow regime. Most recent records elsewhere in the species range are from the Ovens and Goulbourn river systems (~600km upstream from the SA border).

Biology and habitat The distribution, biology and habitat of this species is poorly understood (no information for SA). However it generally occurs in floodplain areas (lakes, lagoons, billabongs) amongst structure such as submerged logs (snags) and leaf litter, with an unknown lifespan or diet (probably lives for 2-3 years as an opportunistic feeder), and spawns in late winter to spring[75,76,77].

Reasons for decline and threats Presumed Extinct in SA, likely a reflection of a limited historic distribution and abundance coupled with a drastically altered River Murray environment, especially the reduction in overbank flows and flow variability important in establishing and maintaining a mosaic of different floodplain habitats. Predation by Redfin and interaction with Gambusia may be a threat in isolated and concentrated floodplain habitat.

Land tenure and conservation

- Previously River Murray corridor.

Recovery objectives

- Continue to monitor for presence in SA.
- Restore floodplain water regime to aid recolonisation (flow volume and patterns).

Conservation actions already initiated

- SAMDB NRM Board has instigated baseline surveys of a number of wetlands and encourages community monitoring[69,70,78,79].
- The Living Murray Initiative aims to restore flow regimes to key ecological assets including the Chowilla region which may provide improved conditions (e.g. flooding) for Flathead Galaxias.

Required conservation actions

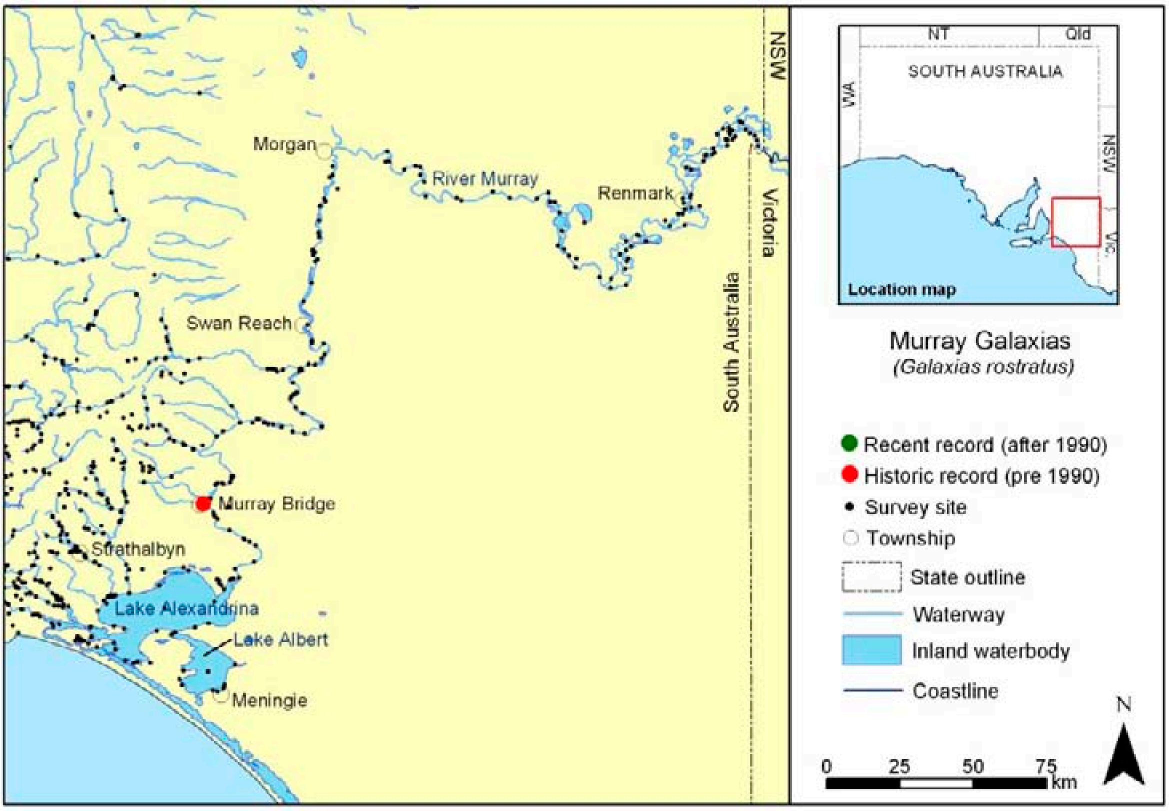
- Targeted surveys in floodplain habitat.
- Appropriate verification of suspected records.
- Longer-term monitoring as part of environmental flow programs.

Organisations responsible for conservation of species

DEH, PIRSA, SAMDB NRM Board, MDBA.

Organisations or individuals involved

Not currently applicable.



Top. Murray Cod
Bottom. Trout Cod

Trout Cod *(Maccullochella macquariensis)*

Other common names: Rock Cod (SA name) and Bluenose Cod

Conservation status *South Australia:* Extinct in SA (EX); Protected (*Fisheries Management Act 2007*). *National:* Endangered (*EPBC Act*). *Interstate:* Threatened in Victoria (Critically Endangered) and Endangered in NSW and ACT.

Taxonomy and identification A medium to large growing species up to ~80cm, but more commonly 30-50cm. Often and historically confused with Murray Cod, a formal separation occurred in 1972, although numerous sources identified the presence of two distinct 'cod' species before this time[80,81]. Distinguishable from the Murray Cod by its undercut lower jaw, speckled rather than marbled body markings (markings absent from gill cover) and a black stripe through the eye which is not clearly visible in adult Murray Cod.

Former distribution The historic distribution and abundance in the SA section of the River Murray is difficult to determine due to taxonomic confusion, limited reporting and no specific investigations on the species. As 'cod' are a prized table fish very few (five) specimens were lodged at the SA Museum, but one of these is a juvenile Trout Cod - collected at Purnong in January 1932. This record follows a reasonably large flood in 1931 and hence may have been displaced from interstate populations. However, local anecdotal information suggests that the species was once a rare inhabitant of the region (e.g. newspaper article from 1892[82]). Unpublished SA Museum notes by T.D. Scott states "evidence taken from fisherman, May-June 1935, ...all still insist that there are 2 species of cod. They call the 'Tout Cod' the Rock Cod from No. 6 Lock down." A later publication suggests Trout Cod was formerly more widespread, but rarely taken in SA by the 1970s[44], and there has since only been one unverified record from Chowilla in the 1980s[83]. An historic presence in SA could also be implied from the documented occurrence in adjoining river sections in Victoria prior to the 1930s[81,84].

Current distribution Presumed Extinct in SA. There is one remaining self-sustaining natural population on the Murray River between Yarrawonga and Tocumwal (>500km upstream of the SA border), and there are other translocated populations (few self-sustaining) in Ovens, Goulbourn and Murrumbidgee catchments (Vic/NSW/ACT)[11,85].

Biology and habitat Unknown in SA. Its remaining range interstate has a strong bias towards cooler, mid-upland river habitats, with an association for deeper flowing areas with instream structure such as hollow logs and boulders, but it clearly occurred under varied conditions prior to major MDB wide declines. Trout Cod is a long-lived predatory species preying on fish, yabbies, freshwater shrimp and larger macroinvertebrates. Spawning occurs in spring within hollows or caves, with larvae free swimming. Movement studies suggest fish tend to remain at the one site and have small home ranges, although exploratory movements of 20-60km have been recorded[11,86,87,88,89].

Reasons for decline and threats The Trout Cod has for several decades been considered an endangered species because of its highly restricted distribution, habitat degradation (e.g. de-snagging, flow regulation), small populations, and threat from angling[11,90]. The primary threats or reasons for decline in SA are likely to be altered flow regimes and habitat from a 2/3 flow reduction of the River Murray, regulated local conditions (i.e. transformation from flowing river to a series of weir pools in the SAMDB), and snag removal.

Land tenure and conservation
Formerly River Murray corridor.

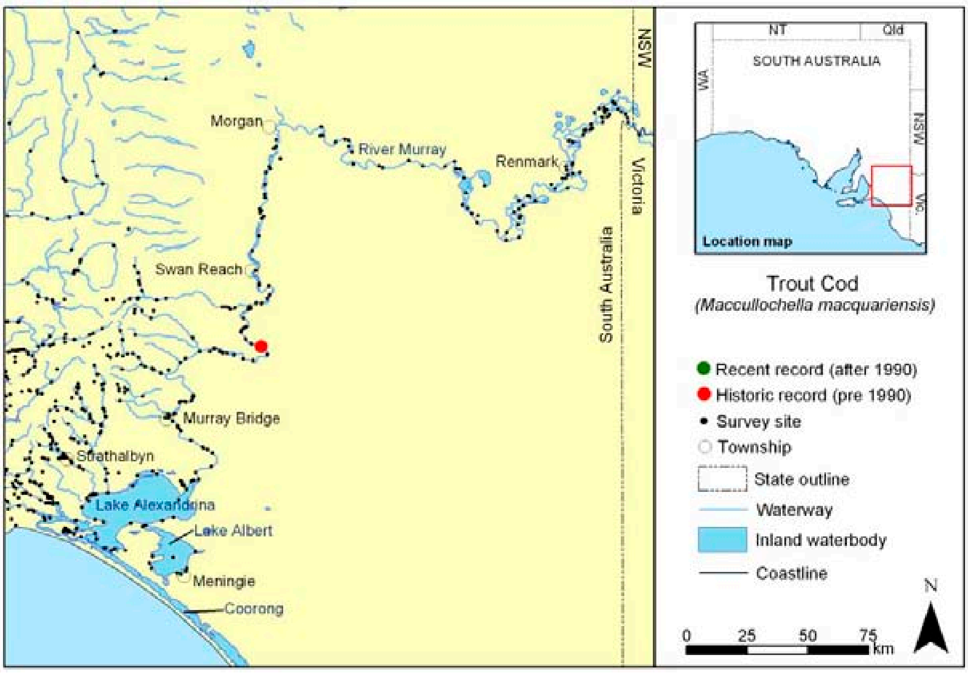
Recovery objectives No immediate recovery objectives can be made as Trout Cod is likely extinct in SA. However some flowing anabranch sections (e.g. around Chowilla) may be suitable habitat, and a better understanding of historic distribution and habitat in SA would be useful for efforts of national recovery (e.g. an objective of the National Trout Cod Recovery Plan is 'To increase the species' distribution by re-establishing populations of suitable size and density within available habitat areas within its former range in the Murray and Murrumbidgee systems').

Conservation actions already initiated
- Protected from fishing pressure (*Fisheries Management Act 2007*).
- A National Recovery Plan has been prepared and considerable research into habitat, ecology and restocking has and is occurring interstate[11,91].
- SARDI Aquatic Sciences have been monitoring Murray Cod in the lower River Murray over recent years, but have not yet found Trout Cod.

Required conservation actions
- Undertake an oral history program within the community and especially commercial fishers or fishing families to collate any available historic information on distribution, frequency of encounters and habitat conditions.
- The lack of information regarding the Trout Cod means that the general public can help by reporting any past or present sightings (www.nativefishsa.asn.au).
- Determine if populations remain in SA through targeted surveys.
- Ensure routine verification of cod species (especially juveniles) occurs in research.
- The current highly altered environment of the River Murray in SA is unlikely to be suitable for the re-establishment of Trout Cod, but research could be focused to identify any areas for habitat restoration to restore the species extent of occurrence and link to the National Recovery Plan (collaborative research).

Organisations responsible for conservation of species
DEH, PIRSA Fisheries, DEWHA, SAMDB NRM Board.

Organisations or individuals involved
SARDI Aquatic Sciences, SAMDB NRM Board, MDBA.



Macquarie Perch *(Macquaria australasica)*

Other common names: Murray Perch, Silver Eye, Black Bream

Conservation status *South Australia:* Extinct in SA (EX).
National: Endangered (*EPBC Act 1999*). *Interstate:* listed as Threatened in Victoria (Endangered) and Endangered in New South Wales and the ACT.

Taxonomy and identification A medium sized species reaching 50cm but commonly smaller. Variable in colour from green/grey to nearly golden, having a blunt snout and large eyes. They can be distinguished from Murray-Darling Golden Perch by a small mouth with equal lower and upper jaws (lower jaw protrudes in Golden Perch, more so in adults) and by having much fewer scales in a line transverse between the first dorsal and anal fins (max 33 v. min 40). Juveniles could be confused with pygmy perches, but they have protruding and more visible spines on the dorsal fin. Macquarie Perch may be a species complex with two distinct forms east and west of the Great Dividing Range, including a single species in the MDB, with some indication of spatial genetic structure[88].

Former distribution There are two SA Museum specimens (both large, adult fish) listed from an unspecified location of the "River Murray, South Australia" from 1917 and 1918. Note that no systematic surveys were conducted for the species, and it was a table fish, so lodging of specimens may not have been a priority. The two SA specimens appear to have been noted at markets in Adelaide from the River Fishery so they likely came from the Morgan or Renmark areas. The collection dates coincide with three high flow years between 1916-1918, including a large flood in 1917. Hence the fish may have been washed or moved downstream. The species was known to inhabit the main stem of the Murray upstream of the SA border between Swan Hill and Yarrawonga (prior to the 1950s) and 56 fish were captured migrating upstream through a fish ladder at Euston (only 150km upstream but above the Darling River junction) between 1938-1942[84,92]. This supports downstream dispersal or even an extension of a main stream population into SA, but it is unknown whether any local reproduction also occurred.

Current distribution No further SA records since 1918 (presumed extinct), and the species has contracted significantly in the MDB to now only occur in forested upland areas of Murray, Murrumbidgee and Lachlan river tributaries in Victoria, ACT and New South Wales.

Biology and habitat Unknown in SA. Remaining habitat of Macquarie Perch interstate is characterised by flowing stream habitat with clear water and low silt loads, however, the species occurred historically over a broader range of habitats including lowland rivers (these had very different flow regimes and habitat conditions than now). This fish is a schooling species which feeds on insects, crustaceans and molluscs and which is moderately long lived (10 or more years). Documented to make spawning movements and was a component of fish caught moving through fish ladder on the mid Murray River at Euston in 1938-1942[88,92].

Reasons for decline and threats Broader change in the MDB has impacted the likelihood of this species moving to SA where habitat conditions themselves are no longer suitable (e.g. reduced flows, lack of free-to-flow river sections, high turbidity and high temperatures). Some general reasons for the broader decline are presumed to include flow reduction (loss), seasonal flow reversal, cold water pollution, increased siltation, habitat loss, interaction with introduced Redfin and trout, susceptibility to disease such as the Epizootic Haematopoietic Necrosis Virus (EHNV), and overfishing[12,92,93].

Land tenure and conservation
- Formerly River Murray corridor.

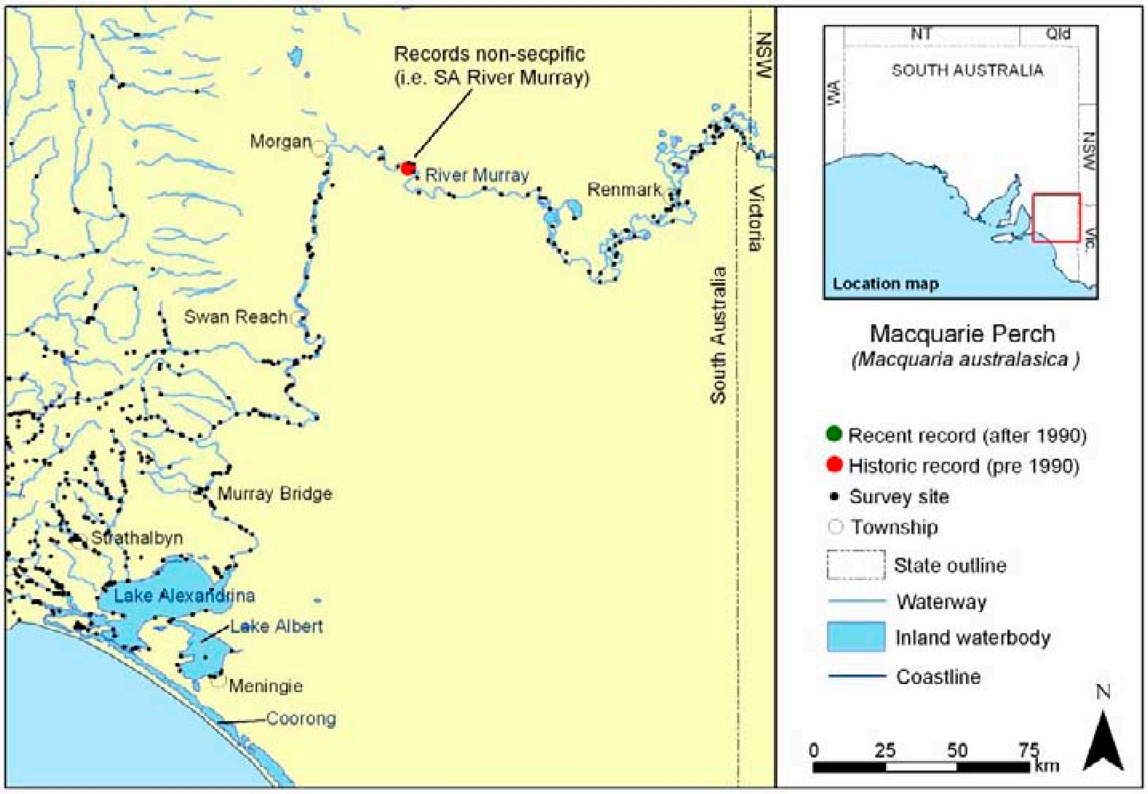
Recovery objectives Broader declines and unsuitable habitats mean there is an extremely low chance that Macquarie Perch could occur or be restocked into SA. Hence evaluating the potential recovery options for the species should be done once ecosystem recovery has been noted.

Conservation actions already initiated
- Not relevant as the species is presumed long extinct in SA.

Required conservation actions Broader ecosystems restoration is required to once again provide suitable habitat (e.g. significant return of flow regime). An oral/local history program may help to assess if the species occurred at other times or more permanently in SA, especially prior to construction of the Locks and Weirs.

Organisations responsible for conservation of species
For historic range – DEH, SAMDB NRM Board, DEWHA.

Organisations or individuals involved
There are numerous stakeholders such as Fisheries agencies involved in research and recovery efforts interstate.



2.2. **CRITICALLY ENDANGERED**

"considered to be facing an extremely high risk of extinction in the wild"

Australian Mudfish *(Neochanna cleaveri)*

Other common names: Tasmanian Mudfish, Mud Galaxias

Conservation status *South Australia:* Critically Endangered (CR B1ab(iii)).
National: not listed. *Interstate:* listed as Threatened in Victoria (Critically Endangered).

Taxonomy and identification A small slender fish reaching 8cm in length. Generally similar to some other galaxias (such as Mountain Galaxias), but has smaller eyes, an anal fin origin set well behind the origin of the dorsal fin and a distinctly rounded tail (caudal) fin. Isolated fish in SA may be a genetically distinct species to interstate populations. The juvenile 'whitebait' stage can be distinguished by the offset fin orientation, speckled head, generally smaller size and a black band on the tail.

Former distribution Unknown; previously known from a single SA Museum specimen from the Bool Lagoon outlet regulator in 1974. Historically, prior to drainage, extensive areas of landlocked wetland occurred in the region surrounding Bool Lagoon and SE SA in general, hence the species may have been more widespread. The construction of Drain M (completed in the early 1970s) created a dispersal route from the coast, and the record may have been based on migration to the area by juvenile fish. However no other diadromous species have been recorded at Bool Lagoon which is 80km inland, and the nearest known Australian Mudfish population is found 350km further around the coast at Cape Otway in Victoria.

Current distribution Intensive sampling from 2000-2006 failed to locate the species[23,55], however a few individuals have recently been discovered near the end of the Drain M (connected to Bool Lagoon)[94]. Habitat is thus likely to include Bool Lagoon to Lake George and smaller connected drains and wetlands (CR B1a).

Biology and habitat The Australian Mudfish can have dual lifecycles – either as (a) a migratory species (most commonly reported) whereby larvae are swept to sea soon after hatching in autumn and winter and return to freshwater as transparent juveniles with other galaxias in spring (collectively known as whitebait) or (b) complete their lifecycle landlocked in freshwater swamps (some Tasmanian populations and related species in New Zealand). Adults are found in small creeks, freshwater wetlands, drains and swamps where they are benthic (living in or close to bottom mud and vegetation), have cryptic and nocturnal habits, and probably feed on small aquatic invertebrates. Lifespan is probably 2-3 years and individuals can sometimes survive periods (dry seasons) without surface water by burrowing into the mud[76,94,95,96,97,98,99].

Reasons for decline and threats The rarity of Australian Mudfish in SA may be a result of its specific habitat requirements, which make it susceptible to habitat changes – extensive loss of wetland and swamp habitat has occurred in SE SA following drainage and agricultural pursuits. Hydrological change is especially evident, in that previous habitat at Bool Lagoon has been dry for most of the last 10 years (e.g. outlet regulates water levels, possible changes in groundwater hydrology, and drains remove general water from the local landscape)(CR B1b(iii)).

Land tenure and conservation Bool Lagoon is a Game Reserve and interlinked with the Hack Lagoon Conservation Park (combined representing a Ramsar site). Drain M is managed by the SEWCDB. There are a few swamps and wetlands surrounding Bool Lagoon and Drain M on private land and Forestry SA land.

Recovery objectives

- Urgently map the range and habitat of Australian Mudfish in South Australia.
- Determine local biology and potential threats.
- Protect and restore potential habitat in the area of known distribution.
- Determine taxonomic position of SA populations relevant to those in Victoria and Tasmania.

Conservation actions already initiated

- Broad baseline survey of aquatic habitats[23], rediscovered during threatened species monitoring[94].
- A project has been initiated which aims to integrate surface water management in the Mosquito Creek Catchment/Bool Lagoon (SE NRM Board, DEH and other project partners).
- Public awareness about Australian Mudfish has been generated through community presentations and media.

Required conservation actions

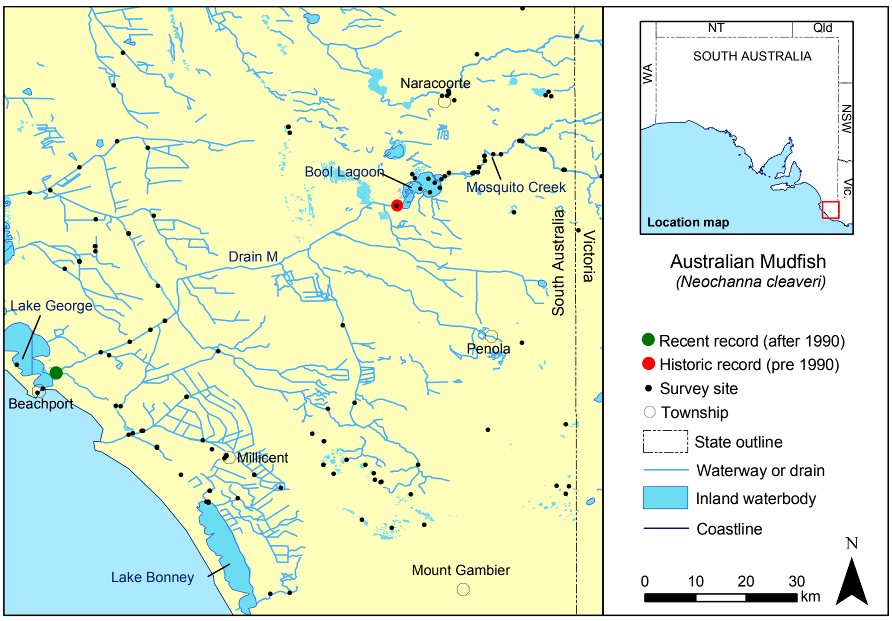
- Targeted and seasonally repeated surveys to determine status in SA, including regular monitoring at Bool Lagoon when surface water is present.
- Targeted habitat restoration in small drain habitat near Lake George.
- Morphological and genetic studies to assess the taxonomic position of SA populations.

Organisations responsible for conservation of species

DEH, SE NRM Board, DWLBC.

Organisations or individuals involved

Native Fish Australia (SA), DEH, community stakeholders, Waterwatch.



Murray Hardyhead *(Craterocephalus fluviatilis)*

Conservation status *South Australia:* Endangered (CR A2c,B1ab(ii,iii,iv)).
National: Vulnerable (*EPBC Act 1999*). *Interstate:* listed as Threatened in Victoria (Critically Endangered) and Critically Endangered in New South Wales.

Taxonomy and identification The Murray Hardyhead is a small silvery fish commonly reaching 3-5cm. There has been a long history of confusion between different hardyheads in southern Australia due to taxonomic uncertainty (now resolved) and the general similar appearance of different species. The Murray Hardyhead is most similar to the Lake Eyre Hardyhead which is endemic to SA from the LEB and Lake Torrens Catchment but is distinguished by non-overlapping geographic range, molecular markers and the characteristics of scales such as shape[100]. Within the SA Murray-Darling Basin it can be distinguished from (a) Smallmouthed Hardyhead on greater body depth and length of gill rakers (<than half diameter of pupil) and (b) from Unspecked Hardyhead based on greater body depth (most easily assessed through the number of transverse scales = 10 or 11 v. 7-8), patterns of scales (irregular v. uniform) and general body colouration (e.g. black lips often apparent in Unspecked Hardyhead).

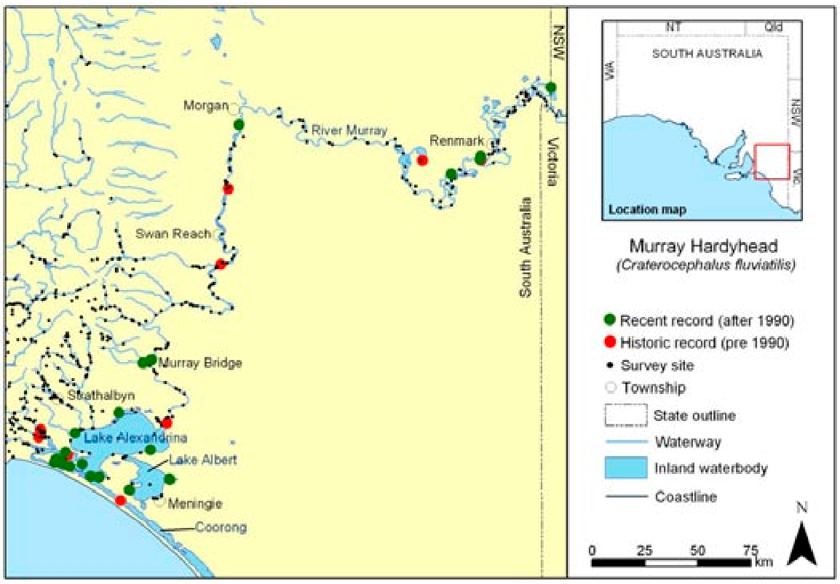
Former distribution Historic distribution is not well documented, but the species appears to have occupied lowland wetland habitats throughout the SA Murray-Darling Basin. It has had a long-term presence in the Lower Lakes (Lakes Alexandrina and Albert), with records dating back to the late 1800s[101], and occurred patchily in the Lower Lakes and River Murray corridor during the 1960-70s[101] and 1980s[35].

Current distribution A reasonable level of suitable sampling has occurred in the SA Murray-Darling Basin in the last five years. Data suggests the species is severely fragmented (CR B1a) with three larger isolated populations: (a&b) Disher Creek and Berri Salt Evaporation Basins near Berri and Renmark, and (c) the Lower Lakes, with the most records and highest abundances in channel habitat on the eastern end of Hindmarsh Island, and scattered records from sheltered edges of Lake Alexandrina and Lake Albert. Other infrequent records of small populations have been detected at a handful of locations along the River Murray corridor including: Lake Littra Inlet (near the SA-NSW border), Scott Creek (a backwater near Morgan), and Riverglades and Rocky Gully wetlands at Murray Bridge. While historic records are few, Murray Hardyhead no longer appear to occur at many places where they were recorded in the 1960-80s. For example, they have apparently disappeared from wetlands in the upper Finniss River arm of Lake Alexandrina, as well as other habitats along the River Murray between Mannum and Berri (e.g. Marne River Mouth, Kroehns Landing, Swan Reach and Lake Bonney). While there are occasional records from the Coorong (a single individual from Long Point, 1984, and irregular captures on the salt water side of the Barrages around Hindmarsh Island), this habitat under current marine conditions, where Smallmouthed Hardyhead is abundant, appears unsuitable[24,58,59,63,70,101]. Further to this broad decline, acute contraction in abundance and area of occupancy has been witnessed in the last two years including loss from the main part of Disher Creek, Riverglades, and much of previous habitat in the Lower Lakes (CR A2c,B1b(ii,iii,iv)[102].

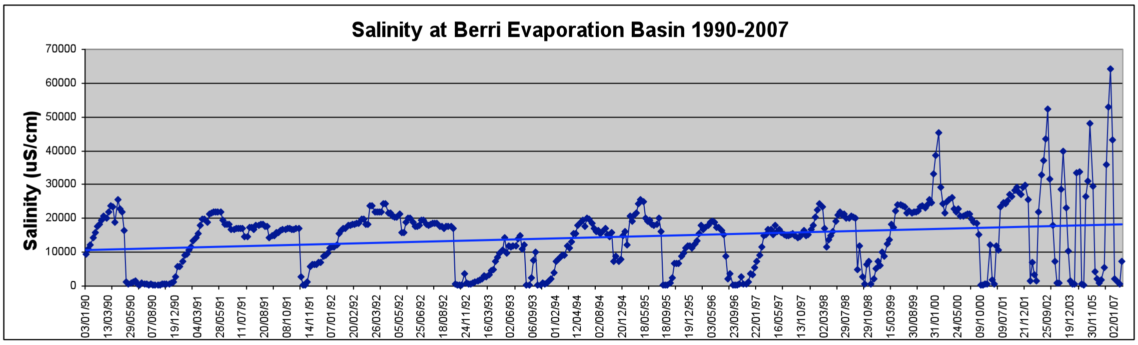
Biology and habitat In SA the Murray Hardyhead is found primarily in wetland and sheltered lake edge habitat, often in areas with high densities of submerged aquatic plants including Milfoil *(Myriophyllum* spp.*)*, Foxtail *(Ceratophyllum)* and Eel Grass *(Ruppia* spp.*)*. Conditions where the species has been detected are often slightly to highly saline (i.e. 1,500-50,000µS or 1,000-35,000ppm), suggesting a physiological and/or competitive advantage in these habitats[24,35,59,63,70,103]. The Murray Hardyhead is a mobile schooling species which is thought to be omnivorous with a diet consisting mainly of zooplankton, insect larvae, detritus and algae[39]. It spawns in spring and summer, with larval abundance peaking in Victorian lake populations during early November[104]. Studies in Victoria suggest the species is primarily an annual species (i.e. most fish reach maturity, spawn and die within a year)[104], with preliminary demographic data from Hindmarsh Island supporting this pattern[58]. Hence any failure in recruitment could be catastrophic for a population. There is some evidence for small-scale movements as fish have been observed to colonise freshly inundated habitat on Hindmarsh Island[50].

Reasons for decline and threats The recent loss of known localities infers a decline in the extent and quality of habitat which is projected to continue with existing and potential threats including:

- Salinity – populations isolated in salt evaporation basins are potentially susceptible to high and rapidly fluctuating salinities (e.g. rapid loss of a population from Elizabeth Lake in Victoria[105]).
- Changes in management - the SA evaporation basins are currently experiencing changing hydrology due to improved irrigation efficiency meaning less runoff (loss of water) from surrounding irrigation, which has meant that salinities have gradually increased in these core populations over the last five years (see Figure 6). At other locations structures have been installed to improve freshwater flow and may be problematic for Murray Hardyhead by reducing salinity or altering local conditions (Riverglades, Scott Creek, Waltowa Swamp). Localities in the Lower Lakes are susceptible to changes in management of water levels and low river inflow.
- Low water levels – reduced River Murray flow and irrigation may cause levels in the Lower Lakes to reach critical lows during summer with drying of sheltered edge habitat and greater exposure to predators.
- Alien species – interaction with predatory Redfin needs to be assessed as they may limit populations and be a biological barrier to movement. Aggressive interactions from Gambusia in shallow habitat may also be a threat under some conditions.
- Broader threats may include: river regulation providing constantly fresh conditions, little temporal variability in flows and reduced floodplain inundation/connectivity, reducing habitat suitability and opportunities for colonisation/movement. The currently fragmented nature of populations means there is a high chance of population losses and longer-term problems with gene flow.



Top. Unspecked Hardyhead
Middle. Smallmouthed Hardyhead
Bottom. Murray Hardyhead
Photo. Ben Smith



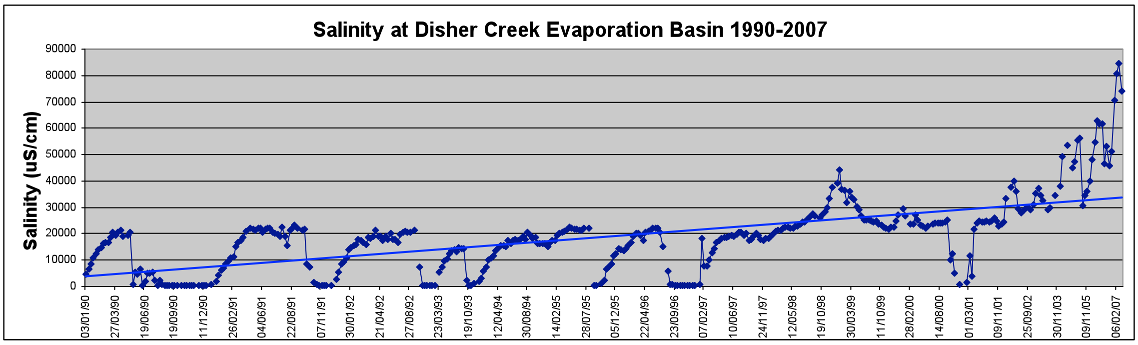


Figure 6. Recent salinity records at two core SA Murray Hardyhead habitats (DWLBC).

Land tenure and conservation Murray Hardyhead occurs within the State Reserve system at Wyndgate on Hindmarsh Island (the Lower Lakes in general are also part of a Ramsar site), Chowilla Game Reserve (Lake Littra) and in a section of the Murray River National Park (Disher Creek). Disher Creek and Berri Evaporation basins are salinity management areas. Remaining localities are connected to public waterways with access through private and public land (e.g. Council Reserves at Clayton and Murray Bridge) where landuse is mostly recreational and with some areas of stock grazing (e.g. Hindmarsh Island).

Recovery objectives

- Secure core populations by appropriate local habitat management and research (may require urgent conservation measures).
- Develop a sound understanding of distribution and biology including identifying the extent and connectivity between different management units, and the effects of potential threats.
- Establish and monitor relationships to environmental conditions, especially with any changes in management and/or conditions.
- Ensure that all key stakeholders are aware of populations and potential threats.

Conservation actions already initiated

- Genetic and morphological studies have resolved taxonomic issues and field researchers are now taking more care with identification.
- A National Recovery Plan is in the final stages of development.
- Habitat on Hindmarsh Island was recently added to the State Reserve system.
- An ecological investigation examining distribution and physiology has been initiated[62,63].
- Population monitoring for threatened fishes is being undertaken on Hindmarsh Island[58].
- SAMDB NRM Board has instigated baseline surveys of a number of wetlands and encourages community monitoring[69,70,78,79].

- 'Habitat restoration' programs are being undertaken at known Murray Hardyhead sites, but the effects of these to this particular species may or may not be beneficial.
- Living Murray Initiative - the Lower Lakes is a key target for environmental flows restoration.
- Colour data sheet with ID tips for Murray fishes are available from NFA(SA)[106].

Required actions

- Continued surveys to determine locations of extant populations, targeting saline habitats.
- Monitor distribution and recruitment at core populations linked with environmental conditions.
- Conduct studies to better understand biology, fine scale habitat requirements, potential threats (especially predators in the Lower Lakes) and dispersal capacity/requirements.
- Urgent conservation measures: access environmental water to maintain salinity at moderate levels and prevent drying, investigate and implement where necessary captive breeding as a backup to catastrophe from severe environmental conditions (e.g. habitat drying at core populations), and carefully monitoring of population trends.
- Ensure that ecological restoration programs include: (a) prior assessment for presence, (b) careful planning encompassing an assessment of potential threats from any proposed changes to habitat and flow conditions, (c) provision for appropriate design suited to the species (may mean no change to current conditions) and (d) monitoring of the population to ensure management can be changed adaptively if declines are noted.
- Investigate new and ongoing management options for the SA salt evaporation basins in the face of change.
- Undertake genetic studies to evaluate diversity and historic gene flow between currently fragmented populations.
- Establish programs to improve awareness of Murray Hardyhead identification, habitat requirements and conservation amongst researchers, managers, planners and the community (e.g. provide identification keys, education material and a system where trained professionals verifying survey records).

Organisations responsible for conservation of species

DEH, DWLBC, DEWHA, local councils (Alexandrina, Murray Bridge), SAMDB NRM Board.

Organisations or individuals involved

SARDI Aquatic Sciences, NFA(SA), University of Adelaide, SAMDB NRM Board, DWLBC, MDBA, DEH, various Landcare and Community groups (Hindmarsh Island, Riverglades, Clayton Environmental) and Goolwa to Wellington LAP.

Agassiz's Glassfish *(Ambassis agassizii)*
Other common names: Olive Perchlet, Chanda Perch, Glassfish

Conservation status *South Australia:* Critically Endangered (CR B1ab(i,iii,iv)); Protected (*Fisheries Management Act 2007*).
National: not listed. *Interstate:* Endangered in New South Wales (MDB population) and listed as Threatened in Victoria (Regionally Extinct).

Taxonomy and identification A short, deep bodied fish attaining a length of 4-5cm. It has large eyes and a semi-transparent to olive body. Agassiz's Glassfish is somewhat similar to pygmy perches and juvenile Murray-Darling Golden Perch, but can be distinguished by having a forked tail, silvery gill cover and larger scales.

Former distribution Historical records indicate this species was apparently always rare. Records are patchy and mostly from the 1960s and 1970s from wetlands along the River Murray including Tailem Bend, Murray Bridge, Kroehn's Landing, Big Bend, Portee Station, Hart Island, Renmark, and extending into Lake Alexandrina (e.g. Finniss River arm)[101]. The last verified record was from the mouth of the Marne River (near Walker Flat) in 1983[39].

Current distribution There have been no verified records of Agassiz's Glassfish in the past 20 years, despite a reasonable level of suitable (but non-targeted) sampling that has occurred in the SAMDB in the last five years. Hence there has been a noted decline (disappearance) in the extent of occurrence and number of localities from the mid 1970s (CR B1ab(i,iii,iv)) and the species may be extinct in SA. A translocated population (sourced from Queensland fish) may exist in artificial habitat near Murray Bridge[36].

Biology and habitat Agassiz's Glassfish is poorly known in SA due to a lack of overall records and observations, although it was a naturally rare and patchy species[107,108]. There is some indication that it was associated with submerged aquatic vegetation such as Ribbonweed *(Vallisneria)* and Foxtail *(Ceratophyllum)*, and clearer water in wetland habitats. It remains common only in the Queensland section of the MDB where it is reported to occur in still or slow flowing habitats with high levels of submerged and emergent vegetation, or structure such as snags. Agassiz's Glassfish is an opportunistic nocturnal micro-carnivore, which spawns in late spring and summer amongst aquatic vegetation. Its lifespan is reported to be up to four years[109,110,111].

Reasons for decline and threats These are largely unknown but could include a combination of factors such as the impacts of river regulation reducing the frequency and duration of River Murray and wetland flooding, and constantly high turbidity from altered flow patterns. There is a casual link between the arrival of Carp and the disappearance of Agassiz's Glassfish (i.e. potential loss of aquatic vegetation or transmission of disease). Ill-planned reintroductions could cause genetic problems for any remnant, but as yet undetected local populations.

Land tenure and conservation

- Previous records from public waterways (sometimes accessed through private property).

Recovery objectives

- Accurately determine the status of Agassiz's Glassfish in SA through targeted surveys.
- If populations are discovered initiate research on the species requirements to assist with conservation and recovery planning.
- Restore a more natural flow regime and preferred micro-habitats.
- Establish the genetic relationship between SA and interstate MDB populations.

Conservation actions already initiated

- Several recent surveys have been undertaken within the range of Agassiz's Glassfish[24,69,70,78].
- An attempt to establish a refuge population in artificial habitat using fish from the Queensland MDB has been made (unknown if successful)[36].
- The Living Murray Initiative aims to restore flow regimes to key ecological assets including the Chowilla region which may provide improved conditions (e.g. flooding) for Agassiz's Glassfish.

Required conservation actions

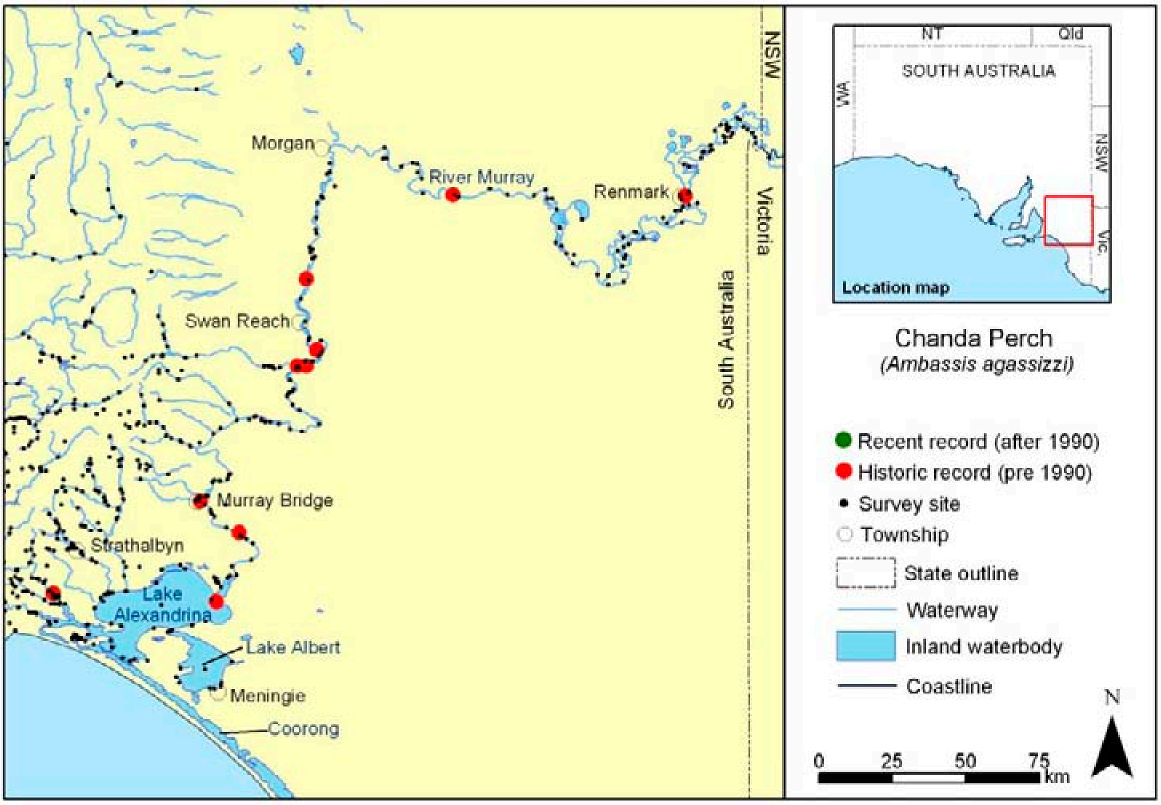
- There is a possibility that populations will be uncovered if comprehensive targeted surveys were conducted, focusing on historic survey locations.
- The lack of information regarding the Agassiz's Glassfish means that the general public can help by reporting any past or present sightings (www.nativefishsa.asn.au).
- Undertake a genetic study using historic museum specimens to determine the suitability of interstate populations for translocation and reintroduction.

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, SAMDB NRM Board.

Organisations or individuals involved

NFA(SA), DEH, SARDI Aquatic Sciences, SAMDB NRM Board.



Yarra Pygmy Perch *(Nannoperca obscura)*

Conservation status *South Australia:* Critically Endangered (CR A2ac); Protected (*Fisheries Management Act 2007*).

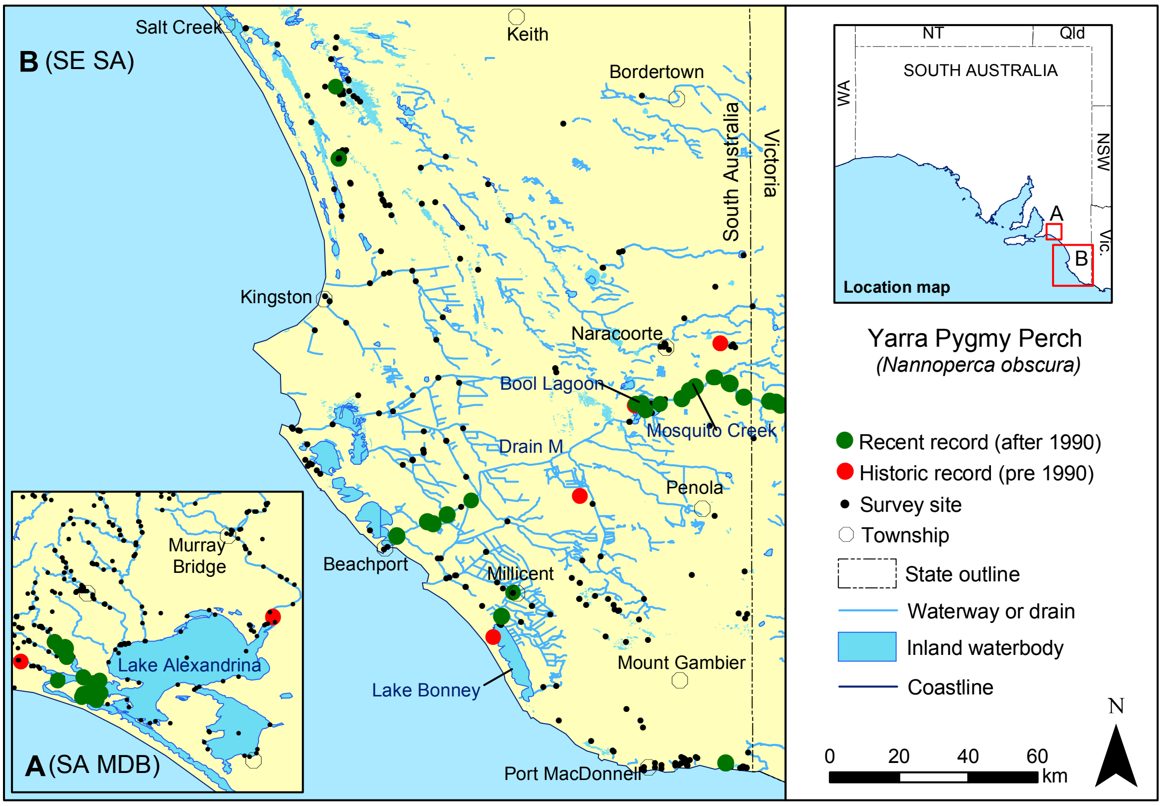
National: Vulnerable (*EPBC Act 1999*). *Interstate:* listed as Threatened in Victoria (Near Threatened).

Taxonomy and identification A small trim fish with a short deep body which reaches a length of 8cm, commonly 4-5cm. In the past, this species and the Southern Pygmy Perch have been confused and grouped together. Distinguished from other SA pygmy perches by a small mouth not reaching below the eye, high dorsal fin and irregular shaped eye pupil (not round) (also has a free lower edge to pre-orbital bone when viewed under the microscope). Recent genetic research through the SA Museum and the University of Adelaide indicates that populations in the SAMDB are distinct from those in the SE and comprise separate Management Units[55].

Former distribution Very little historic data was available prior to the review of SA Museum specimens as part of Phase 1 of the Action Plan. The often cited western limit of the species was considered to be Bool Lagoon. However from the review and with additional research[13] we now know the western range (SA) included (a) permanent habitats throughout the South East with documented localities included Crescent Pond (west of Piccaninnie Ponds), Mosquito Creek/Bool Lagoon system, the Lake Bonney area (1913), Bakers Range Watercourse as far north as Mandina Marshes (parallel with the southern Coorong) and Henry Creek[23,101,112] and (b) the lower section of the SAMDB with records from the Lower Murray, Lake Alexandrina and wetlands on connected tributary stream arms of the Lake (records date back to 1915 and 1928). A record from Piccaninnie Ponds proper[44] cannot be verified as the specimen is missing from the labelled jar at the SA Museum.

Current distribution Prior to 2007 remaining known localities were highly fragmented and included for the South East region: Mosquito Creek system (including Bool, Little Bool and Hacks lagoons (when wet!), Dead Man Swamp and occasional records from Drain M), Picks Swamp, the Lake Bonney/Millicent Region (SE); and for the MDB: eastern Hindmarsh Island, vegetated edges of the Goolwa channel, and the upper Finniss River arm of Lake Alexandrina[23,24,50,55,59,113]. There have been major recent declines in both the area of occurrence and local abundance of Yarra pygmy perch, and also a possible major reduction in extent of occurrence. Most recently severe drought has exacerbated existing threats with large declines in local abundance and area of occupancy noted. A rapid fall in Lake Alexandrina water level since late 2006 has virtually eliminated all required Yarra Pygmy Perch habitat with the species feared regionally extinct[102,114,115]. In the South East five remaining populations are under critical threat: confirmed extinct at Henry Creek; feared extinct at Lake Bonny; in low abundance at Crescent Pond; highly restricted in the lower Drain M area; and in sharp decline at Mosquito Creek – a 75% reduction in relative abundance and 40% reduction in area of occupancy was noted between spring 2006 and 2008[94] (CR A2ac).

Biology and habitat In South Australia the Yarra Pygmy Perch occurs in permanent environments including slow flowing streams, lakes, sinkholes (pond habitat) and wetlands. Associated with emergent and submerged aquatic vegetation including Milfoil *(Myriophyllum)*, Foxtail *(Ceratophyllum)*, Club Rush *(Schoenoplectus)*, Water Ribbons *(Triglochin)* and Cumbungi or Bulrushes *(Typha)* and water transparency at most recorded sites is limited due to natural tannin colouring. The biology of the species is little known, but fish in spawning condition have been found during September-November and fish probably live for less than 4 years, with most fish in a population being 1-2 years old[23,24,55,59,112]. Data from Victoria indicates food items include macroinvertebrates common on submerged surfaces such as insect larvae and copepods[116] and suggests that when occurring together Yarra and Southern pygmy perch compete for similar micro-habitats, potentially forcing Yarra Pygmy Perch to use deeper areas (and thus be more susceptible to Redfin predation)[117]. The species is not known to undertake migratory movements.



Reasons for decline and threats Historic declines appear be related to habitat alteration such as loss of permanent wetlands through drainage of much of the South East and levees which isolated and removed swamps along the River Murray between Wellington and Mannum. More recently the drying of habitat on Mosquito Creek/Bool Lagoon and Lake Alexandrina due to altered hydrology is the critical threat to survival[94,113,118]. Any impacts to specific habitat components such as emergent vegetation or submerged vegetation would be detrimental due to loss of habitat, food resources and cover from predators (e.g. from stock damage, constructive works, aquatic vegetation control, low water levels, sedimentation, altered water transparency, destruction by Carp). For example Yarra Pygmy Perch abundance at a site on the Finniss River declined annually in line with a decreasing amount of submerged vegetation (Milfoil) and an increase in Redfin[113]. The general role of predation from Redfin and competitive interactions with Gambusia are likely to be significant but need confirmation. Forced interaction between Yarra and Southern pygmy perch through reduced flows, pool/lake levels or habitat loss (e.g. damage to riparian vegetation) may add further competitive pressure between the two species and predation from introduced species, especially for small, restricted populations of Yarra Pygmy Perch (e.g. Henry Creek). Rising salinity is a threat to at least one population where recruitment has failed (in combination with reduced flow and pool levels)[112].

Land tenure and conservation Known from the Naracoorte Caves NP, Bool Lagoon GR, Hacks Lagoon CP, on land owned by DEH for conservation at Picks Swamp (SE) and Wyndgate, Hindmarsh Island (the Lower Lakes is also a Ramsar site). Some private land at Henry Creek and Mosquito Creek has been fenced and is being managed for conservation. Wetlands in the Finniss River arm of Lake Alexandrina have a mix of stock grazing and areas used for recreation or that are inaccessible to stock.

Recovery objectives

- Ensure that the two genetically distinct populations are conserved (SAMDB and SE) with secure habitat for multiple populations in each.
- Establish and monitor relationships to environmental conditions, especially with any changes in management and/or conditions.
- Improve understanding of species life history, habitat dynamics and potential threats.
- Ensure that all key stakeholders are aware of populations and potential threats (improve awareness, particularly regarding species identification).

Conservation actions already initiated

- Habitat based conservation measures to try and secure populations have been attempted or underway for SE populations[119,120].
- Captive maintenance has been initiated as part of urgent conservation measures for fish in the SAMDB and SE in response to major habitat drying[113,120].
- Annual flow related monitoring has been initiated at Mosquito Creek and a project has been initiated which aims to integrate surface water management in the Mosquito Creek Catchment (SE NRM Board and DEH together with several other project partners).
- Securing of physical habitat at Picks Swamp (DEH) and habitat restoration is in progress to improve water quality at Lake Bonney.
- Initial moves to secure water requirements in the SAMDB (e.g. Environmental Flows Program for EMLR, Living Murray Initiative), although critical lows have not been prevented.
- Population monitoring occurs on Hindmarsh Island and the Finniss River[58,113].
- Data sheet produced for the SE to aid awareness and identification[121].
- A national Recovery Plan is in preparation (currently at a draft stage).

Required conservation actions

- Secure and protect surface and groundwater water supply (hydrology) for core populations through studies and management programs.
- Support and expand captive maintenance as a last resort backup in the face of critical threats to populations.
- Document life history and relationships to changes in water levels and vegetation through continued monitoring of populations and expand the network to include more locations in Lake Alexandrina and the SE.
- Determine the water quality requirements of adults and eggs/larvae.
- Undertake studies of aquatic plant biology and dynamics in the Lower Lakes directed towards protection and enhancement of core habitat.
- Establish long-term government and community support structures to promote the Yarra Pygmy Perch within regional planning and management, restoration and education programs.

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, DEWHA, DWLBC, SAMDB & SE NRM boards, SEWCDB & USE Program, Alexandrina & Millicent councils.

Organisations or individuals involved

DEH, NFA(SA), Aquasave, SARDI Aquatic Sciences, SAMDB NRM Board, USE Program, DEWHA, Pembroke High School, local landholders.

Variegated Pygmy Perch *(Nannoperca variegata)*
Other common names: Ewens Pygmy Perch

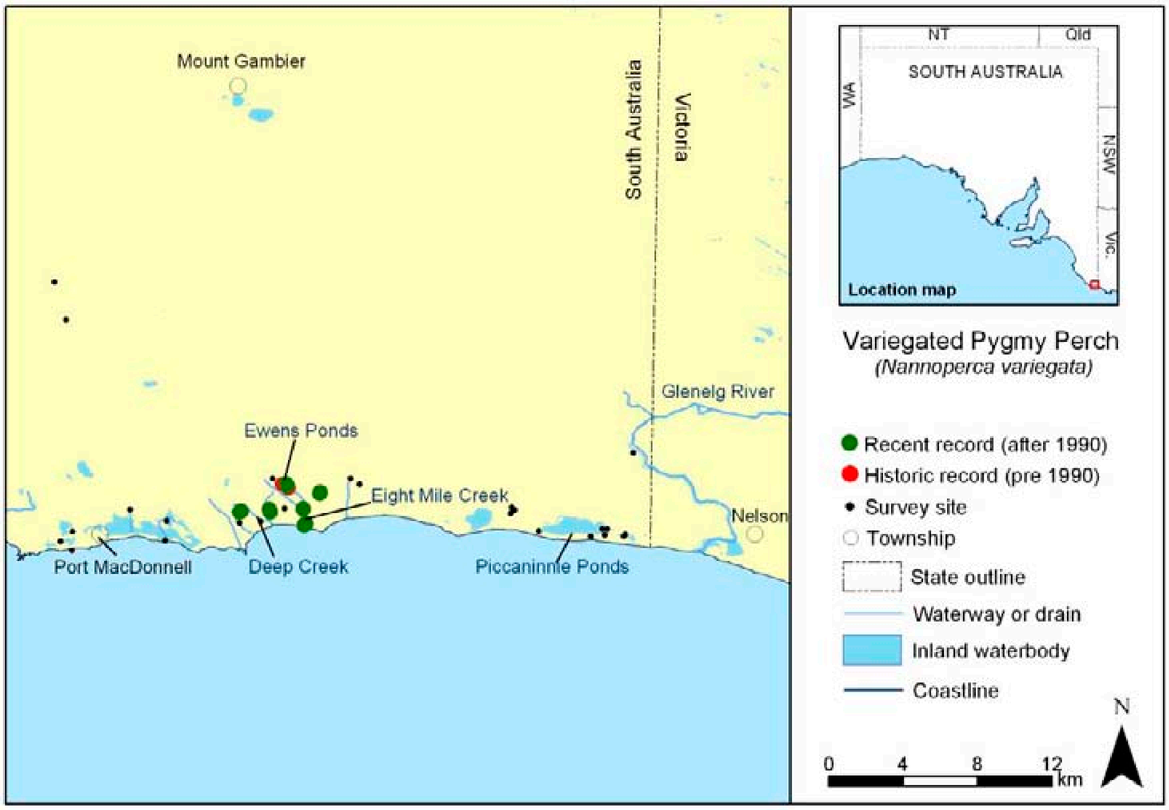
Conservation status *South Australia:* Critically Endangered (CRB2ab(i,iii)); Protected (*Fisheries Management Act 2007*).
National: Vulnerable (*EPBC Act 1999*). *Interstate:* listed as Threatened in Victoria (Endangered).

Taxonomy and identification A small, deep-bodied fish reaching a maximum length of ~6.5cm (commonly 3-5cm). The variegated body patterning is most obvious in juveniles and females, with males having a yellow-green body especially during spawning. It co-occurs with Southern Pygmy Perch in SA, but can be distinguished by a lack of scales on the top off the head and a second dorsal spine shorter than the third. Body patterning and a distinct black dot at the base of the tail is also a good guide.

Former distribution Only discovered and formally described in the 1980s[122], with limited information prior to this (e.g. retrospective identifications of museum specimens). The species range in SA includes a small section of habitat in the Lower South East (also known from the adjacent Glenelg River system in Victoria). Verified records in SA are known from Ewens Ponds (where the species was first found) and other parts of the Eight Mile Creek system upstream and downstream of the Ponds and in Spencer Pond. Also occurs in the Deep Creek system (formerly connected to Eight Mile Creek before an artificial mouth was cut to the sea) including upper Deep Creek, Stratmans Pond and 54 Foot Pond. It may have also occurred in the Piccaninnie System between Eight Mile Creek and the Glenelg River, but records from here cannot be verified[23,123,124].

Current distribution Has a highly restricted area of occupancy (<4km^2) in what is essentially one location fragmented into two parts due to channel alteration (CRB2a). Has declined slightly in extent of occurrence due to drying and loss of habitat above Ewens Ponds (CRB2b(i)), and there has been a decline and now overall low abundance in the Deep Creek system. The quality of habitat across its SA range has been observed to decline through loss of flow, increased nutrients and habitat alterations, as described below (CRB2b(iii))[94,125].

Biology and habitat The regional habitat supporting the Variegated Pygmy Perch is comprised of a landscape of limestone containing rising springs that form ponds with fast flowing outflow creeks. It is most common in areas with fast flow, clear water, lush submerged aquatic vegetation and good emergent and riparian (edge) cover. Also occurs in low numbers amongst submerged vegetation in pond habitat and still shallows, but Southern Pygmy Perch is more common in this habitat. Biology is little known, with indications that it spawns in spring and has a short lifecycle (~2-4 years), and diet likely includes small aquatic invertebrates picked from underwater surfaces. Movements have been speculated but do not appear necessary for spawning[122,123,124].



Reasons for decline and threats Given the flow reliance of the Variegated Pygmy Perch, the primary threat is reduced flow due to declining spring discharge (assumed to be largely supplied by the regional unconfined aquifer). Changes in stream flow (spring discharge) occur as a result of a reduction in the water table level and aquifer pressure due to groundwater extractions, especially in dry periods where water demand for irrigation increases and thus represents a higher use compared to aquifer recharge rates[126]. There has been a rapid proliferation in intense irrigation pumping of groundwater in the immediate vicinity of Variegated Pygmy Perch habitat since the 1990s (Figure 7), that is exacerbated by below average recharge to the aquifer from a protracted low rainfall period, and that is predicted to worsen for the future under climate change scenarios. Flow has decreased at Eight Mile Creek by 20-30% since 1990[126,127] and local groundwater levels have declined alarmingly in the same period[128]. Groundwater extraction also creates the additional risk of salt water intrusion (elevated salinity), and increased nutrient infiltration into shallow aquifers combined with reduced flow creates a potential for increased algal growth smothering underwater surfaces. Most of Eight Mile Creek and Deep Creek are currently managed as artificial habitat (drains) and consequently have poorly developed riparian habitat and unstable edges, thus affecting the quality of edge habitat for the species. Regular dredging also creates intense disturbance to in-stream habitat[57]. Predatory alien fish are a potential threat to the species. A general lack of awareness of the presence and requirements of Variegated Pygmy Perch and the subsequent failure for inclusion in management and planning, is also a threat to the species.

Land tenure and conservation Occurs in the Ewens Ponds CP and on drainage reserves abutting dairy properties, with some public access from roadways.

Recovery objectives

- Urgently secure water requirements and habitat of Variegated Pygmy Perch.
- Monitor population trends and link to environmental conditions.
- Restore habitat of the Variegated Pygmy Perch (longer-term).
- Increase awareness and knowledge of the species.

Conservation actions already initiated

- Recognised and described as a distinct species.

• Initial distribution and habitat surveys have been undertaken.

• Review and assessment of groundwater extraction scenarios and a recent review of water use undertaken. Review of water allocation planning in progress.

• Information sheets with information on identification and for raising awareness[121].

• 'Protected' from exploitation under the *Fisheries Management Act 2007.*

• Recent level of publicity over concern for decline in flows and health of Ewens Ponds[127].

• Dredging of Eight Mile Creek is now seen as damaging and alternatives are being sought.

Required conservation actions

• Review local hydrological models at the appropriate scale, and water use and loss of stream flow (including climate change scenarios) in the Eight Mile Creek and Deep Creek systems.

• Protect environmental requirements through appropriate water allocation.

• Undertake adaptive management incorporating environmental monitoring data to improve habitat conditions in the Eight Mile Creek and Deep Creek systems (e.g. dredging and riparian vegetation management initiatives).

• Establish long-term government and community support structures to promote the Variegated Pygmy Perch within regional planning and management, and aquatic protection, restoration and education programs.

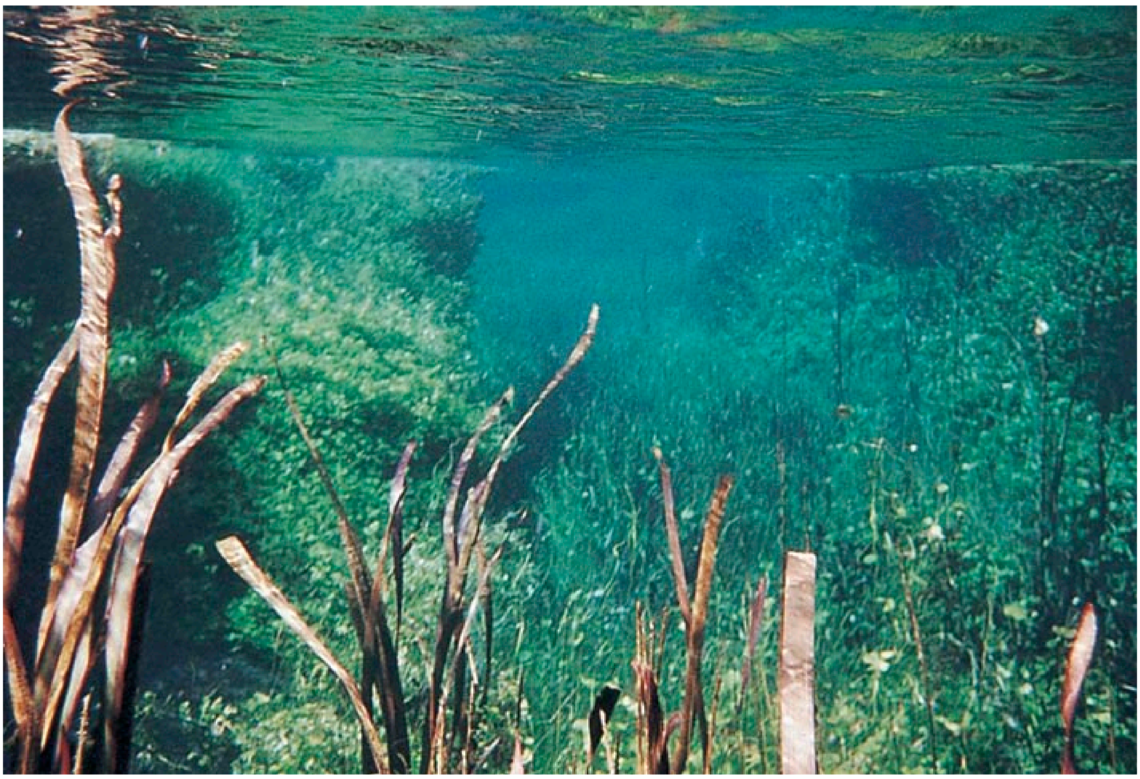
• Regular field monitoring of the distribution and abundance of Variegated Pygmy Perch to detect any responses or declines to changing conditions as a key indicator species for the health of the Ewens Ponds and Eight Mile Creek system.

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, DEWHA, SEWCDB, DWLBC, SE NRM Board.

Organisations or individuals involved

NFA(SA), DEH, DWLBC SE NRM Board, SEWCDB, Australian and New Guinea Fishes Association.



Variegated Pygmy Perch habitat at Ewens Ponds

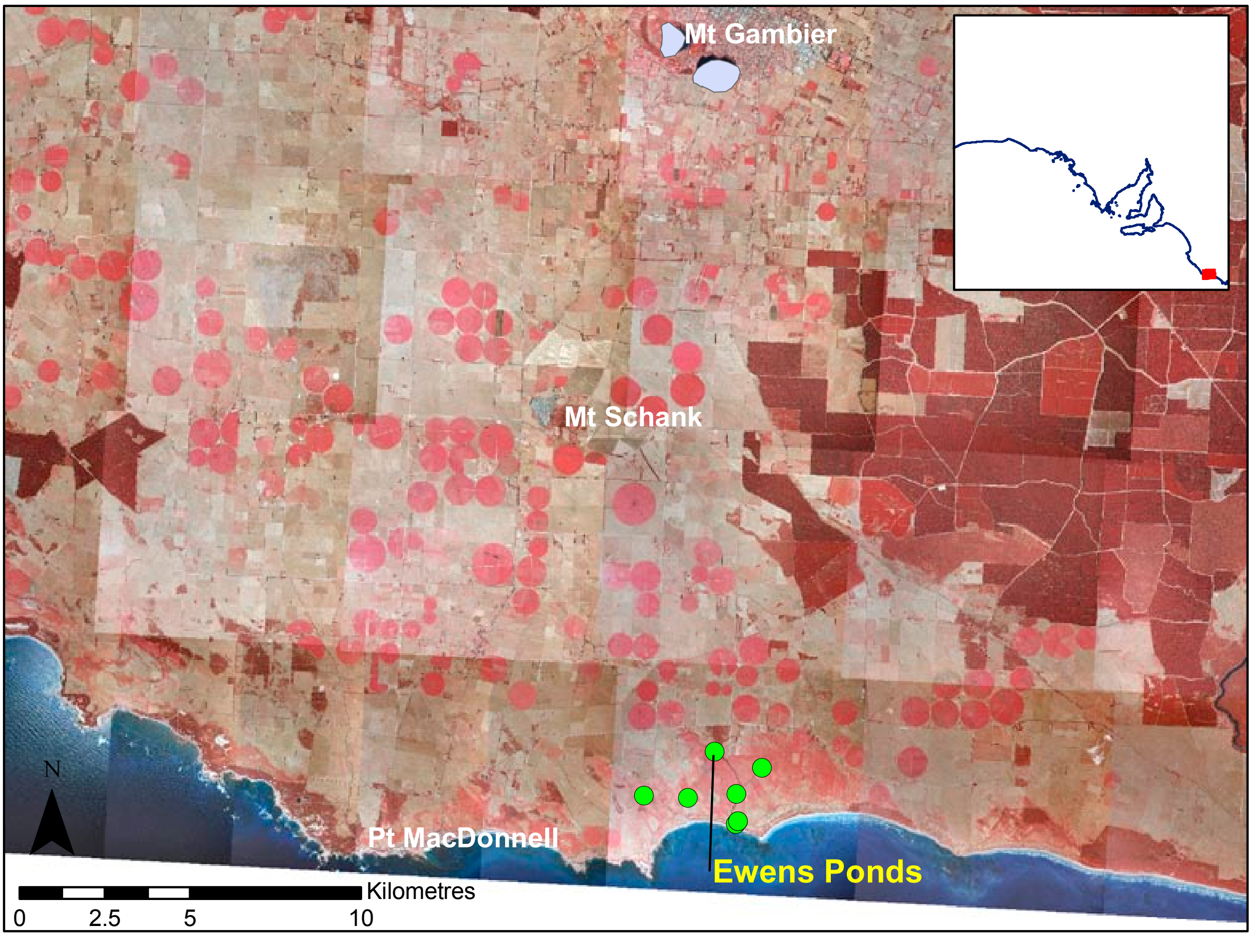


Figure 7. Aerial view (2003) of irrigation surrounding Variegated Pygmy Perch habitat (shown with green dots). Irrigation is indicated by the widespread red circles and other similarly coloured red areas surrounding Ewens Ponds (Orthoimagery supplied by DEH, Environmental Information)

Southern Purple-spotted Gudgeon *(Mogurnda adspersa)*

Other common names: Chequered Gudgeon, Purplestriped Gudgeon, Krefftius, and Mogurnda

Conservation status *South Australia:* Critically Endangered (CRB1ab(i,ii,iii,v)); Protected (*Fisheries Management Act 2007*)

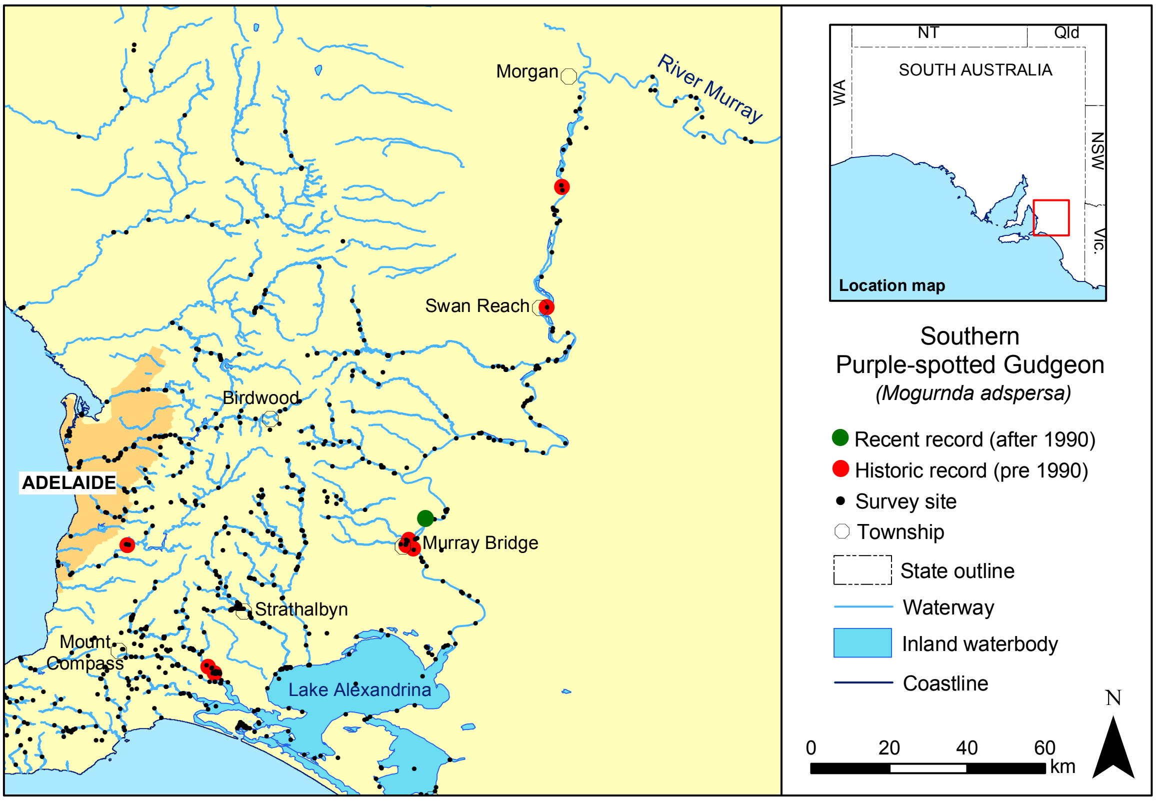
National: not listed. *Interstate:* listed as Endangered in New South Wales and Threatened in Victoria (Regionally Extinct).

Taxonomy and identification A small robust fish reaching around 12cm in length, but more commonly 4-7cm. The taxonomic status and genetic distinctness of fish from the Adelaide region compared to the remaining range remains to be determined. Distinguished from other gudgeons (e.g. Dwarf Flathead Gudgeon) by purple stripes on the gill cover and brick red body spots. There is a subtle difference between related species of Purple-spotted Gudgeon including presence of darker vertical bars and differences in lateral scale counts.

Former distribution The Southern Purple-spotted Gudgeon was previously widespread and common in patches throughout the lower section of the River Murray in South Australian with records from Lower Finniss River, Murray Bridge, Swan Reach and Blanchetown (between 1888 and the 1970s), and also being present (but little known) in the Torrens and Onkaparinga rivers (Adelaide Region, verified records prior to 1920)[17,18,101,107]. The Southern Purple-spotted Gudgeon was once common enough to be used by anglers as live bait for Murray Cod, Golden Perch and Redfin[17,36]. There is an unusual Australian Museum specimen with details "Moonta SA" (1933), an area with no natural waterbodies (the top of Yorke Peninsula, falls distantly between the Broughton and Wakefield rivers).

Current distribution Declared regionally extinct in SA in the early 1990s[36] with no verified records in the past 30 years from the River Murray and Adelaide regions despite a reasonable level of suitable sampling (although this has not necessarily been targeted to potential habitat of Southern Purple-spotted Gudgeon). Hence a decline (disappearance) in the extent of occurrence and number of localities has been noted from the mid 1970s (CRB1ab(i,ii,iii)). The species was however rediscovered in the Lower Murray from one location between Blanchetown and Wellington in 2004[129]. Genetic data indicate this population to be native, and quite different to a translocated population sourced from fish in the Queensland MDB[36] established near Murray Bridge[130,131]. The continued lowering of River levels has caused drying of the only known wetland (Figure 8), with a related crash in local abundance (CRB1b(v)), and is likely to result in the loss of this remaining population in South Australia and hence the southern Murray-Darling Basin[129].

Biology and habitat Information on historic habitat in South Australia suggests the species occurred in areas of dense submerged or emergent vegetation such as Ribbon Weed *(Vallisneria)*, Foxtail *(Ceratophyllum)* and Bullrush *(Typha)* in lowland river edges, wetlands and swampy drains[17,18,42,108]. The recently discovered site also had high levels of edge cover and submerged vegetation[129]. Other specific information on biology comes from interstate suggesting the species is carnivorous feeding on small fish and macroinvertebrates such as Glass Shrimp and small Yabbies, maturing at around 4-5cm and utilising hard substrate for spawning during summer[109,132,133].



Reasons for decline and threats The reasons for the considerable decline of the Southern Purple-spotted Gudgeon are little known but is likely due to progressive decline in the suitability of local habitats from a combination of reduced flows, increases in turbidity along the River Murray, decreased water quality, and loss of submerged and emergent macrophytes. Interaction with introduced fishes is also likely to be significant, especially Redfin predation (e.g. Adelaide Region), and aggressive interactions, competition and predation of fry by Gambusia, an often cited potential threat elsewhere[74,132,134]. There is a casual link between the arrival of Carp in the River Murray and the disappearance of Southern Purple-spotted Gudgeon (i.e. potential habitat modification through loss of aquatic vegetation or transmission of disease). Disease incidence was high just prior to wetland drying of the last known wild site[129]. Exploitation is a threat to small populations. Ill-planned reintroductions could cause genetic problems.

Land tenure and conservation

- River Murray corridor and formerly in the City of Adelaide, possibly Onkaparinga River NP.

Recovery objectives

- Ongoing assessment of status in the wild (known and potential habitat).
- Secure core habitat with flow and habitat protection.
- Further research species requirements to assist recovery planning.
- Look to expand population range to provide greater population security through a captive breeding and reintroduction program.

Conservation actions already initiated

- Protected from exploitation (*Fisheries Management Act 2007*).
- Several recent surveys have been undertaken within the species range[24,25,28,69,70,78].
- Previous trials have shown that refuge populations can be established in artificial habitat[36].
- Emergency captive maintenance has been initiated due to severe habitat loss at the remaining known site, included the rescue of around 50 individuals[129].
- A Reintroduction Plan is in preparation and links to a current SA DEH Drought Action Plan.

Required conservation actions

- There is a possibility that more populations will be discovered through comprehensive targeted surveys focusing on historic survey locations and suitable habitat.
- Better document information on species' biology and historic habitat including an oral history program and potential collaboration with interstate researchers.
- The lack of information regarding the Southern Purple-spotted Gudgeon means that the general public can help by reporting any past or present sightings (www.nativefishsa.asn.au).
- Continue support of urgent conservation measures (captive maintenance, habitat monitoring).
- Develop a strategy and actions to expand the species range to more natural and artificial habitats (captive breeding, habitat restoration, environmental water provisions).
- Undertake a genetic study using historic museum specimens to assess relationships between different SA and interstate populations, and to evaluate diversity within wild and captive fish.

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, DWLBC, AMLR & SAMDB NRM boards.

Organisations or individuals involved

DEH, PIRSA, MDBA, SAMDB NRM Board, NFA(SA), Aquasave, SARDI Aquatic Sciences, SAMA.

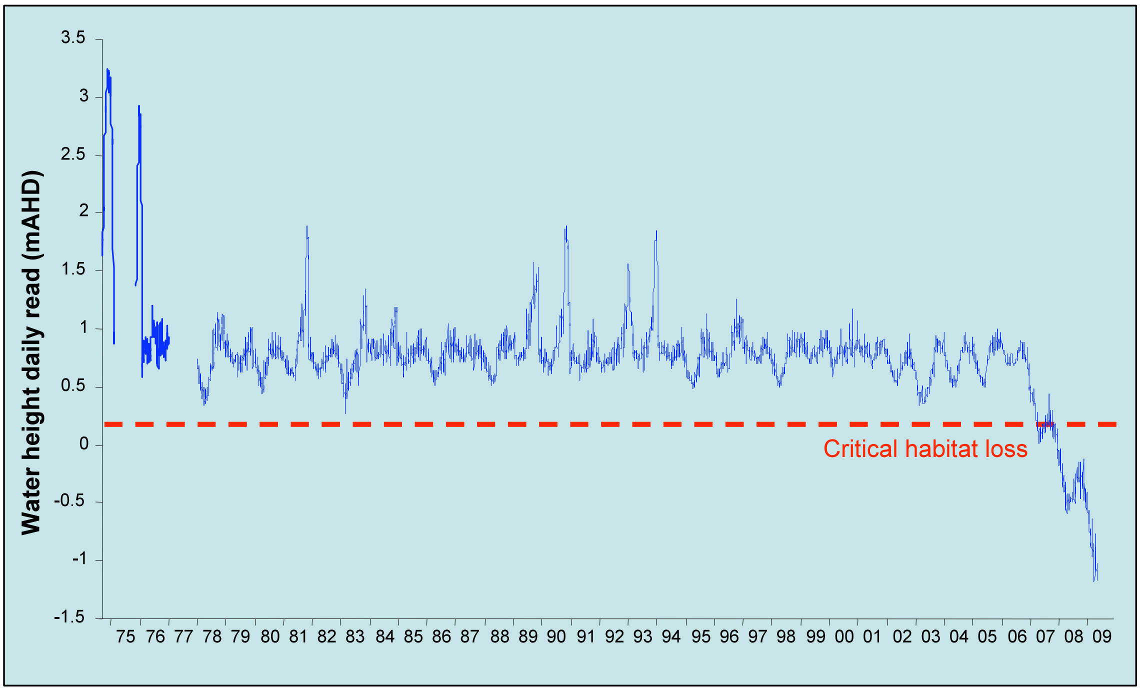


Figure 8. Indicative long-term record of water height at the recently discovered Southern Purple-spotted Gudgeon habitat on the Lower River Murray (metresAHD, observed at Mannum recorder A4261067)[135]. Critically low levels after 2007 are clearly highlighted, with the level in 2009 more than one metre below average sea level. The dashed line indicates the point where the wetland dried.

Flinders Ranges Purple-spotted Gudgeon *(Mogurnda clivicola)*

Other common names: Flinders Mogurnda

Conservation status *South Australia:* Critically Endangered (CRB2ac(ii,iv)); Protected (*Fisheries Management Act 2007*).
National: Vulnerable (*EPBC Act 1999*).

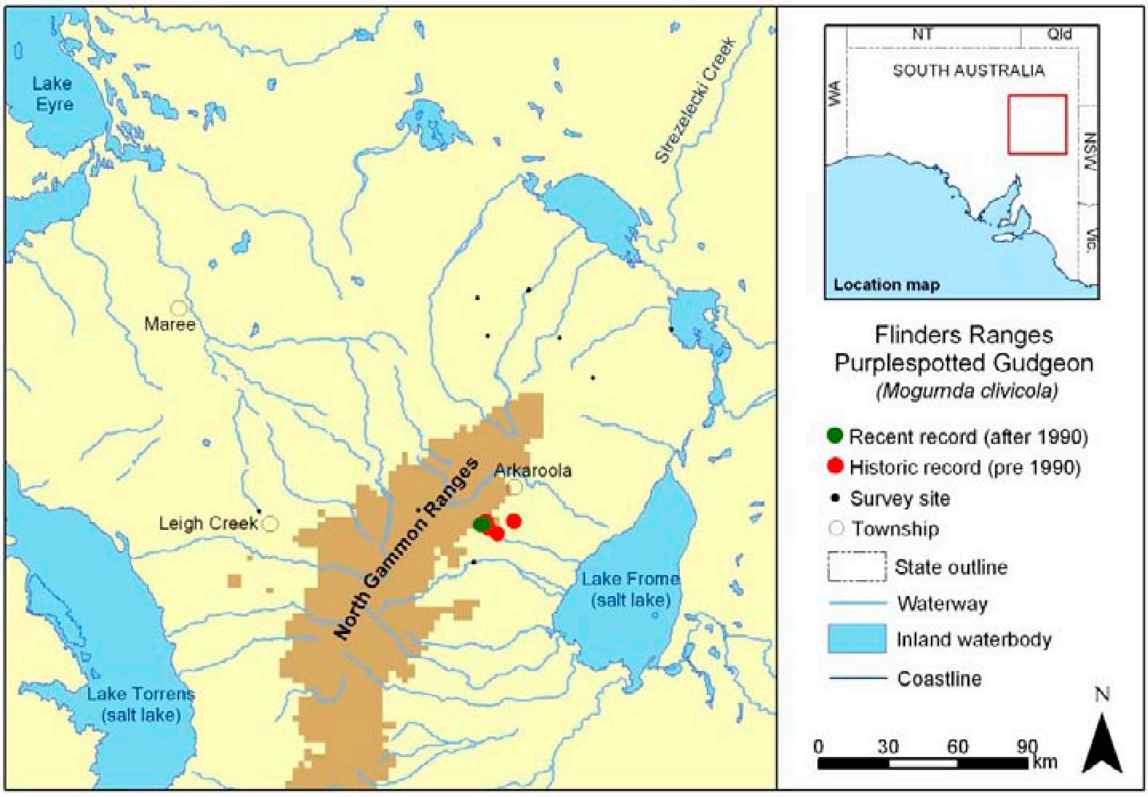
Taxonomy and identification A small robust fish reaching a size of ~15cm, more commonly 5-8cm. Recently described as a distinct species[136], some taxonomic issues remain to determine relationships between other populations thought to be this species in the upper Cooper Creek (Barcoo River) and Bulloo River systems. There is little chance of confusion between other species in the region it is found, but reports of Flinders Ranges Purple-spotted Gudgeon often turn out to be of Spangled Grunter which does have pale body speckling (but orange as opposed to the brick red spots of the gudgeon) and has a single dorsal fin and square to slightly forked tail (v. two dorsal fins and rounded tail for the gudgeon). There are subtle differences between this and other related species of purple-spotted gudgeon including the lack of darker vertical bars and differences in lateral scale counts.

Former distribution Known only from a 12km section of Balcanoona Creek, a small stream (<10m wide) in the Flinders Ranges (North Gammon Ranges) draining toward Lake Frome[107,137.] Flinders Ranges Purple-spotted Gudgeon has reportedly been translocated to other streams and artificial habitat in the area[31,32].

Current distribution Recent detailed monitoring has not been undertaken, but opportunistic records and observations suggest that area of occupancy remains at much less than 10km^2 due to dry recent conditions (CR B2a). The population in Balcanoona Creek is thought to contract considerably in dry periods (CR B2c(ii,iv)), possibly as low as 150 individuals in a few pools associated with two small springs[137]. A translocated population appears established at Nepouie Springs, but another in a large rainwater tank at the local National Park Headquarters appears to have been lost. There is a minor possibility that the species occurs naturally in other small refuges in the Flinders Ranges[55,101].

Biology and habitat The Flinders Ranges Purple-spotted gudgeon is found in rocky stream habitat in the lower foothills of a deep-sided gorge. This habitat is maintained by springs thought to be sourced from local rock aquifers, with occasional expansion of habitat following local rainfall and increased surface water flows. Habitat comprises small pools with high levels of physical cover of rock and snag, leaf litter and bark from River Redgums fringing the stream, and some submerged and emergent vegetation. A reasonable level of biological information is available from a study into the natural history of the species in the mid 1980s[137] and other opportunistic observations[32]. Spawning occurs in spring and summer, and possibly later if flood events occur during the warmer months, with a peak (or mass spawning) noted following an influx of underwater structure and thus spawning sites when Redgums shed their bark in

December. Spawning occurs on solid surfaces whereby males guard and fan the eggs. Schools of juveniles occur in surface waters before becoming more cryptic and territorial after maturation at 6-7cm, with most individuals in the population 1-2 years old and a few larger adults up to around five years old. Adults are opportunistic feeders on adult stages of aquatic macroinvertebrates (e.g. dragonflies), small fish, frogs and tadpoles, and other small terrestrial vertebrates. The Balcanoona Creek population does not co-exist with other fish species. Movement is restricted by limited habitat. Flinders Ranges Purple-spotted Gudgeon is affected by a nematode which appears to regrade the condition of adults under high density and thus regulate population density. Melanomas have also reportedly been detected on the species[138].



Reasons for decline and threats The single known population is small, isolated and fluctuates in occupied area and abundance making it highly susceptible to natural chance events and local and global human related impacts such as:

- Climate change – a reduction in the amount of rain received and an increase in the frequency of large storm disturbances (e.g. floods) may impact water availability and springs.
- Water abstraction – given the small habitat reliant on spring flows, any major water extractions in the region (e.g. mineral exploitation) pose a serious potential threat of extinction in a short time frame.
- Cancer – the influence of increased ultraviolet radiation is suggested to cause increased mortality in the Flinders Ranges Purple-spotted Gudgeon[138].
- Water quality - related species are sensitive to water contamination with uranium[139].
- Alien fishes – the small area of habitat increases the likelihood of interactions with introduced species, especially aggressive Gambusia.
- Introduced terrestrial vertebrates - feral goats frequenting stream habitat were suspected to cause water quality problems (e.g. algal blooms and deoxygenation) prior to pest control programs[32].
- Major habitat impacts – a proposal to mine within the Balcanoona Gorge (Figure 1) could have had devastating impacts to the species' habitat and water supply.
- Over harvest – illegal collecting of the species has been reported[32], and such removal could inhibit recovery or survival when the population is critically restricted during dry times.

- Any research needs to be careful not to cause disturbance to habitat, species ecology and ensure equipment is free from biological or chemical contaminants.

Land tenure and conservation

- Occurs within the Gammon Ranges National Park which was established in 1982 (formerly Balcanoona Station).

Recovery objectives

- Maintain and protect habitat, discourage fish introductions.
- Re-establish artificial refugia (sourced during times of greater wild abundance).
- Specifically investigate potential impact of climate change.
- Increase awareness within local natural resource management of species requirements and threats.

Conservation actions already initiated

- A vertebrate pest control program has been initiated and maintained in the region (i.e. feral goats).
- Scientific Expedition Group has been monitoring water quality, macroinvertebrates and rainfall in and around Balcanoona Gorge for over a decade.
- A SARDI Aquatic Sciences Stock Assessment Program was initiated in the 1990s[138,140], however this information is not available.

Required conservation actions

- Initiate regular monitoring to assess habitat extent and quality, estimate population status (numbers and health) and to ensure Gambusia and other alien species are not present.
- Develop contingency plans for extreme conditions or new threats (e.g. refuge drying, control of fish introductions) and investigate sites and methods for establishing artificial refugia.
- Continue terrestrial vertebrate pest control program.
- Undertake systematic regional surveys for other potential populations.
- Determine taxonomic relations with populations in the Cooper and Bulloo systems.

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, DEWHA, Arid Areas NRM Board.

Organisations or individuals involved

DEH (National Parks), SARDI Aquatic Sciences, SEG, SA Sporting Shooters Association, traditional owners.


Habitat of the Flinders Ranges Purple-spotted Gudgeon at Balcanoona Creek

2.3. **ENDANGERED**

considered to be facing a
very high risk of extinction
in the wild

Pouched Lamprey *(Geotria australis)*

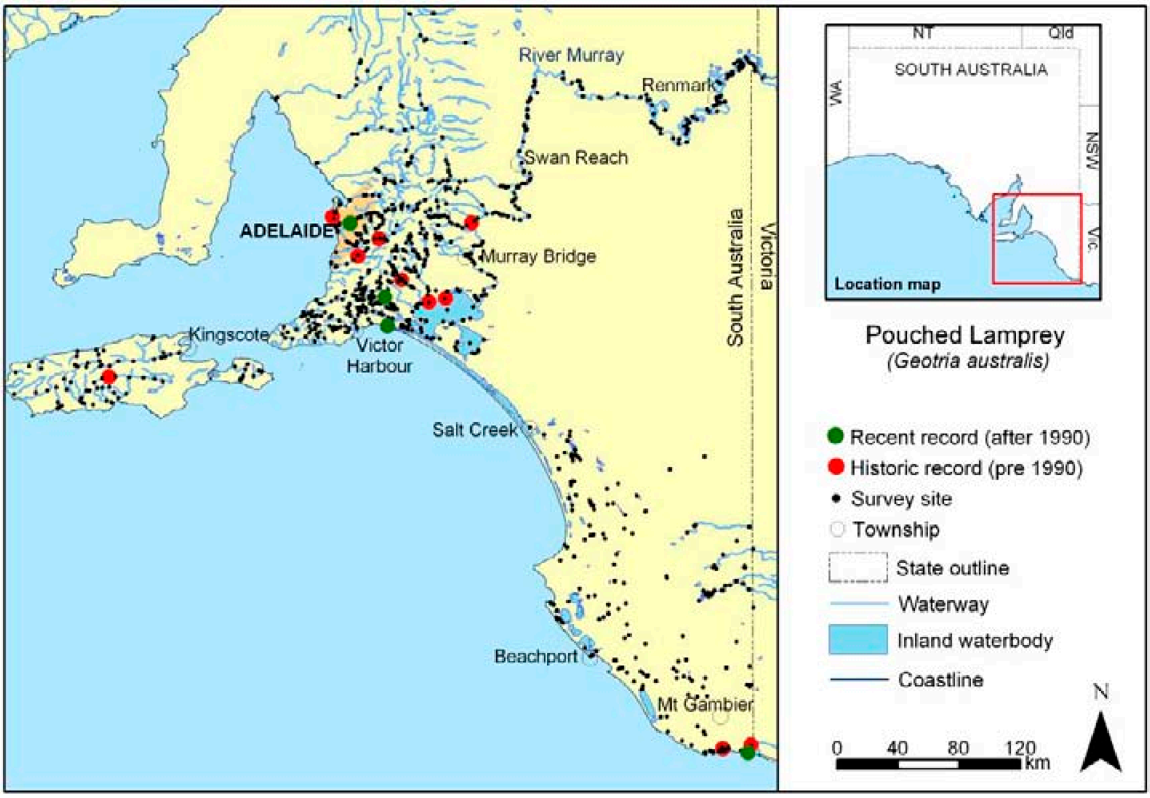
Conservation status *South Australia:* Endangered (EN A2c).
National & interstate: not listed.

Taxonomy and identification An eel like fish reaching 70cm; adults have a unique jawless, suction cap like mouth (oral disk). Pouched Lamprey can be distinguished easily from other freshwater fishes by a series of circular openings on the head (gills), the oral disk, and two distinct dorsal fins (eels have a long singular fin). They are similar in appearance to (and are often confused with) Shorthead Lamprey, but have eyes positioned to the side of the body (laterally) and circles of finer teeth on the outer oral disk. Pouched Lamprey are also generally lighter in colour and adults returning to freshwater are larger in size. Note that only males develop a pouch behind the head, and only when they are ready to spawn, hence this character is not reliable for identification. The worm like juveniles (ammocetes) can be distinguished by the alignment of the cloaca (akin to an anus) which is close to the front edge of the dorsal fin.

Former distribution Due to the unusual appearance of lampreys there is a reasonable level of opportunistic historic records held at the SA Museum (comparative to other species), mostly prior to the 1930s, with a few more recent records (>1980) helping to fill in the known distribution. However there is no indication or study relating to their former abundance. Pouched Lamprey has been recorded from four main freshwater areas: (1) in the Adelaide region within and near the larger streams - Torrens from as early as 1886 and Onkaparinga (1901 & 1906) including a record of a sub-adult high up in the catchment at Cox Creek, Bridgwater (1879), (2) the SAMDB (by far the largest are of habitat available) including Coorong/Lower Lakes, tributary streams (Bremer, Angas and Finniss rivers) and lower River Murray (records as far upstream as Mannum in 1932), (3) Kangaroo Island (ammocetes found in a well from a non specific location in 1928), and (4) Lower South East - SA section of the Glenelg River (1928) and from Ewens Ponds (1982). Pouched Lamprey spend part of their lives at sea.

Current distribution The current distribution and abundance of Pouched Lamprey is difficult to ascertain without targeted investigations using suitable gear types as the species is cryptic as both adults and juveniles. However, opportunistic records have diminished and reasonable levels of sampling have occurred within historic habitat including electrofishing and fyke netting in Adelaide Hills catchments, the EMLR, southern Fleurieu Peninsula, Kangaroo Island with no or few records[26,27,28,141], suggesting the area of occupancy in SA is limited and declining. Current records include observations of low numbers of upstream migrating adults at the Torrens River city weir in the middle of Adelaide in 1992, 1998 and 2001[28,101] and Murray Barrages (2002 and 2007)[101,142], with two individuals recently collected from the Piccaninnie Ponds fishway[55].

Biology and habitat The Pouched Lamprey has a multi-staged lifecycle switching between fresh and marine habitat via determined migrations (a diadromous species). The general lifecycle model and biology is reasonably well established for populations interstate (SW Western Australia) but details remain to be confirmed in SA. Adult Pouched Lamprey spend two years at sea where they use their oral disk to latch onto a host fish and feed parasitically. They migrate into freshwater streams and rivers during winter and spring and are able to negotiate small barriers with the aid of their suction cap like oral disc. Spawning occurs the following spring (site poorly known, but likely to be in flowing upper stream sections). Adults don't eat while in freshwater and are generally found amongst structure such as rocks and snags, they die after spawning. Juveniles (ammocetes) are worm like and live in the stream bed, in silty areas with shade and slow permanent flow, a habitat type generally occupying only a small proportion of available river and stream habitat (although again this is poorly known, especially in SA). The ammocetes are filter feeders, consuming algae and zooplankton. Juveniles grow until metamorphosis (change in body form) after around 4.5 years whereby they migrate downstream to the sea during high winter flows[87,143,144,145]. The overall dispersal ability of Pouched Lamprey is unknown, for example whether individuals could disperse to different catchments from adjoining areas or interstate.



Reasons for decline and threats The primary threats to Pouched Lamprey appear to be the interplay of major catchment modifications to hydrology, habitat and fish movement. Reduced stream and River Murray flows (e.g. via extensive farm dam development and water storages in the MLR, massive upstream diversion and storage in the MDB) are predicted to have led to a decrease both in the amount of wetted habitat available, the quality of remaining habitat (e.g. reduced dissolved oxygen and increased temperatures with flow loss) and reduced connectivity into and within catchments for migration (e.g. no access though the barrages since 2007). Broad habitat change from land clearance causes changes in stream flow and morphology, and combined with local impacts such as trampling and removal of edge vegetation by stock, the suitability of streams for larval lampreys is diminished (e.g. loss of shade, disruption of stream bed). Other processes such as dredging (e.g. extensive modification of Eight Mile Creek[57]), drain maintenance, road works or development also represent potential threats to larval and adult habitat. Numerous larger barriers to fish movement exist in the known range of Pouched Lamprey, particularly in the River Murray system (major barriers at the Barrages, Locks and Weirs) and in the Adelaide region through major reservoirs such as Mt Bold and numerous weirs and reservoirs along the Torrens[146]. Such barriers act to restrict access to suitable spawning habitat in parts of catchments or act as partial barriers reducing adult numbers through exposure to conditions or predators[145]. Introduced animals including trout and Marron (Kangaroo Island) may prey on eggs and juvenile lampreys[147,148].

While there is not direct observational data on decline of Pouched Lamprey, the recent low incidence of detection and a significant decline in the available area and quality of freshwater habitat critical for the species' lifecycle indicates the species is susceptible to loss or extreme fluctuations within catchments and the State. Ongoing reductions in the abundance of individuals in freshwater habitat (both growing ammocetes and returning adults) is also suspected, especially with recent increasing levels of hydrological development[149,150] in stream habitats (e.g. loss of pools and perennial flow), particularly degradation and blocked access through the barrages in the Lower Murray[151] (EN A2c). Specific assessment of available and suitable freshwater habitat may reveal Pouched Lamprey to be more threatened than currently realised. Being cryptic they could equally decline without being noted.

Land tenure and conservation Known to occur in or move through the Ewens Ponds CP, Piccaninnie Ponds CP, Lower Glenelg NP, Coorong NP and Onkaparinga River NP. Other land is managed by councils (e.g. Adelaide City Council), private land (MLR streams) or has public access (e.g. Lower Lakes and River Murray).

Recovery objectives

- Improve knowledge of Pouched Lamprey: (a) distribution and abundance in SA, (b) habitat requirements and tolerances, especially for ammocetes, and (c) migration ability.
- Improve catchment management to assist recovery of Pouched Lamprey by: (a) maintaining or restoring natural flow regimes (habitat availability and condition), (b) re-establishing natural pathways
- for migration (flows and fishways), and (c) restoring suitable freshwater habitats to enable growth and survival of ammocetes.
- Improve awareness on the biological requirements and uniqueness of the Pouched Lamprey.

Conservation actions already initiated

- Initial assessments of distribution undertaken opportunistically from surveys occurring throughout much of the known range of Pouched Lamprey.
- Fishways have been installed at the Barrages and some Locks and Weirs as part of a large MDBA project aiming to restore fish passage between the sea and Hume Weir. Detailed study has been initiated at these fishways[142].
- A fishway has recently been installed at the mouth of the River Torrens (AMLR NRM Board).
- Dredging of Eight Mile Creek is now seen as damaging and alternatives are being sought.

Required conservation actions

- Targeted temporally repeated monitoring to detect the distribution, habitat and behaviour of adult and juvenile Pouched Lamprey, plus other research into dispersal ability at broad and local scales.
- Undertake environmental flow assessment and restoration programs to ensure sustainable surface water and groundwater supplies, including provision for climate change scenarios (especially MLR, plus broader improved management of water resources in the MDB).
- Assess and prioritise barriers potentially impacting migration, investigate fishway options, including studies to test their effectiveness.
- Undertake projects to protect and restore larval habitat, and monitor their effectiveness.
- The lack of information regarding the Pouched Lamprey means that the general public can help by reporting any past or present sightings (www.nativefishsa.asn.au).
- The unique form, complex biology and threatened status of the Pouched Lamprey make them a good icon for the sustainable use and improvement of waterways in SA, especially the Adelaide region. This needs to be fostered through improved education and natural resource management within government and community groups.

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, DWLBC and the KI, AMLR, SAMDB & SE NRM Boards.

Organisations or individuals involved

NFA (SA), SARDI Aquatic Sciences, AMLR NRM Board, SA Water, DWLBC, MDBA.

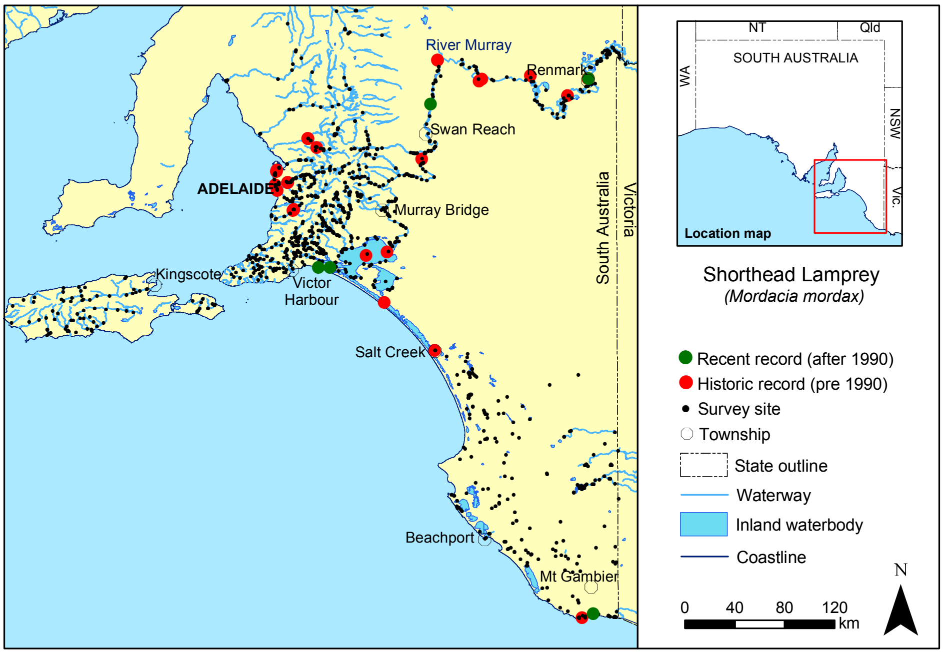
Shorthead Lamprey *(Mordacia mordax)*

Conservation status *South Australia:* Endangered (EN A2c).
National & interstate: not listed.

Taxonomy and identification An eel like fish reaching 50cm, adults have a unique jawless suction cap like mouth (oral disc). Shorthead Lamprey can be distinguished easily from other freshwater fishes by a series of circular openings on the head (gills), the oral disk, and two distinct dorsal fins (eels have a long singular fin). They are similar in appearance to Pouched Lamprey (and are often confused with them) but have eyes positioned towards the top of the body (dorsally) and ridged teeth on the outer oral disk. Shorthead Lamprey are also generally darker blue in colour and returning to freshwater smaller in size than their Pouched Lamprey counterparts. The worm like juveniles (ammocetes) can be distinguished by the alignment of the cloaca (akin to an anus) with the middle of the dorsal fin.

Former distribution Due to the unusual appearance of lampreys there is a reasonable level of opportunistic historic records held at the SA Museum (comparative to other species), with reasonably continuous records of Shorthead Lamprey through to the 1970s[101] from two main freshwater areas: (1) the Adelaide region including the Gawler Catchment (Gawler River and South Para River prior to 1928), Port River estuary (1941 & 1960), Torrens River (1877-1932), Patawalonga Creek, Glenelg (1920) and Onkaparinga River (1880 & 1928), and (2) the River Murray system including the Coorong including Salt Creek (1877-2006), Lake Alexandrina (1938 & 1972) and along the main channel and occasional wetlands of the River Murray including at Waikerie, Overland Corner, Morgan, Berri and Renmark[101]. There are unverified (anecdotal) reports from rivers in the SW of Kangaroo Island and a single record from marine habitat in the SE (both areas have potential habitat). While no investigations were undertaken the species appears to have been reasonably common in the River Murray - large aggregations have been reported clinging to Lock 1 in the past (~1960s). The Shorthead Lamprey was reported to be very common in the River Torrens prior to the construction of the weir at the river mouth in 1937[152], with "many specimens" reported near the Torrens outlet (1951)[153] (note both accounts may have included Pouched Lamprey as there are verified records of both in the system[101]).

Current distribution The current distribution and abundance of Shorthead Lamprey is difficult to ascertain without targeted investigations using suitable gear types as the species is cryptic as both adults and juveniles. However opportunistic records have diminished since the 1970s and despite increased levels of scientific sampling including electrofishing and fyke netting in Adelaide Hills catchments, the EMLR, southern Fleurieu Peninsula, Kangaroo Island and the SE which did not yield any records[25,26,27,28,141]. A few records have come from near to the Murray Mouth with recent intensive and temporally repeated sampling (e.g. Goolwa Barrage, Hunters Creek, Denver Creek on Hindmarsh Island[59,101,142,154]) and two single individuals were recorded along the River Murray channel[155]. Hence combined data suggests the area of occupancy in SA is limited.



Biology and habitat The Shorthead Lamprey has a multi-staged lifecycle switching between fresh and marine habitat via determined migrations (a diadromous species). The general lifecycle model and biology is reasonably well established for populations interstate (Victoria) but details remain to be confirmed in SA. Adult Shorthead Lamprey spend time at sea and in large estuaries where they use their oral disk to latch onto a host fish and feed parasitically. They migrate into freshwater streams and rivers during late winter and spring, being able to negotiate small barriers with the aid of their oral disc. Spawning occurs the following spring (site poorly known, but likely in flowing upper stream sections) with adults not eating while in freshwater and generally being found amongst structure such as rocks and snags. Juveniles (ammocetes) are worm like and burrow into silt, especially along protected banks in shallow slow flowing areas. They probably require permanent flow and shade (they are rarely found in stagnant or highly eutrophic waters). SA juveniles have been recorded near Walkers Flat, River Murray (1960) and in flowing habitat below Lock 1 at Blanchetown (2002). Ammocetes are filter feeders, consuming algae and zooplankton. Juveniles grow until metamorphosis (change in body form) after around 3.5 years whereby they migrate downstream to the sea during high winter flows[87,143,144,148]. The overall dispersal ability of Shorthead Lamprey is unknown, for example whether individuals could disperse to different catchments from adjoining areas or interstate.

Reasons for decline and threats The primary threat to both lamprey species occurring in SA appears to be the interplay of major catchment modifications to hydrology, habitat and fish movement. Reduced stream and River Murray flows (e.g. via extensive farm dam development and water storages in the MLR, massive upstream diversion and storage in the MDB) are predicted to have led to a decrease both in the amount of wetted habitat available, the quality of remaining habitat (e.g. reduced dissolved oxygen and increased temperatures with flow loss) and connectivity into and within catchments for migration (e.g. extended period of no flow). Access through the Murray barrages has been blocked since 2007 owing to very low water availability completing a major decline in predicted population size[151] and quality of the largest section of the species habitat (EN B2c). Broad habitat change from land clearance causes changes in stream flow and morphology, and combined with local impacts such as trampling and removal of edge vegetation by stock, the suitability of streams for larval lampreys is diminished (e.g. loss of shade, disruption of stream bed). Other processes such as dredging (e.g. extensive modification of Eight Mile Creek[57]), drain maintenance, road works or development also represent potential threats to larval and adult habitat. Numerous larger barriers to fish movement exist in the known range of Shorthead Lamprey, particularly in the River Murray system (major barriers at the Barrages, Locks and Weirs) and in the Adelaide region through major reservoirs such as Mt Bold and numerous weirs and reservoirs along the Torrens[146]. Such barriers act to restrict access to suitable spawning habitat in parts of catchments or acts as partial barriers reducing adult numbers through exposure to adverse conditions or predators. Introduced animals including trout and potentially Marron (Kangaroo Island) may prey on eggs and juvenile lampreys[147,148].

While there is not direct observational data on decline of Shorthead Lamprey, the recent low incidence of detection including a lack of records from the Adelaide region, and a significant decline in the available area and quality of freshwater habitat critical for the species' lifecycle indicates the species is susceptible to loss from extreme fluctuations from catchments within the State. Ongoing reductions in the abundance of individuals in freshwater habitat (both growing ammocetes and returning adults) is also suspected, especially with recent increasing levels of hydrological development[149,150] in stream habitats (e.g. loss of pools and perennial flow). Specific assessment of available and suitable freshwater habitat may reveal Shorthead Lamprey to be more threatened than currently realised, especially regarding deterioration in their main habitat, the River Murray (e.g. lack of access for prolonged periods with low water availability).

Land tenure and conservation Shorthead Lamprey occurs or moves through several conservation reserves along the River Murray corridor (Coorong NP, land managed for conservation at Wyndgate, Ngaut Ngaut CP, Roonka CP, Morgan CP, Murray River NP), as well as numerous council reserves and public riverfront access. Also likely to occur in private lands in stream catchments of the MLR.

Recovery objectives

- Recovery objectives and conservation actions match those for the Pouched Lamprey, except with a stronger emphasis on conservation of the River Murray, and could easily be combined:
- Improve knowledge of Shorthead Lamprey: (a) distribution and abundance in SA, (b) habitat requirements and tolerances, especially for ammocetes, and (c) migration ability.
- Improve catchment management to assist recovery of Shorthead Lamprey by: (a) maintaining or restoring natural flow regimes, (b) re-establishing natural pathways for migration, and (c) restoring suitable freshwater habitats to enable growth and survival of ammocetes.
- Improve awareness on the biological requirements and uniqueness of the Shorthead Lamprey.

Conservation actions already initiated

- Initial assessments of distribution undertaken opportunistically from surveys occurring throughout much of the known range of Shorthead Lamprey.
- Fishways have been installed at the Barrages as part of a large MDBA project to restore fish passage between the sea and Hume Weir. Research has been initiated at these fishways[142].
- A fishway has recently been installed at the mouth of the River Torrens (AMLR NRM Board).
- Dredging of Eight Mile Creek is now seen as damaging and alternatives are being sought.

Required conservation actions

- Targeted temporally repeated monitoring to detect the distribution, habitat and behaviour of adult and juveniles, plus other research into dispersal ability at broad and local scales.
- Undertake environmental flow assessment and restoration programs to ensure sustainable surface water and groundwater supplies, including provision for climate change scenarios.
- Assess and prioritise barriers potentially impacting migration, investigate fishway options, including studies to test their effectiveness.
- Undertake projects to protect and restore known or potential larval habitat, and monitor their effectiveness (also for sites with threatening processes).
- A lack of information means that the general public can help by reporting sightings.
- The Shorthead Lamprey is a suitable icon for the sustainable use and improvement of waterways, especially the River Murray.

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, DWLBC and the KI, AMLR, SAMDB & SE NRM Boards.

Organisations or individuals involved

NFA (SA), SARDI Aquatic Sciences, AMLR NRM Board, SA Water, DWLBC, MDBA.

Freshwater Catfish *(Tandanus tandanus)*

Other common names: Murray Catfish/Tandan, Catfish, Eel-tailed Catfish and Pomeri (Ngarrindjeri)

Conservation status *South Australia:* Endangered (EN A2bc); Protected (*Fisheries Management Act 2007*). *National:* not listed. *Interstate:* listed as Threatened in Victoria (Endangered) also recommended Vulnerable in NSW[74].

Taxonomy and identification Freshwater Catfish is a stout fish reaching a maximum length of 90cm, but more commonly attaining 30-50cm. It has a distinctive appearance due to four pairs of barbells around the mouth and a tapering eel-tail forming part of the body. This fish can be distinguished from other catfishes such as Cooper Catfish and Hyrtl's Catfish by the length of the second dorsal fin which extends to the mid body of the fish from the tail. Sharp spines are present on the dorsal and pectoral fins. There are taxonomic problems with Freshwater Catfish as studies indicate multiple species within the current species description. However only a single inland species is presumed for the MDB and SA[156,157]

Former distribution As with many of the larger edible fishes, verified records such as museum specimens are limited, and no detailed historic assessments of status were conducted. However, general reports indicate it was common throughout the SA section of the River Murray until around the mid 1960s, occurring in the main channel, billabongs[152], wetlands (including channels at Murray Bridge in the 1920s[41]), Lower Lakes and the lower reaches of tributary streams in the EMLR (Finniss River).

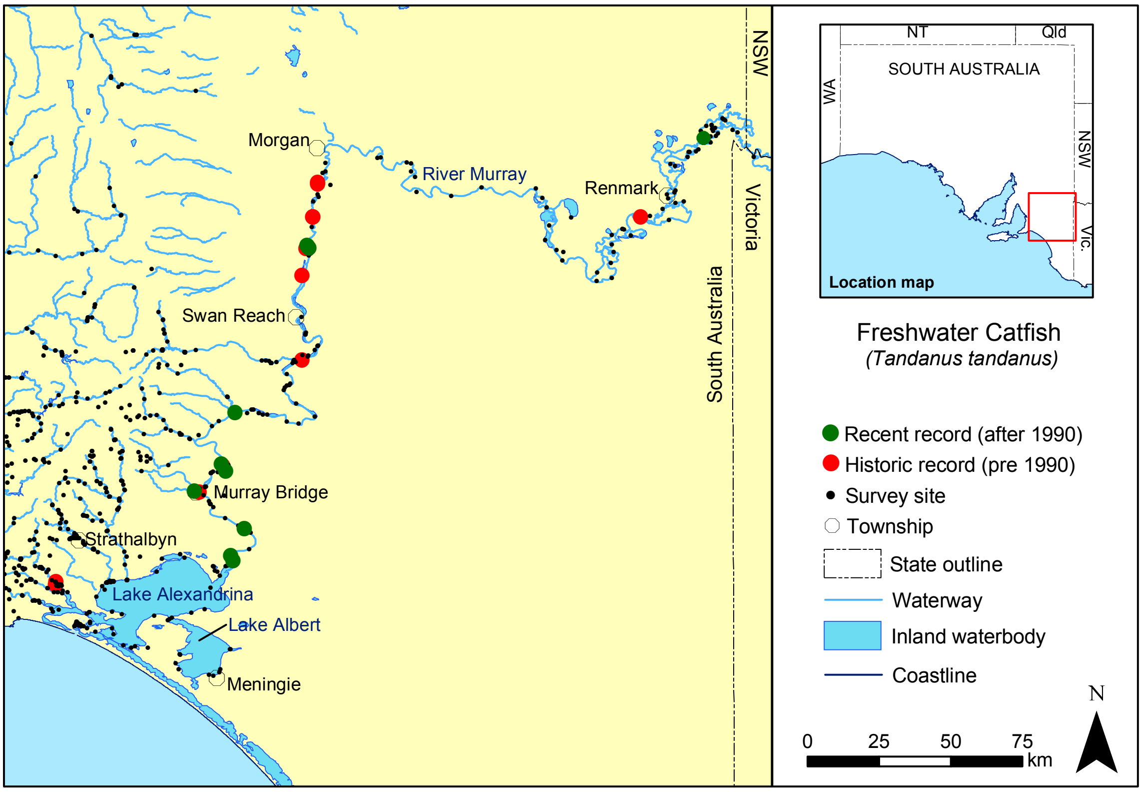
Current distribution The current distribution of Freshwater Catfish is patchy. Recent records are limited to a handful of locations from wetlands and the main Murray channel including juveniles from wetland habitat at Chowilla, Blanchetown, Mypolonga, Murray Bridge, Tailem Bend and Wellington [55,69,70,158,159,160]. Populations established in the WMLR through translocation are known from the Torrens, Wakefield and Field river catchments[28,53,55,65].

Biology and habitat The biology of Freshwater Catfish has not been studied in detail in SA, hence information is largely drawn from interstate studies and from translocated populations in WMLR. Freshwater Catfish prefer slow flowing habitat such as rivers and wetlands with reasonable levels of structure including snags, undercut banks and aquatic plants. They are common over gravel and rock habitat and submerged aquatic vegetation in the Torrens and Wakefield Rivers in sections which receive seasonal flushing flows. Freshwater Catfish are carnivorous feeding on fish, shrimps, freshwater prawns, Yabbies, and other macroinvertebrates which are mostly taken from the river bottom. Reproduction occurs in spring and summer with warmer water temperatures trigger distinctive behaviour as the male builds a large circular nest comprised of various material including rocks, course sand and gravel, which he guards actively. The larvae hatch and disperse away from the nest. Fish mature from 2-5 years of age and probably can live for 12 or more years[87,161]. Freshwater Catfish do not appear to undergo long-distance movements in South Australia[162].

Reasons for decline and threats Anecdotal information indicates that Freshwater Catfish almost disappeared from the River Murray after the 1960s, prior to this they were considered to be in high abundance. Trends in commercial fishing catch, as an approximate index of population size, illustrate the decline with catches progressively diminished to very low levels by 1980 which have not recovered (Figure 9). The reduction in catch plus limited current research records suggests a conservative estimate of decline over the last three generations (assume generation time of 10 years) of at least 50% (EN A2b) presumably due to declining environmental conditions or a failure to deliver suitable conditions or flows for recovery (EN A2c).

The reasons for a significant decline of Freshwater Catfish and current threats limiting population recovery remain poorly understood. Long periods of low flow and subsequent settlement and build up of silt is likely to interfere with their bottom feeding behaviour (smother productive surfaces), nesting requirements (coarse particles being covered with fine silts), and general habitat requirements (loss of structure and aquatic vegetation). Hence significant river regulation and loss of flow volume (only one third or less of the natural flow now reaches SA) and flushing flows/floods on the River Murray are likely to be a long term threat. Alien species may also be contributing to the decline of Freshwater Catfish. There is overlap in the diet and habitat of both juvenile and adult Freshwater Catfish and Carp in the River Murray implying the potential for competition or direct interaction (e.g. disturbance of nests) between the two species, especially considering the high abundance Carp in lowland river reaches including the SA River Murray[134,163,164]. Freshwater Catfish numbers appear to have declined before the arrival of Carp, but subsequent invasion and proliferation of Carp may have limited any potential recovery (Figure 9).

Land tenure and conservation Occurs along the River Murray corridor which incorporates several State Reserves (e.g. Chowilla GR, Murray River NP, Morgan CP, Roonka CP, Ngaut Ngaut CP) as well as numerous council reserves (specifically including Rocky Gully Wetland Council Reserve) and public riverfront access (introduced population occurs along the Torrens Linear Park).



Recovery objectives

- Restore environmental conditions to improve habitat quality and promote a self-sustaining population.
- Protect an adequate spawning population of adult Freshwater Catfish.
- Better define species biology in SA (e.g. recruitment, flow and habitat requirements).
- Develop an appropriate index to track population status.

Conservation actions already initiated

- Freshwater Catfish are protected from exploitation through fisheries legislation (generally well accepted by the community).
- The Living Murray Initiative aims to restore flow regimes to key ecological assets including the River Murray channel important for Freshwater Catfish recovery.
- A Recovery Plan has been prepared for Freshwater Catfish across its range (MDB) and this serves as an additional guide to recovery principles and actions for SA[164].

Required conservation actions

- Environmental flow programs to provide appropriate conditions for breeding and recruitment (monitored for effectiveness).
- Obtain fisheries independent monitoring data on Freshwater Catfish habitat use, important spawning sites or regions, abundance and demography to more fully explore status and population trends, especially in relation to environmental conditions. Disseminate research findings to the public.
- Continue education and enforcement of Protected status, encourage reporting of incidental captures (e.g. location and fish length) to help improve knowledge on status.
- Undertake study of the introduced populations in the Torrens to better understand conservation requirements in natural habitat.

Organisations responsible for conservation of species

PIRSA Fisheries, DEH, SAMDBNRM Board, DWLBC.

Organisations or individuals involved

SARDI Aquatic Sciences, PIRSA Fisheries, MDBA, DWLBC.

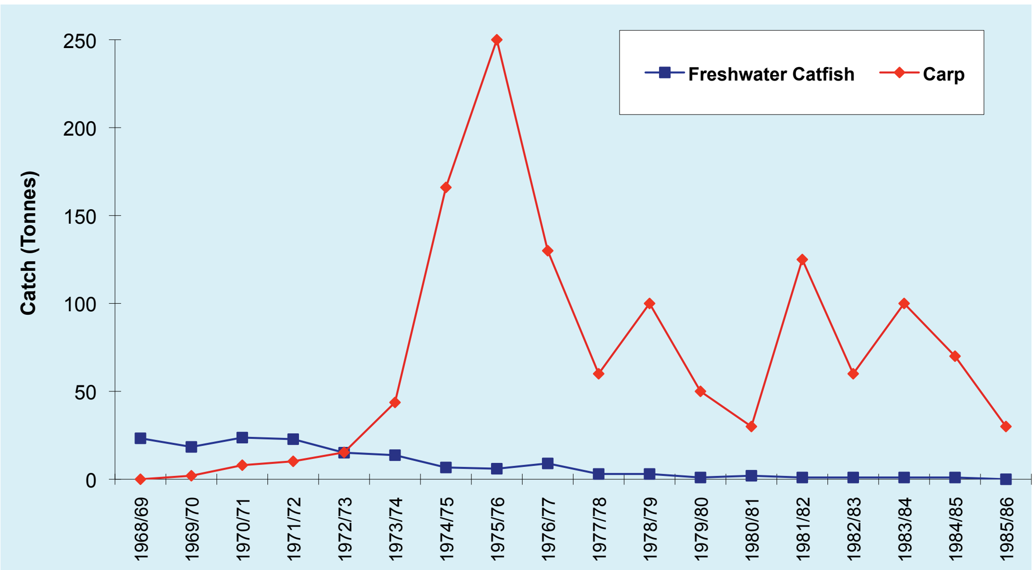


Figure 9. Catch data for Freshwater Catfish (compared to Carp) from the SA River Murray Commercial Fishery between 1968-1986 based on SA Fisheries Statistics[165].

Australian Grayling *(Prototroctes maraena)*

Other common names: Cucumber Mullet

Conservation status *South Australia:* Endangered (EN B2ab(ii,iii)).
National: Vulnerable (*EPBC Act 1999*). *Interstate:* listed as Threatened in Victoria (Vulnerable) and Tasmania and is Protected in New South Wales.

Taxonomy and identification A slender silvery fish reaching a size of 30cm, but commonly 15-18cm; has a distinctive cucumber odour when freshly caught. This species can be confused with various species of mullet which occur in freshwater, but it has a distinctive adipose fin (small fleshy fin) between the dorsal fin and tail, and the pectoral fin sits below rather than at the upper edge of the gill cover. Migrating juveniles are similar to juvenile galaxias (but have an adipose fin) and very similar to Smelt (but there are slight differences in fin and head shape).

Former distribution Lower South East SA is the very western limit of the species distribution. One verified (photographic) record from Ewens Ponds (part of the Eight Mile Creek system) in 1982[48] and other anecdotal reports from a similar time period in nearby Stratmans Pond (Deep Creek system) (EN B2a). Piccaninnie Ponds is also mentioned as recorded habitat, but without verification[166].

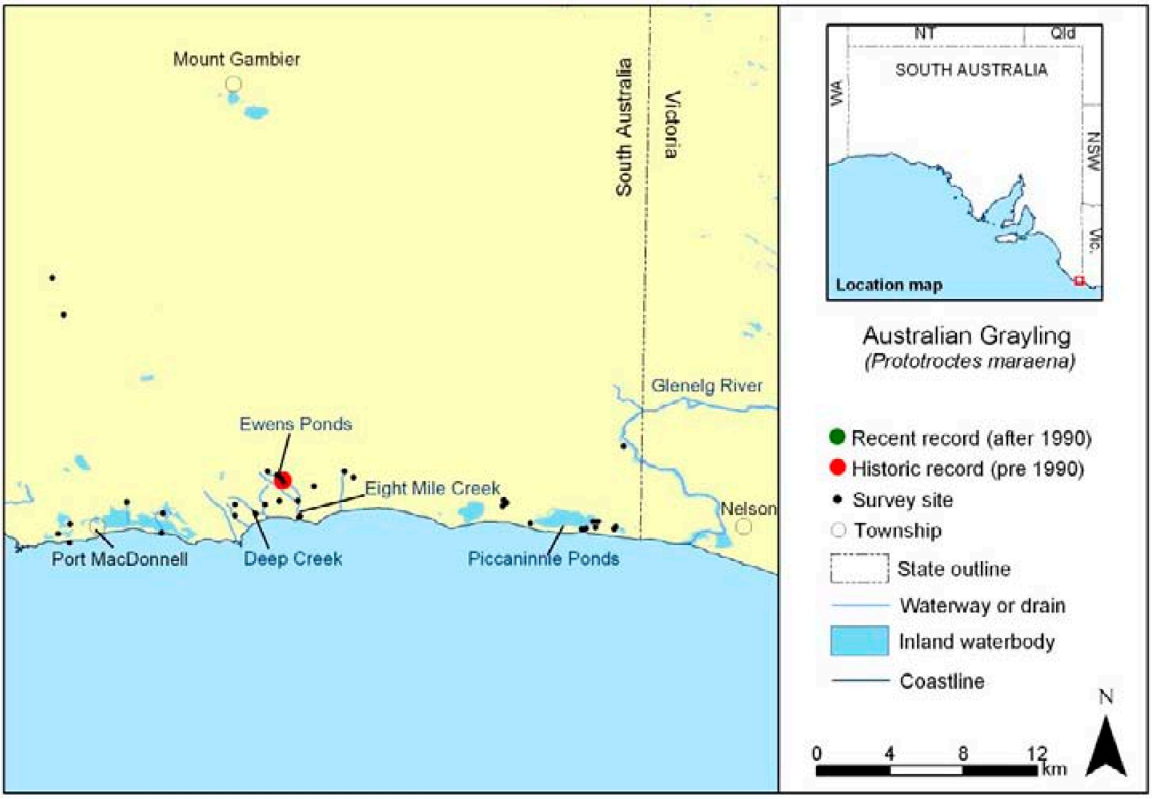
Current distribution No recent records despite a reasonable level of sampling in historic habitat[23,55,] potential habitat includes streams with coastal access in the LSE. It is unknown whether the Australian Grayling was a permanent inhabitant (sustaining population) in SA, and/or whether it had, and could again have, occasional individuals in the State due to migration of juveniles from nearby source habitat in Victoria.

Biology and habitat Unknown in South Australia. It is diadromous, with spawning in Victoria taking place during autumn whereby larvae are swept to sea. The young return to freshwater in spring. Habitat interstate is reported as deep pools and clear streams with moderate flow (i.e. matching rising spring habitat of the Lower South East well). A schooling species reported to be quite shy, fleeing when disturbed. The Australian Grayling lives for three to five years, with most fish reaching two years of age. It feeds opportunistically on algae, and aquatic and terrestrial insects[87,167.]

Reasons for decline and threats Threats to the presence of Australian Grayling in South Australia are likely to be linked to those interstate (i.e. source fish) and the suitability of habitat for adults. A reduction in habitat condition and suitability may have occurred from continual stream modifications (e.g. dredging on Eight Mile Creek), human activity and disturbance to a shy species (e.g. heavy recreational use of Ewens Ponds) and reducing stream discharge noted in the Lower South East springs (EN B2b(ii,iii)). Other general threats include the construction of migration barriers without adequate fish passage and the potential for predation from introduced trout (not currently present in the LSE).

Land tenure and conservation

• Ewens Ponds Conservation Park and other land managed by the SEWCDB.



Recovery objectives

- Improve conditions at potential habitat.
- Continual monitoring for presence and assess status in the wild.
- Gain a better understanding of biology and habitat in South Australia (if species is recorded).
- Increase awareness and reporting on the species presence.

Conservation actions already initiated

- Surveys in historic habitat.
- Review of dredging procedure for Eight Mile Creek.
- Hydrological and groundwater investigations initiated.
- A fish ladder has been installed on a weir at Piccaninnie Ponds.

Required conservation actions

- Protect and restore groundwater discharge to rising springs of the Lower South East.
- Undertake riparian habitat restoration along Eight Mile Creek and Deep Creek to improve stream side shelter and bank stability.
- Determine if the species remain in SA through ongoing surveys and movement studies to detect if juvenile migration is occurring (and hence recruitment to adult habitat is an issue).
- The lack of information regarding the Australian Grayling means that the general public can help by reporting any past or present sightings (www.nativefishsa.asn.au).

Organisations responsible for conservation of species

DEH, DEWHA, SENRM Board, DWLBC, SEWCDB.

Organisations or individuals involved

NFA(SA), DEH, SEWCDB,SENRMB, DWLBC.

Spotted Galaxias *(Galaxias truttaceaus)*

Other common names: Muddies, Mountain Trout or Trout Minnow

Conservation status *South Australia:* Endangered (EN B2ab(ii,iii)).
National & interstate: not listed (however a related subspecies from SW Western Australia is Critically Endangered (*EPBC Act 1999*) and Protected in WA).

Taxonomy and identification A long stout fish, reaching 24cm but more commonly 14-18cm. Adults are easily distinguished from other galaxias by uniform dark body spots (e.g. Common Galaxias can be speckled). This species is sometimes confused with the alien species Brown Trout, but Spotted Galaxias lack scales and an adipose fin (small fleshy fin between the dorsal and tail fin). Whitebait juveniles can be distinguished by a black band on the tail and a lack of speckling on the head.

Former distribution Historic data is lacking for this species, but it has likely always been restricted to specific cool flowing habitats of the Lower South East in the Port MacDonnell area. The first verified record was from Eight Mile Creek in 1979[101], with anecdotal reports the species was common in the same location in the 1950s[55].

Current distribution Cool groundwater fed habitats (spring pools and flowing creeks) of a small section of the Lower South East including the Eight Mile Creek and Deep Creek systems (i.e. Ewens, Stratmans and 54 Foot ponds)[124] with recent (2006 & 2007) records from the outflow from Piccaninnie Ponds[55] (the Ponds formerly drained toward the Glenelg River, but an artificial outlet was constructed in the 1930s) (ENB2a).

Biology and habitat Occurs in cool flowing habitat and spring pools amongst dense edge submerged or emergent vegetation, and is secretive and active during low light conditions[23,55]. Biology in South Australia is little known but spawning was recently documented at Piccaninnie Ponds in June[55]. In coastal Victoria and Tasmania the species is diadromous with adults spawning in autumn-winter with a possible downstream spawning migration. Larvae are swept to sea and return to freshwater habitat in spring to summer as transparent juveniles (one of the species collectively known as whitebait). Food includes aquatic and terrestrial invertebrates[76]. It is unknown whether recruitment of juveniles and hence adult occupation of the Lower South East occurs from local spawning and/or migration from nearby populations in Victoria.

Reasons for decline and threats Degradation of stream and pond edge habitat (e.g. through drainage practices and stock access) and reduction in spring discharge are considered primary, ongoing threats (EN B2b(ii,iii))[94,125]. Any new barriers to fish passage should be strongly avoided due to the migratory nature of this species. A Tasmanian study provides strong evidence that Brown Trout adversely affect Spotted Galaxias[168] and hence illegal introductions of salmonids into habitat such as Eight Mile Creek could have negative consequences. The shy nature of the species may mean it is sensitive to human use of aquatic habitats (e.g. Ewens Ponds).

Land tenure and conservation

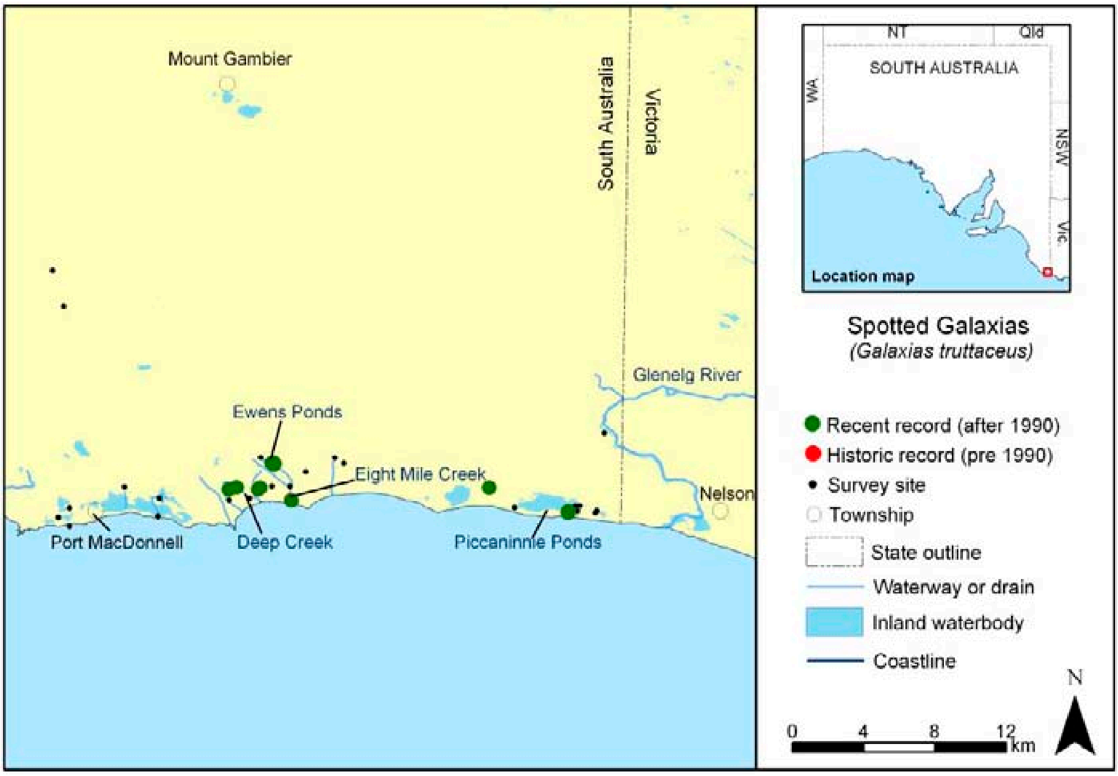
• Occurs in the Ewens Ponds CP, Piccaninnie Ponds CP and on land managed by the SEWCDB.

Recovery objectives

• Secure and restore core adult habitat.

• Monitor species abundance and recruitment to assess population trends.

• Increase awareness and reporting on the species presence.



Conservation actions already initiated

• Baseline surveys to detect presence and distribution have been undertaken.

• A fish ladder has been included and constructed within a weir designed to restore the natural pool level of the Piccaninnie Ponds region (the species has been shown to utilise the ladder)[169].

• Fish identification sheets have been developed[121] to help assist divers and the community with recognising and reporting the species (e.g. due to its larger size and appearance it is sometimes confused with trout and may be the target of well-meaning control for the alien species).

Required conservation actions

• Develop a monitoring program for adults (low impact or remote survey) and juveniles (i.e. targeted movement study) to assess population trends and recruitment.

• Protect and restore groundwater discharge to rising springs of the Lower South East.

• Undertake riparian habitat restoration along Eight Mile Creek and Deep Creek to improve stream side shelter and bank stability.

• The lack of information regarding the Spotted Galaxias means that the general public can help by reporting any past or present sightings (www.nativefishsa.asn.au).

Organisations responsible for conservation of species

DEH, SENRM Board, DWLBC, SEWCDB.

Organisations or individuals involved

NFA (SA), DEH, SENRM Board.

River Blackfish *(Gadopsis marmoratus)*

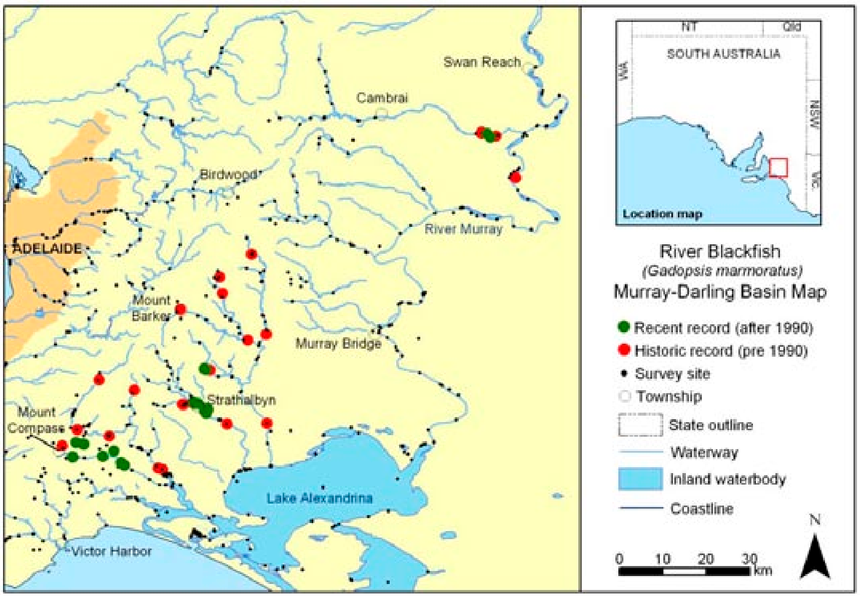
Other common names: Slipperies, Slimies, Black Perch and Freshwater Blackfish

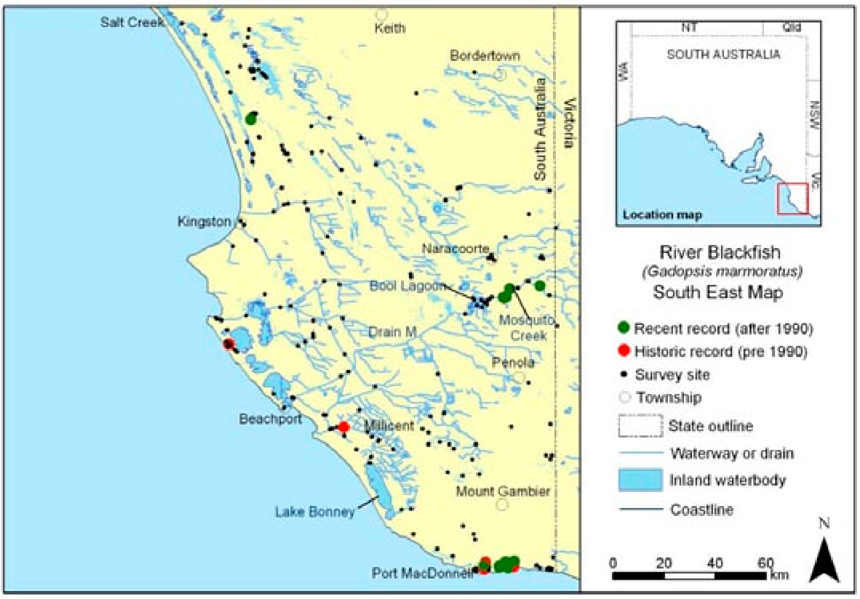
Conservation status *South Australia:* Endangered (EN B2ab(i,ii,iii,v)); Protected (Fisheries Management Act 2007).
National & interstate: not listed.

Taxonomy and identification A medium sized, elongate and slender species reaching a size of 35cm (commonly15-20cm) in South Australia. Most often confused with Climbing Galaxias (both are slippery, dark in colour and similar in size as adults), however there are numerous features for distinguishing the two – River Blackfish have small scales present, a long dorsal fin (> half body length) and unique modified pelvic fins which have single branched rays (finger-like). Two forms of River Blackfish occur in Australia essentially in systems north and south of the Great Dividing Range – a 'northern' form occurs patchily in the MDB and SESA/Glenelg River system, and a 'southern' form is found in the remainder of coastal Victorian catchments and northern Tasmania. There is genetic and morphological evidence to suggest that the two forms are distinctive at the species level, and two valid species should eventually be recognised[130,170,171].

Former distribution Occurred widely in the SAMDB in tributary streams with records from the Tookayerta, Finniss (including Meadows Creek and Bull Creek), Angas (including Dawson Creek), Bremer and Marne catchments[25], and the main channel and anabranches of the River Murray[44,101]. In the SE, records are patchy and from widespread locations including Henry Creek (USE, 2001), Robe Lakes (1903), near Millicent at Rendelsham (1944), Mosquito Creek and several locations in the Lower South East around Ewens Ponds and Eight Mile Creek (it is likely they had a more continuous distribution in the SE but historic data is limited). There is a single enigmatic record from Kangaroo Island in 1987, with no specific collection details[101]. Reports from the Torrens and Onkaparinga rivers were made in the early 1900s which came from an authoritative source but without verified records[28,172], and their presence here remains to be confirmed.

Current distribution The River Blackfish has undergone a significant and continuing decline. Its area of occupancy is now well less than 500km^2, with only six fragmented locations remaining (EN B2ab(i,ii,iv)). In the SAMDB there have been no verified records from the River Murray for at least 50 years, but four small populations remain in restricted refuges of the Eastern Mount Lofty Ranges – the Tookayerta Creek Catchment (~20km^2); a ~2km section of the Angas River; a single pool on Rodwell Creek (Bremer Catchment); and a <1km section of the lower Marne River. The species appears to have disappeared from the Finniss Catchment. Habitat in the EMLR has contracted considerably since the mid 1990s with the demise of groundwater fed springs[25]. In the South East, recent local extinction has occurred at Henry Creek[112], and at Mosquito Creek River Blackfish has experienced significant habitat change with pool drying and loss of spring flow during the last 10 years, reducing the population to individuals only in 2008, a 90% reduction from 2006 data[94]. Reasonable populations remain in the Ewens Ponds region, however decline in groundwater flow and habitat deterioration has also been noted here recently[23,55,94,173]. The species is presumed extinct from Kangaroo Island and the Upper River Torrens after extensive sampling failed to locate the species[26,28].





Biology and habitat Remaining habitat for River Blackfish in SA comprises large, deep, spring fed pools or flowing stream sections, with an abundance of emergent (fringing) vegetation (e.g. Reeds) or snags. All habitats have some form of linkage to groundwater to secure water supply (historically at least). River Blackfish is a nocturnal predator consuming larger macroinvertebrates such as shrimp and caddis fly larvae and the occasional small fish. Spawning is thought to occur in late spring in hollows or within undercut banks[39,55]. The species probably lives for 4-5 years and is not known to move large distances, instead occupying relatively small home ranges for most of the time[174]. Larvae and first year juveniles (0+) have a heavy dependence on cover such as leaf litter or emergent and riparian vegetation[55,175].

Reasons for decline and threats The recent loss of known localities relates to a decline in the extent and quality of habitat which is projected to continue with existing and potential threats (EN B2b(iii)). The primary reason for recent decline and the principal threat to remaining populations is the loss of permanent flow to stream sections as a result of water abstraction and extraction. This has been exacerbated by recent dry climatic conditions and could conceivably become worse with predictions of climate change. Other factors likely stressing remaining populations include reduced water quality (e.g.

stormwater and other pollution and increasing salinity), interaction with the alien predatory fishes Redfin, Brown Trout and Rainbow Trout (i.e. predation, competition and disease), habitat loss limiting available cover, sedimentation (infilling pools and habitat), and channel alterations and disturbance (e.g. from ongoing dredging of Eight Mile Creek[57]). Some historic reasons for decline are less tangible but may include flow regulation on the River Murray eliminating suitable habitat (e.g. weir pools instead of flowing river and high turbidity), initial interactions with alien fishes, widespread use of toxic pesticides following WWII[25,176,] fishing pressure, and general habitat degradation or pollution from land clearance or mining (e.g. Mt Barker and Dawesley creeks)[25].

Land tenure and conservation All known localities in the SAMDB are on private land and most are managed for conservation except for a strip of Council Reserves in Strathalbyn. In the South East the species has been recorded in the Naracoorte Caves Conservation Park and private land on Mosquito Creek (which includes at least one section fenced from stock). In the Lower South East the species occurs in Ewens Ponds Conservation Park and on Drainage Reserves, road crossings and private land.

Recovery objectives

- Secure required environmental conditions (especially permanent flow) at remaining populations.
- Establish and monitor relationships to environmental conditions, especially with any changes in management and environmental conditions.
- Urgently increase the area of occupancy in critical areas by protecting and restoring habitat.
- Ensure that all key stakeholders are aware of populations and potential threats (awareness).

Conservation actions already initiated

- Remaining and historic range relatively well established (including survey and oral history).
- Initial local biological investigations undertaken.
- The water resources of the Marne River Catchment have been prescribed and an environmental flow study undertaken[177] with other EMLR catchments to follow.
- A project has been initiated which aims to integrate surface water management in the Mosquito Creek Catchment.
- Protected from fishing pressure under the *Fisheries Management Act 2007.*
- Recent drought related response has included artificial watering at Rodwell Creek, and captive maintenance programs for fish from Rodwell Creek and Mosquito Creek[120,178].

Required conservation actions

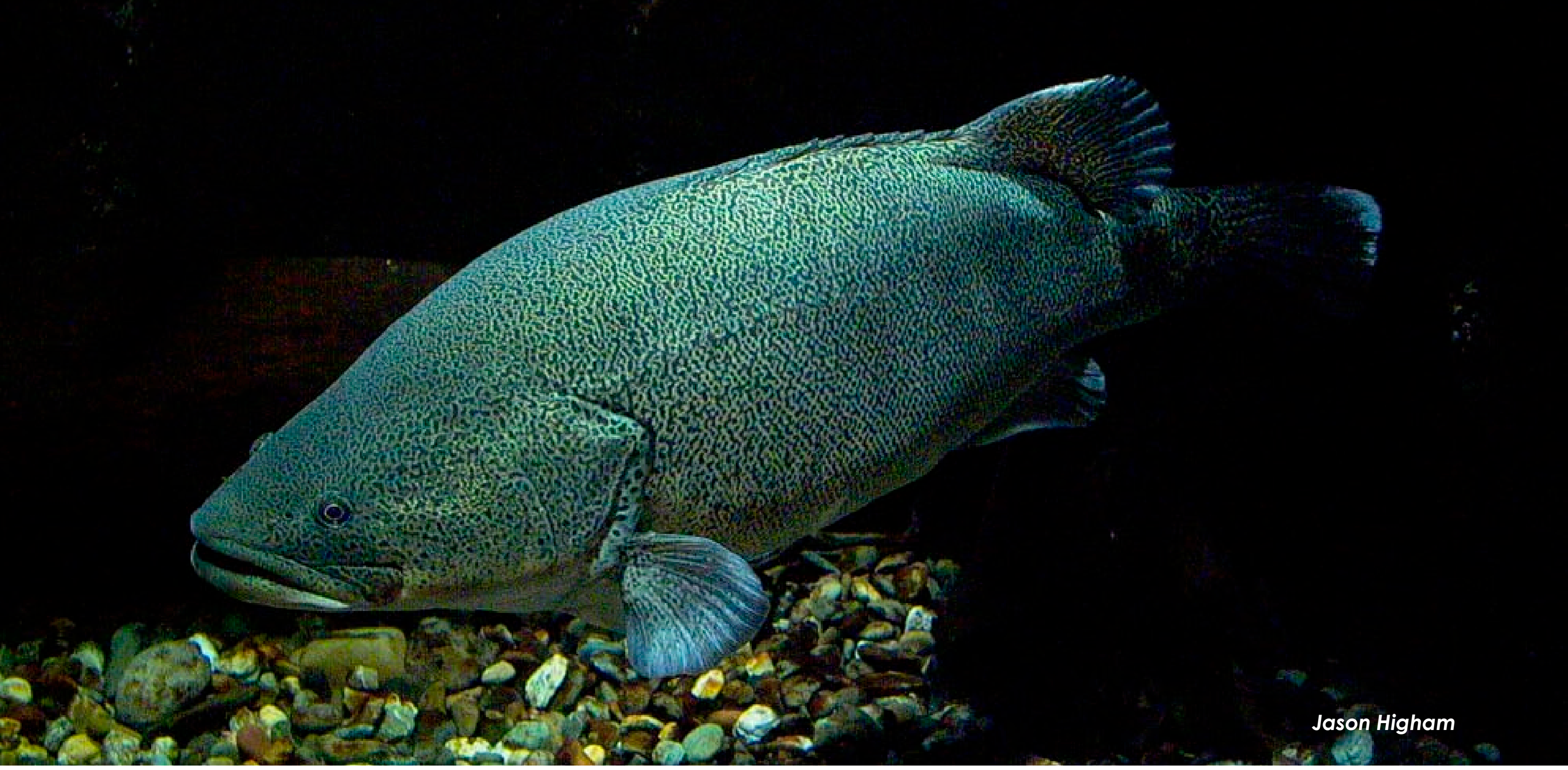
- Secure groundwater sources in key areas, including surface water management (i.e. recharge) and establish contingency plans for critically threatened populations.
- Continue and initiate urgent conservation measures in response to critical threats (e.g. artificial watering of habitat, captive maintenance).
- Develop sound understanding of hydrology surrounding remaining populations as part of Environmental Water Requirement Studies.
- Continue population monitoring and research, especially EMLR[179] and Mosquito Creek (SE).
- Manage physical (e.g. nutrients, stormwater) and biological (alien fishes) pollutants.
- Establish long-term government and community support structures to promote the River Blackfish within regional planning, management, restoration and education.
- Ensure that restoration programs in the known range of River Blackfish include a prior assessment for presence and consider species requirements carefully as in some cases the species relies on altered conditions (e.g. shade and structure from willows).

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, SAMDB & SE NRM boards, SEWCDB, USE Program, Alexandrina Council.

Organisations or individuals involved

NFA(SA), SAMDB & SE NRM boards, DEH, SEWCDB and various Landcare/Catchment groups.



Murray Cod *(Maccullochella peelii peelii)*
Other common names: Cod and Ponde (Ngarrindjeri)

Conservation status *South Australia:* Endangered (EN A2bcd).
National: Vulnerable (*EPBC Act 1999*). *Interstate:* listed as Threatened in Victoria (Endangered).

Taxonomy and identification Murray Cod is Australia's largest freshwater fish attaining lengths of to 1.8m, but more commonly 0.3-1.2m. Quite distinctive in appearance but sometimes confused with the similar Trout Cod from which it is distinguished by its equal length jaws and marbled body markings extending onto the gill covers.

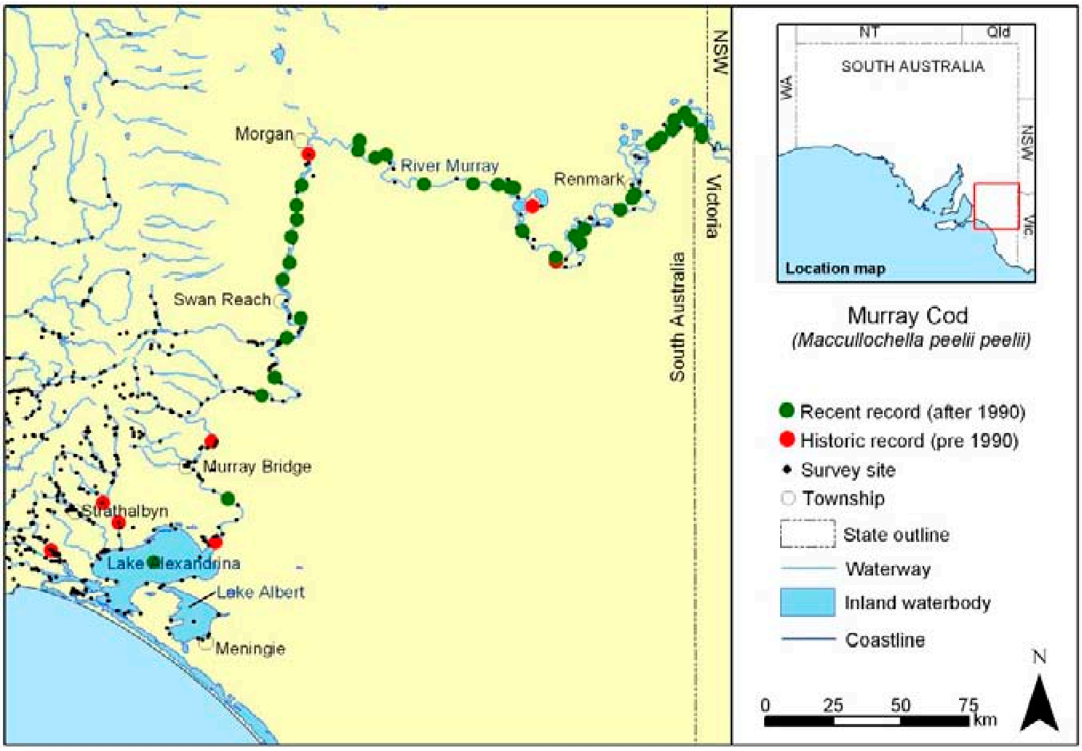
Former distribution The number of verified specimens is limited and mainly relies on oral history and fisheries records for this distinctive, well-known species (some records may have been confused with Trout Cod). Murray Cod was common along the length of the SA River Murray and connected anabranches, as well as the Lower Lakes and the lower sections of streams draining from the Mount Lofty Ranges (especially Bremer River[25]). Possibly present naturally in Burra Creek[52]. Early records (1920s) indicated juveniles were common in some wetland habitat (drains) along the Lower Murray at Murray Bridge[41].

Current distribution The current area of occupancy of Murray Cod remains similar, but it is now more commonly recorded upstream of Swan Reach, with a general decline noted in the River Murray below Mannum, Lower Lakes and Mount Lofty Ranges region (e.g. local extinctions in lower reaches of Mount Lofty Ranges streams[25]). The species has been translocated into various dam and stream habitats in the western Mount Lofty Ranges and the Cooper Creek[1,180] (probably from fish sourced from interstate hatcheries rather than SAMDB stock). Juvenile fish have not been recorded in recent wetland sampling[35,69,70,181].

Biology and habitat Most biological study on Murray Cod has occurred interstate and hence SA research is still required to confirm patterns observed elsewhere[182]. Both juvenile and adult Murray Cod are predators, consuming larger prey including Yabbies, shrimp and fish. Adult Murray Cod generally occur in river channels or larger flowing anabranches in or near deep holes with cover in the form of rocks, fallen timber or tree stumps. Spawning occurs in spring and early summer when water temperature reach 15-20°C. The eggs are attached to solid objects such as hollow logs, rocks and cavities in clay banks and the male guards and fans the eggs until larvae hatch[88]. Adult condition and recruitment appears to benefit from flooding (especially sequential flood years in SA[182]), with and important small breeding areas at the Chowilla anabranch system where there is in-channel flow[160]. Fish mature after around 4 years (variable in size) and the species is long lived with fish aged 20-50 years old recorded[183,184]. Individual Murray Cod often have a defined local home range or territory, however long distance migrations have been noted at certain times especially around the spawning period and high flow which is thought to relate to upstream migration to spawn followed by a return to their home range[162].

Reasons for decline and threats The decline of Murray Cod as a common River Murray fish likely relates to numerous historic changes such as extensive snag removal (i.e. fallen trees) to aid navigation and recreation, general habitat transformation, and movement barriers from Locks and Weirs, large early catches representing overfishing, and the introduction of fishes which compete for food or modify habitat conditions (i.e. Redfin and Carp). An overarching and continuing threat however, is reduced and altered flow patterns from massive upstream regulation and abstraction (Figure 10) which appears to interfere directly in Murray Cod ecology or impact ecological processes (e.g. food resources and appropriate habitat for juveniles). The River Murray now receives on average only a third of natural flow volumes and the frequency, magnitude and timing of floods have been dramatically altered[185,186]. Reduced flows and related poor water quality may also lead to fish kills as seen interstate recently.

Trends in commercial fishing catch, as an approximate index of population size, indicate a significant reduction (decline) since the 1950s of at least 30% over the last three generations, assuming a generation time of 20 years (Figure 10). Declines were dramatic during the 1960s, and catches remained very low through to the 1980s, resulting in a prohibition from fishing in the early 1990s. Slight increases in catch occurred in 2000-2002 following a successful recruitment event[182], but further declines are likely through if poor flow and related habitat conditions continue to limit recruiment[187] (EN A2bc). The low number of mainly large individuals from a few specific cohorts (i.e. individuals from a particular spawning event) are susceptible to exploitation by legal and illegal recreational fisheries (EN A2d)[182,187]. Stocking of hatchery reared Murray Cod is an additional threat to SA stocks (e.g. genetic pollution and reduced genetic diversity[188]).



Land tenure and conservation Occurs along the River Murray corridor which incorporates several State Reserves (Chowilla GR, Murray River NP, Morgan CP, Roonka CP, Ngaut Ngaut CP) as well as numerous council reserves and public riverfront access.

Recovery objectives

- Restore environmental conditions to promote a self-sustaining population.
- Protect an adequate spawning biomass of adult Murray Cod[182].
- Better define biology in South Australia (recruitment, habitat requirements, migration).
- Develop an appropriate index to track population status.
- Maintain and enhance the high profile of Murray Cod as a tool for conservation.

Conservation actions already initiated

- SARDI Inland Waters have been monitoring Murray Cod in the SA River Murray over recent years, including recruitment[187].
- The Living Murray Initiative aims to restore flow regimes to key ecological assets including the Chowilla region which is important for Murray Cod recovery[83].
- Fishways have and continue to be constructed and monitored on major barriers to fish movement on the River Murray.
- A habitat restoration pilot study involving returning large snags to the River Murray has been initiated at Mypolonga to improve habitat and provide spawning sites for species such as Murray Cod.
- A National Recovery Plan is being prepared, with a vision for future recovery being: 'Self-sustaining Murray Cod populations managed for conservation, fishing and culture'. This will contain more detailed Recovery Objectives and Actions applicable to SA.
- Fisheries regulations to protect breeding stock including moratoriums.

Required conservation actions

- Environmental flow programs to provide appropriate conditions for breeding and recruitment.
- Establish more habitat protection and restoration areas (Cod need snags!).
- Obtain fisheries independent monitoring data on Murray Cod abundance and demography to more fully explore status and population trends, especially in relation to environmental conditions. Disseminate research findings to the public.
- Manage the recreational fishery for Murray Cod in a sustainable manner while recognising the social, economic and recreational value of the fishery. Potentially provide fishing free refuges to protect breeding stock and promote safe handling of large fish (anglers and researchers).
- Involve the community in the conservation and management of Murray Cod to increase education on threats and requirements. Document the significance of Murray Cod in the community and harness
- aspects in conservation initiatives and education.

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, DEWHA, SAMDB NRM Board, DWLBC.

Organisations or individuals involved

SARDI Aquatic Sciences, PIRSA Fisheries, SAMDB NRM Board, DEWHA, Greening Australia (SA), Mannum to Wellington LAP.

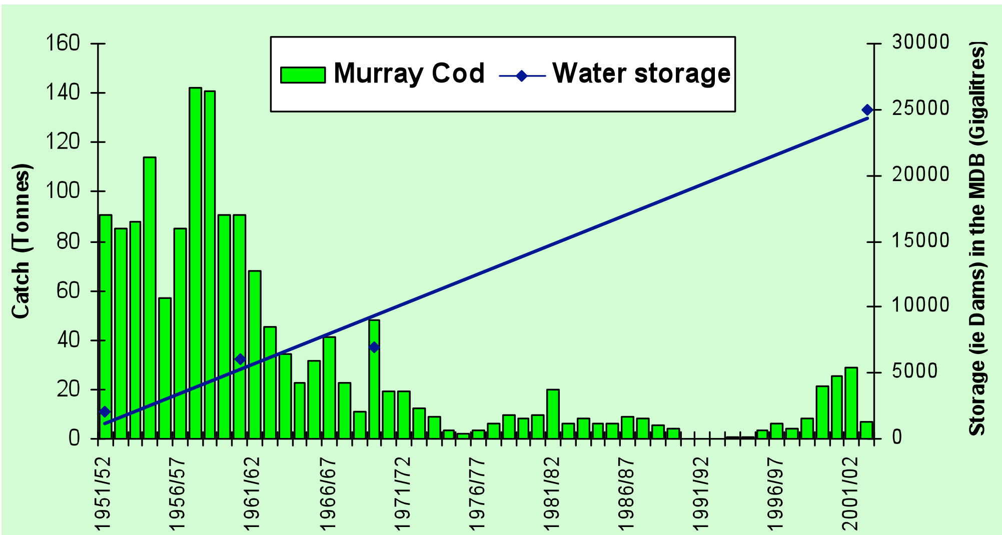


Figure 10. Catch data for Murray Cod from the SA River Murray Commercial Fishery (between 1951-2003) based on SA Fisheries Statistics[83,163,165,182,189], with comparison of water storage capacity[83] in the Murray-Darling Basin (i.e. the potential holdings of large dams and reservoirs).

Estuary Perch *(Macquaria colonorum)*

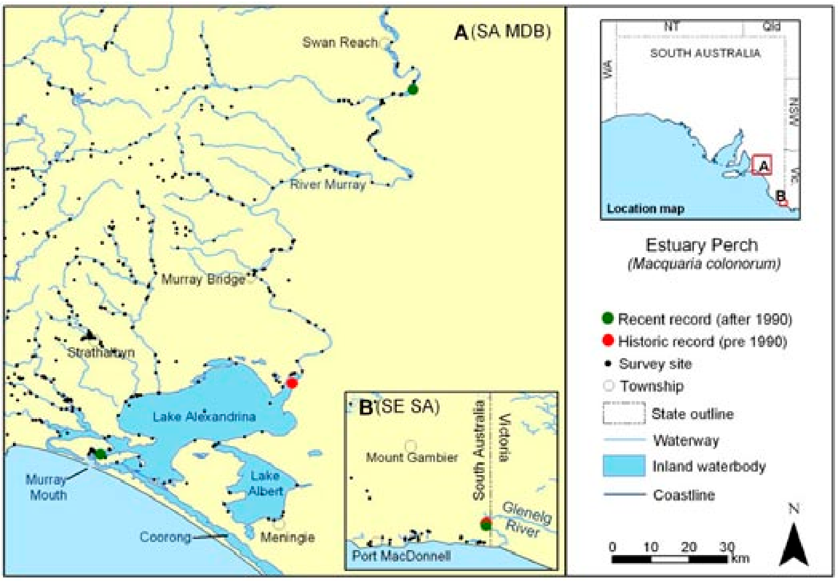
Other common names: Salt Water Perch and Taralgi (Ngarrindjeri)

Conservation status *South Australia:* Endangered (EN B1ab(iii,v)).
National & interstate: not listed.

Taxonomy and identification A medium sized species, up to 75cm in length but more commonly 30-40cm. In the River Murray system it was and can be mistaken for a colour variety of Murray-Darling Golden Perch (Callop)[44], however it can be distinguished from Callop and juvenile pygmy perches by its forked tail fin, and it has a much larger mouth than pygmy perches and Silver Perch.

Former distribution The Estuary Perch has been recorded from the small section of the Glenelg River (specimens from 1932 and 1986) which flows through SE SA, and the lower reaches of the SAMDB. It was apparently rare in the Lower River Murray channel (SA Museum specimens taken in 1932 and 1963). Professional fisherman reported it to be more common around Lake Alexandrina and especially within a few kilometres of the Murray Mouth prior to the construction of the Barrages (late 1930s). Estuary Perch was thought to be reasonably abundant prior to European settlement as it was well known by the Ngarrindjeri people[190].

Current distribution Remains restricted to two locations (EN B1a), and has declined significantly at one of these, the SAMDB (EN B1b(iii,v), where adult fish have only been taken occasionally in recent years (e.g. Mundoo Channel (freshwater) in 1990 and River Murray at Nildotte near Swan Reach in 2002[101]). Confirmation has been made of the presence of Estuary Perch in the Glenelg River recently[55] including occasional records from anglers, however abundance here is unknown.



Biology and habitat The Estuary Perch is associated with estuaries with freshwater influence, occurring in brackish or lower freshwater reaches of rivers and lakes in or upstream of tidal influence (SA). Juveniles have been recorded over rocky and sheltered habitats in the Glenelg River SA in summer in half strength sea water[55]. Biology in SA, especially the SAMDB, is unreported, but fish recorded near the Murray Mouth may have been congregating for spawning or were within their preferred habitat. Interstate, the species is known to feed on crustaceans and fish. Adults mature after 2-3 years and migrate downstream to near the mouth of estuaries to spawn (diadromous) during winter to spring before moving back to their preferred habitat which includes areas with structure (e.g. snags). Eggs and larvae are thought to be swept to sea or lower estuaries[88,191]. It is unknown whether populations in the SAMDB were self-sustaining or relied on migration from other populations to the south east in Victoria.

Reasons for decline and threats Given that the Estuary Perch prefers estuarine environments and has a need to move to spawning habitat in lower river reaches, the primary reason for its decline in the SAMDB relates to a continuing decline in the area and quality of suitable habitat (EN B1b(iii)) due the Barrages combined with a 2/3 reduction in River Murray flow. The Barrages have acted as a physical barrier to dispersal between freshwater and the sea, and with reduced flow to the Coorong the habitat on the seaward side of the barrages is often purely marine (almost exclusively so in the last 10 years), and purely fresh on the upstream side, providing no area of true estuarine conditions. The species probably suffers from competition and predation with high numbers of Redfin in the Lower Lakes and lower River Murray, and is also susceptible to fishing pressure across its range when they congregate in areas for spawning.

Land tenure and conservation The Murray Mouth region falls in the Coorong NP and the Lower Lakes and Coorong (a Ramsar site). Remaining distribution is in public waters with access through public and private lands. The SA section of the Glenelg River is in the Lower Glenelg River CP with a small area of public land at Donovans Landing.

Recovery objectives

- Better determine the status in the wild.
- Research to gain a better understanding of biology and habitat in SA.
- Increase awareness to encourage reporting of the species.
- Improve species status through environmental restoration (restore a more natural flow regime).

Conservation actions already initiated

- Construction of fishways and improved operational procedures at the Barrages and environmental flow release into the Coorong could improve habitat conditions for the species.
- Fish diversity and movement at and around Murray fishways is being monitored[142,154].

Required conservation actions

- Targeted surveys to assess status (SAMDB and SE).
- Undertake an assessment of the biology and status of fish in the Glenelg River (collaborative with Victorian agencies), and develop relationships with commercial fishers of the SAMDB to report sightings or oral history.
- Limits on recreation and commercial fishing interstate are likely to benefit SA populations (e.g. protecting the number of spawning adults) and a State and cross-jurisdictional review of sustainable harvest should be undertaken.
- Public awareness campaign to help improve recognition, reporting and protection.
- Establish the genetic relationship between SA and interstate populations, which could include understanding the potential for coastal migration into the SAMDB.

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, SAMDB and SE NRM boards.

Organisations or individuals involved

SARDI Aquatic Sciences, MDBA, SA Water, DWLBC.

Southern Pygmy Perch *(Nannoperca australis)*
Other common names: Swamp Perch

Conservation status *South Australia:* Endangered (EN B1ab(i,ii,iii,v)); Protected (*Fisheries Management Act 2007*).
National: not listed. *Interstate:* Endangered in New South Wales.

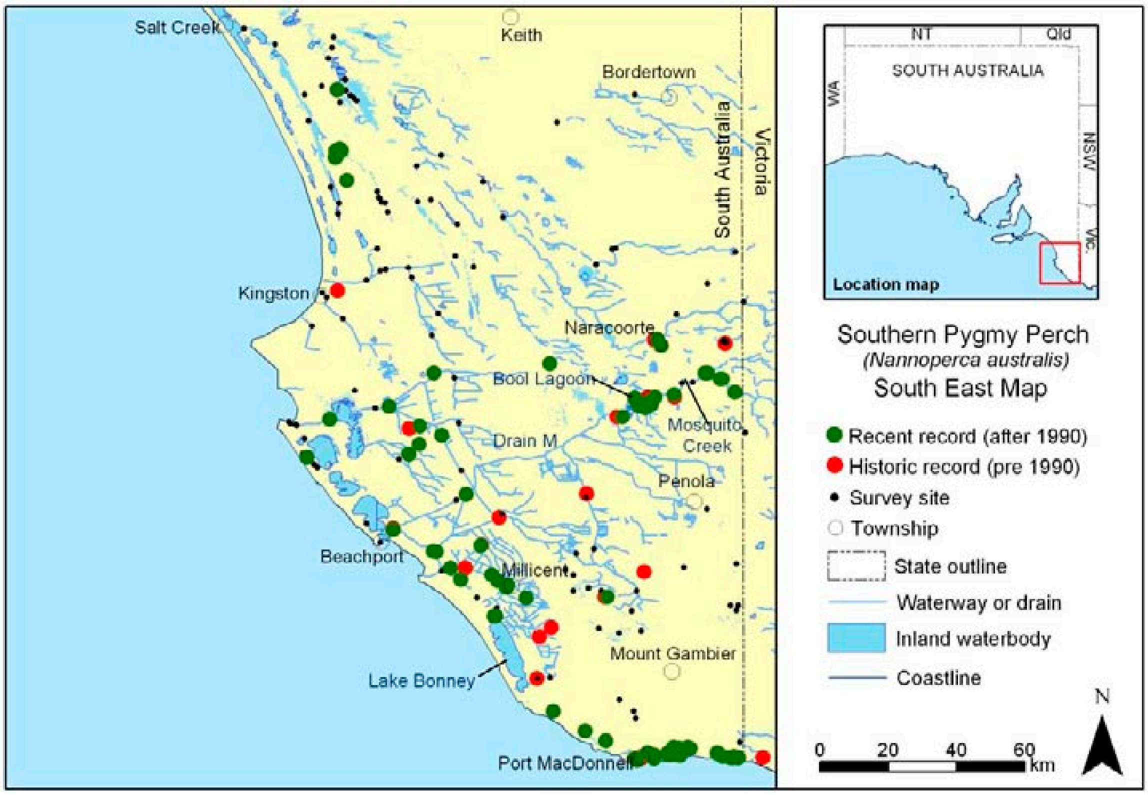
Taxonomy and identification A small, deep-bodied species reaching a maximum 10cm in length (commonly 3-5cm). It is characterised by a large eye and has brilliant red fins during spawning (males). Southern Pygmy Perch can be distinguished from Yarra Pygmy Perch by a larger mouth reaching below the eye and a regular (round) eye pupil; from Variegated Pygmy Perch by having scales on the top of its head and its second dorsal spine longer than its third; and from Agassiz's Glassfish by having a rounded rather than forked tail. Southern Pygmy Perch is sometimes confused with juvenile Redfin (an exotic species), however Redfin has a mouth which is much larger and can be opened right out, has two distinct dorsal (top) fins, and has vertical black stripes which develop after fish reach about 5cm.

A recent genetic study identified that the 'Southern Pygmy Perch' actually comprises two distinct species with an Eastern species in Gipplsand (Vic), Flinders Island and NE Tasmania, and a Western species occurring coastally west of Wilsons Promontory and in the MDB[13,22]. The Western species has two distinct genetic lineages divided by the Great Dividing Range (i.e. coastal v. Murray-Darling) that warrant recognition at the sub-species level. Hence there are two distinct units of Management in SA: (a) Murray lineage and (b) SE lineage.

Former distribution There are numerous records of Southern Pygmy Perch from the SE, although most are after 1970; two earlier records were from swamps at Kalangadoo (1912) and Kingston (1928)[101]. Records after the 1970s (post drainage) are from across the region and the species was undoubtedly widespread under historic conditions of extensive wetland habitat. In the SAMDB, the species was widespread in the fringing swamps and tributary streams of the lower River Murray and Lake Alexandrina (e.g. historically plentiful in the smaller backwaters and swampy lowlands of the Finniss River[18]), and it is also likely to have been commonly found in areas associated with the River Murray through to Victoria (e.g. recorded from the Renmark region in the 1970s[192] and 1980s[83]). A new population slightly to the west of the Murray Drainage on the Southern Fleurieu Peninsula (Inman Catchment) was first documented in 2001, and a subsequent review provided oral history of its long-term presence[13,51].

Current distribution In the South East, available habitat is much reduced due to extensive drainage and there are several presumed local extinctions (Kingston, Kalangadoo, Benara Creek, swamps near Mosquito Creek). In recent periods this lineage has remained relatively widespread and common[23], however rising salinity and drying of habitats in the Upper South East and Mosquito Creek is projected to cause further declines (EN B1b(iii))[94]. The range, abundance and area of occupancy of the Murray lineage has, and continues, to decline[21,22,51], especially in the last two years (EN B1b(i,ii,iii,v))[102,115]. Genetic evaluation of the remaining populations of the Murray lineage indicates five genetically distinct sub-populations separated by land barriers only 10km or less in some areas, all of which have contracted in their extent of occurrence and number of sites in the last 10 years. The remaining populations include (1) a patchy distribution in swampy edges and drains around Lake Alexandrina, but which has declined dramatically since 2007 with lowered Lake Alexandrina levels (previous core populations on eastern Hindmarsh Island, Black Swamp and near Milang, presumed extinct along the River Murray proper), and four stream catchments: (2) Inman River – two disjunct populations, both extremely small and with one suffering from stream drying, (3) Tookayerta Creek where populations are reasonably continuous and more secure in slow-flowing or Fleurieu Swamp sections, but an overall small catchment, (4) Finniss River, in a few highly restricted sites and recent possible local extinctions, and (5) Angas River, where they remain in a small stretch of stream, with recent loss of fish from two tributary streams (Dawson and Middle creeks). Populations within individual streams are severely fragmented, especially those contained in the Inman, Finniss and Angas catchments (EN B1a). Habitat conditions continue to deteriorate (e.g. Angas Catchment) or have a high potential for deterioration with habitat drying (e.g. during critical low water levels as experienced in Lake Alexandrina in 2007 and beyond).

Biology and habitat Remaining habitat is varied across and within different regions, but generally comprises smaller pools, swamps and wetlands (plus some artificial refuges including drains) with dense structure. Structure can include either physical components such as rock and snags or submerged plants such as algae and Pond Weeds (*Potamogeton* spp), but most often emergent or overhanging edge vegetation such as grasses, Water Ribbons (*Triglochin*), Club Rush (*Schoenoplectus)* and Cumbungi (*Typha*). Preferred habitat can include large pools with edge cover where large predatory fish are absent and often comprises areas with cooler temperatures due to shade or spring flows, reaching the highest densities in the MLR in fenced or ungrazed areas. Southern Pygmy Perch also benefit from the seasonal inundation (winter/spring) of edge and emergent vegetation as this provides prime habitat and cover for juveniles and shelter for adults during high flows. There are likely to be some biological differences between the two lineages in SA, and fish in the MLR do seem more sensitive to habitat and flow changes. In both regions individuals in spawning condition have been noted in spring and occasionally through summer in areas with permanent cool flow. They have a diet of small invertebrates which they pick from underwater surfaces, and are short lived (~4 years) with only a small percent of most populations older than 1 or 2 years (they reach sexual maturity within a year). Movement is fairly limited, especially in the streams of the MLR, with dispersal occurring across inundated shallows rather than against flow[21,22,23,25,39,51,55].


Salt Creek
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Port MacDonnell
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WA
NSW
Vic.
Location map
Southern Pygmy Perch
(Nannoperca australis)
South East Map
Recent record (after 1990)
Historic record (pre 1990)
Survey site
Township
State outline
Waterway or drain
Inland waterbody
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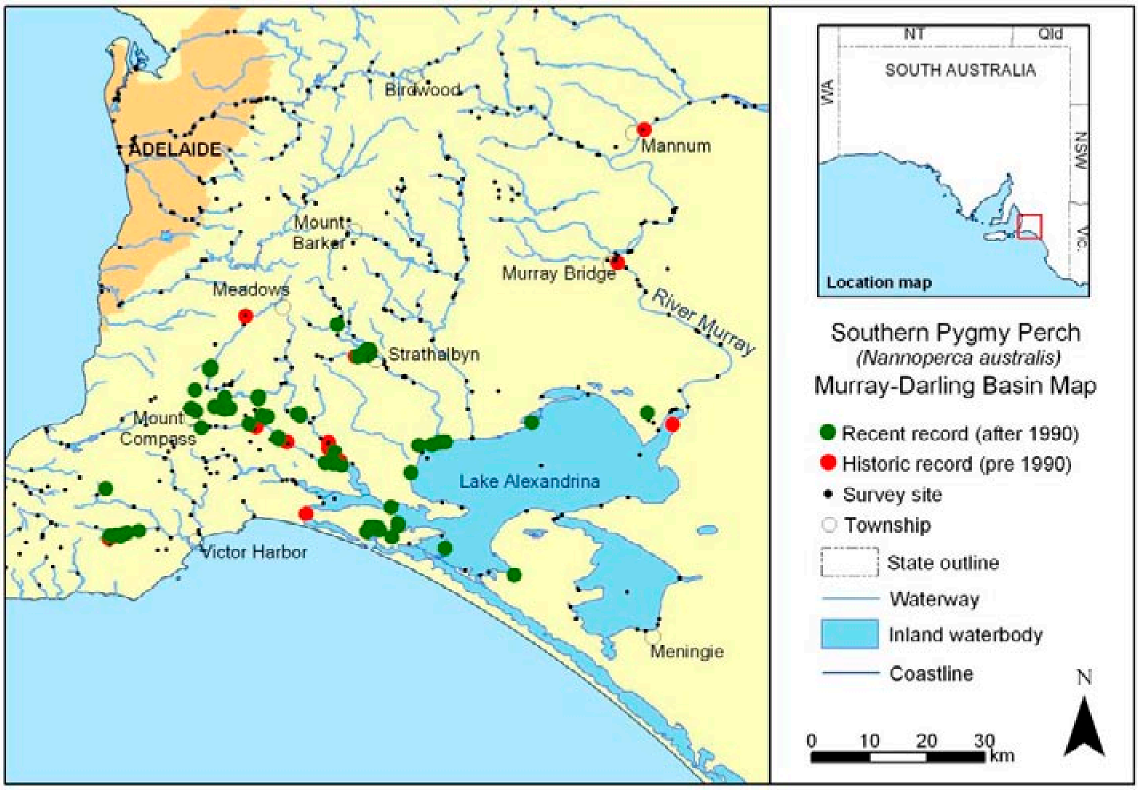
ADELAIDE
Birdwood
Mannum
Mount Barker
Murray Bridge
River Murray
Meadows
Strathalbyn
Mount Compass
Lake Alexandrina
Victor Harbor
Meningie
NT
Qld
SOUTH AUSTRALIA
WA
NSW
Vic.
Location map
Southern Pygmy Perch
(Nannoperca australis)
Murray-Darling Basin Map
Recent record (after 1990)
Historic record (pre 1990)
Survey site
Township
State outline
Waterway
Inland waterbody
Coastline
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Springfed habitat of Southern Pygmy Perch in the Finniss River, Eastern Mount Lofty Ranges

Reasons for decline and threats The main reason for historic decline appears to be habitat alteration and loss such as drainage or reclamation of swamps (e.g. much of the SE, levees that have isolated and removed swamps along the River Murray between Wellington and Mannum, clearance and drainage of Fleurieu Swamps), which are now compounded by (a) altered flow regimes, (b) ongoing habitat change, (c) alien species, and (d) a lack of awareness:

- The general nature of remaining habitat, often highly restricted distribution and their presumed poor dispersal ability leaves Southern Pygmy Perch (especially SAMDB lineage) susceptible to unnatural cycles of drying. Water abstraction (e.g. farm dams), extraction (e.g. groundwater pumping) and drainage have lead to the loss of numerous once permanent refuge habitats (as above), and would be affecting the flow requirements of the species (e.g. lateral connections to riparian areas).
- Habitat loss through stock damage to stream edge vegetation and banks (e.g. shallowing and silting pools), plus other impacts from altered landuse (e.g. increased nutrients, illegal instream works) have been highlighted as issues to the sustainability of the species in the Mount Lofty Ranges[21,51].
- Predation by Redfin and trout (e.g. they have mutually exclusive distributions[25,27,51]), and competition with the Gambusia (e.g. laboratory experiments suggesting dietary overlap[39] and observations for related Pygmy Perches[193,194]) are believed to be contributing to declines.
- Artificial refuges have so far been hard to sustain in the longer term as dams in close range to remnant populations lack the right mix of natural conditions.
- A general lack of awareness surrounding the existence and conservation requirements of native fish in the MLR by the wider community and government agencies (management and planning) is an immediate concern[21,22].

Land tenure and conservation South East: occurs in the Ewens Ponds CP, Piccaninnie Ponds CP, Naracoorte Caves NP, Bool Lagoon GP, Hacks Lagoon CP and Little Dip CP, also in numerous council and drainage reserves and private land. Mount Lofty Ranges streams: close to Cox Scrub CP and Finniss CP, other locations on private land managed for conservation (e.g. Meadows Creek, Lower Finniss River, Swampy Creek), a few populations still with stock access, and the remaining core pool in the Angas River is surrounded by a new housing development. Lake Alexandrina: occurs in Land Managed for Conservation at Wyndgate and on Mud Islands Game Reserve, some fenced properties or areas inaccessible to stock, and a few grazing areas and artificial drains used for water pumping (pumping provides slow flow and prevents stagnation).

Recovery objectives

- Secure the species in each region of SA, with a priority for urgent species recovery in the MLR and Lake Alexandrina. Previously recognised recovery objectives[22] include:
- Improve the status of the Southern Pygmy Perch by increasing the security and extent (range and density) of populations in each of the five occupied drainage areas, and by increasing the amount and quality of stream and swamp habitats (e.g. minimise threatening processes, secure core populations, provide artificial refuges, feral fish control, further biological research, water quality monitoring).
- Establish long-term government and community support structures to promote Southern Pygmy Perch (subsequently native fish in general) within regional planning and management as well as aquatic protection, restoration and education programs (e.g. environmental flow programs, education, recognition in planning and management, formal conservation status).
- These objectives remain valid, however, dedicated actions regarding further research, monitoring, education and critical habitat management would greatly improve the local viability of sub populations, and could be applied more broadly to the SE lineage also.

Conservation actions already initiated

- Currently one of the most well-known of South Australia's threatened fishes due to recent research and education programs, however conservation actions have been slow to initiate and new and existing threats continue. Actions relating to objectives are already being perused through various programs (provided in detail elsewhere[21]) and a summary (mostly related SAMDB) includes:

- An initial detailed research program, ongoing monitoring and detailed range mapping[13,21,24,25,27,50,51,58,59,69,70,195].
- Maintained fencing at some core sites, plus attempts to establish refuge populations.
- Initial moves to secure water requirements (e.g. Environmental Flows Program for EMLR, Living Murray Initiative).
- Detailed Recovery Outline and review of performance produced and disseminated.
- Positive progress on education and awareness (e.g. chocolate pygmy perch, involvement of Fleurieu Schools, signage, media articles).
- Alien fish-outs (e.g. to remove Redfin) have occurred in some areas (Angas Catchment), and trout stocking has been formally discontinued by PIRSA Fisheries from the Inman, Tookayerta, Angas and Mosquito Creek catchments (but continues in the Finniss River Catchment).

Required conservation actions

- The species is suffering large declines, however, there is a good potential for conservation and securing the local viability of genetic forms unique to SA. Localised community programs will be effective, but must be underpinned by broader catchment management, particularly the provision and enhancement of environmental flows (especially to maintain permanent pools, springs in stream habitat and Lake Alexandrina freshwater levels). Other specific actions include:
- Continue to work on the objectives and actions previously outlined, especially continuing to ensure that core populations are carefully managed and prevented from further habitat changes (including checking for species presence before constructive or restoration works in the known range).
- Continue to monitor adaptive responses to improved or declining environmental conditions such as habitat and flow.
- Further research and implement control (with monitoring) of alien fish species.
- Conduct a taxonomic review to confirm species and subspecies of Southern Pygmy Perch.

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, AMLR, SAMDB & SE NRM Boards, SEWCDB, Alexandrina Council.

Organisations or individuals involved

A long list of stakeholders have so far been involved (see 'Recovery Progress report[21]'), but major organisations include NFA(SA), SAMDB NRM Board, Goolwa to Wellington LAP, SARDI Aquatic Sciences, DWLBC and community groups, especially Angas River and Inman catchment groups.

Silver Perch *(Bidyanus bidyanus)*

Other common names: Bream, Black Bream and Tcheri (Ngarrindjeri)

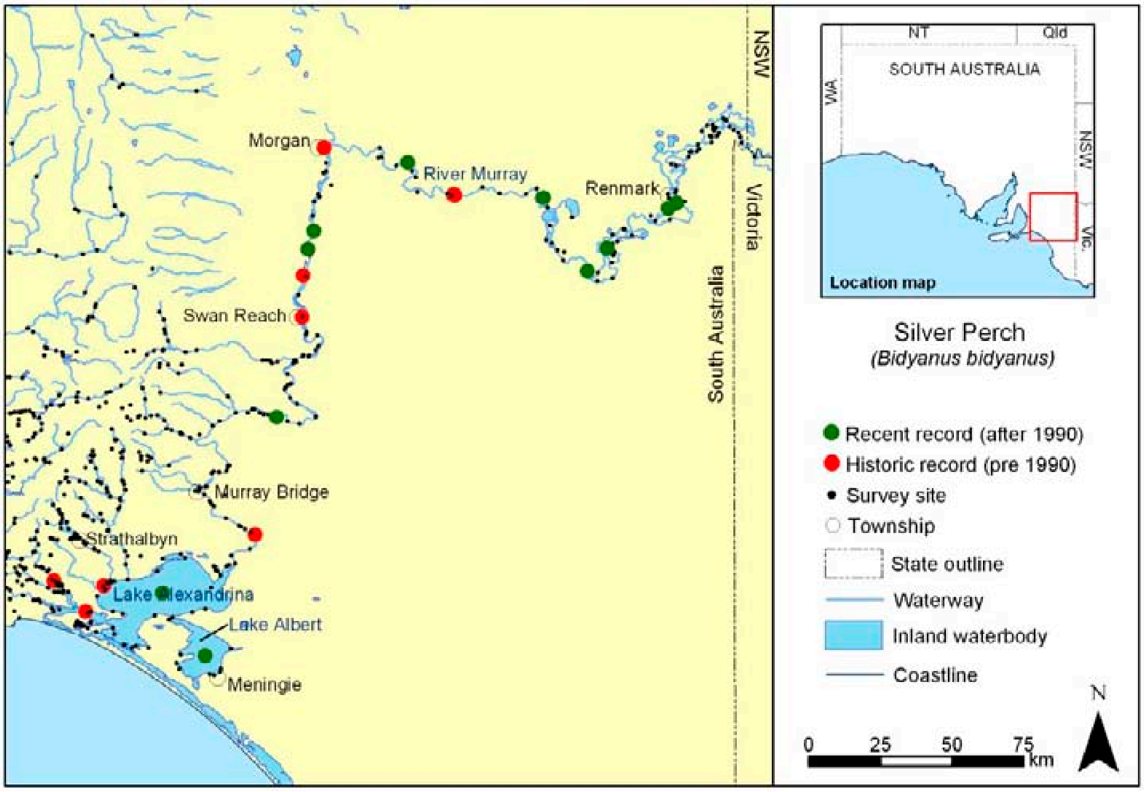
Conservation status *South Australia:* Endangered (EN A2bc); Protected *(Fisheries Management Act 2007).*
National: not listed. *Interstate:* listed as Threatened in Victoria (Critically Endangered) and Endangered in NSW and ACT.

Taxonomy and identification A medium to large sized fish up to 60cm in length, more commonly 25-40cm. Silver Perch is actually a species of grunter and can be distinguished from perches in the MDB by its small mouth and/or a flat edged to forked rather than round tail. The Silver Perch is very similar in appearance to Welch's Grunter which occurs in the LEB (e.g. Cooper Creek) with taxonomic keys distinguishing them on body depth and the number of lateral scales.

Former distribution As with many of the larger edible fishes, verified records such as museum specimens are limited, and no detailed historic assessments of status were conducted. Anecdotal evidence and commercial fishery catches suggest that Silver Perch was common throughout lowland river habitat in the SAMDB including the main river channel, Lower Lakes (e.g. Milang, Clayton, Hindmarsh Island) and lower sections of eastern Mt Lofty Ranges streams (Finniss and Bremer rivers)[25,152,176]. For example it was considered one of the most abundant species in the River Murray system in the 1960s[153].

Current distribution Silver Perch has declined considerably from its historic abundance in SA to the point that species is rarely seen and its distribution is now patchy. Recent records from fishway sampling, wetland studies and the commercial fishery (1995-2000) are mainly of a few individuals from limited localities[69,70,155], although juveniles (15-30cm) have been recorded from the main channel in areas such as Blanchetown[158]. The species has likely been translocated into various dam and stream habitats in the Mount Lofty Ranges and other areas of the State including Clayton Bore in the LEB[31] but fish were probably sourced from interstate hatcheries rather than SAMDB stock.

Biology and habitat Little research has occurred on Silver Perch in SA and hence most data is from interstate. Silver Perch is reported as a schooling fish which occurs across a variety of climatic types and environmental conditions, but generally in flowing river habitat. It is omnivorous, consuming aquatic plants, snails, shrimps and macroinvertebrates. Spawning occurs in spring and early summer involving large numbers of small semi-buoyant eggs shed into the water column, and requiring a trigger of water level rise or flooding. It has been reported that little or no spawning occurs in drought years. Upstream spawning migrations have been documented (including SA[162]) and adults and juveniles display active movement outside the spawning period, possibly stimulated by river flows. Silver Perch are long-lived with fish maturing at 3-5 years old and reaching a maximum age of at least 27 years[84,196,197].



Reasons for decline and threats Silver Perch appear to be particularly sensitive to flow regulation[198] as they are a species with biological requirements dependent of flows and flooding for biology. Habitat degradation, overfishing, and impacts from alien fish have also been suggested as causes for decline across the range of Silver Perch in the MDB[134]. These factors could all apply to SA, especially the progressive alteration (reduction) in flow to SA and the dramatic loss of smaller and medium sized flood events[185,186]. Additional threats to the species in SA include competition with Carp for similar food resources, numerous barriers to upstream movement during low flow conditions (this is currently being addressed) and stocking of hatchery reared Silver Perch is a threat to local stocks (e.g. genetic pollution, reduced genetic diversity and disease[188]).

Anecdotal information heralded a heavy decline of Silver Perch from the River Murray after the 1960s. Trends in commercial fishing catch, as an approximate index of population size, capture these low levels in the 1970s, indicating a slight recovery during the mid 1980s before a collapse of the fishery which failed to recover (Figure 11). While populations of this species may fluctuate naturally and data is limited, the reduction in catch (which targeted mature adults) plus few current records suggests a conservative estimate of decline over the last 3 generations (assume generation time of 10 years) of at least 50% (EN A2b). This apparent trend is likely to be due to declining environmental conditions from a highly regulated flow regime especially with recent protracted low flow conditions on the River Murray cumulating in serious drought in 2006/2007 (EN A2c).

Land tenure and conservation Occurs along the River Murray corridor which incorporates several State Reserves (Chowilla GR, Murray River NP, Morgan CP, Roonka CP, Ngaut Ngaut CP) as well as numerous council reserves and public riverfront access.

Recovery objectives

- Restore environmental conditions to promote a self-sustaining population.
- Protect an adequate spawning biomass of adult Silver Perch.
- Better define biology in SA (recruitment, flow and habitat requirements, migration).
- Develop an appropriate index to track population status.

Conservation actions already initiated

- Silver Perch is protected from exploitation through fisheries legislation (generally well accepted by the community).
- The Living Murray Initiative aims to restore flow regimes to key ecological assets including the River Murray channel important for Silver Perch recovery.
- Fishways have and continue to be constructed on major barriers to fish movement on the River Murray (mainly locks and weirs). Monitoring of the effectiveness of fishways is being undertaken by SARDI in conjunction with other interstate agencies and the MDBA.
- A Recovery Plan has been prepared for Silver Perch across its range (MDB) and this serves as an additional guide to recovery principles and actions for SA[199].

Required conservation actions

- Environmental flow programs to provide appropriate conditions for breeding and recruitment (monitored for effectiveness).
- Obtain fisheries independent monitoring data on Silver Perch habitat use, trends in abundance, and demography to more fully explore status, especially in relation to environmental conditions. Disseminate research findings to the public.
- Continue education and enforcement of Protected status, encourage reporting of incidental captures (e.g. location and fish length) to help improve knowledge on status.

Organisations responsible for conservation of species

PIRSA Fisheries, DEH, SAMDBNRM Board, DWLBC.

Organisations or individuals involved

SARDI Aquatic Sciences, SAMDBNRM Board, PIRSA Fisheries, MDBA, DWLBC.

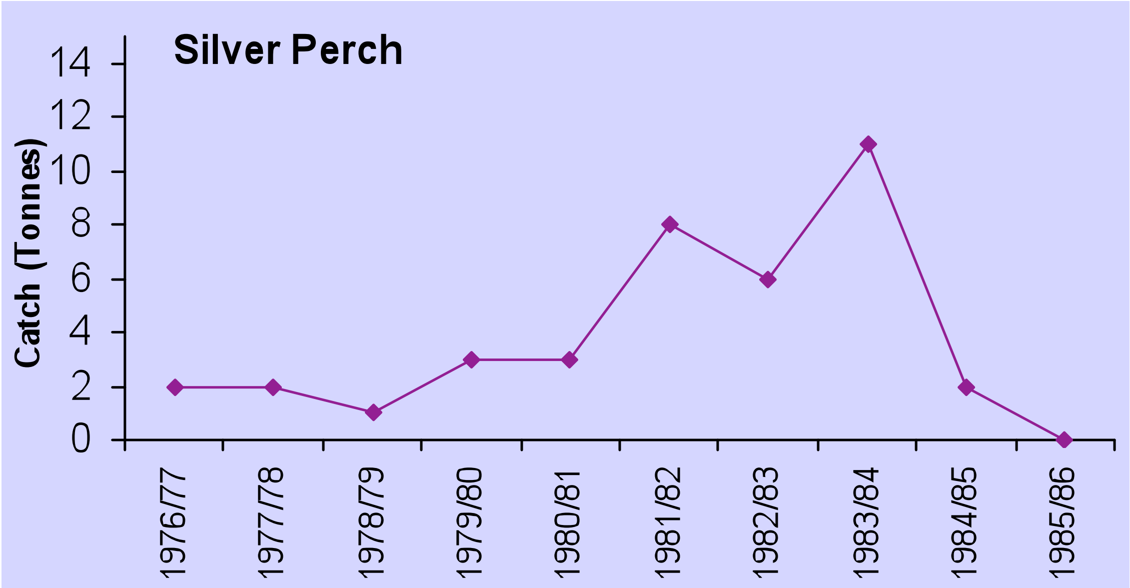


Figure 11. Catch data for Silver Perch from the SA River Murray Commercial Fishery between 1976-1986 based on SA Fisheries Statistics[165].

2.4. **VULNERABLE**

considered to be facing
a high risk of extinction
in the wild

Mountain Galaxias *(Galaxias olidus)*

Other common names: Minnows, Muddies or Slipperies.

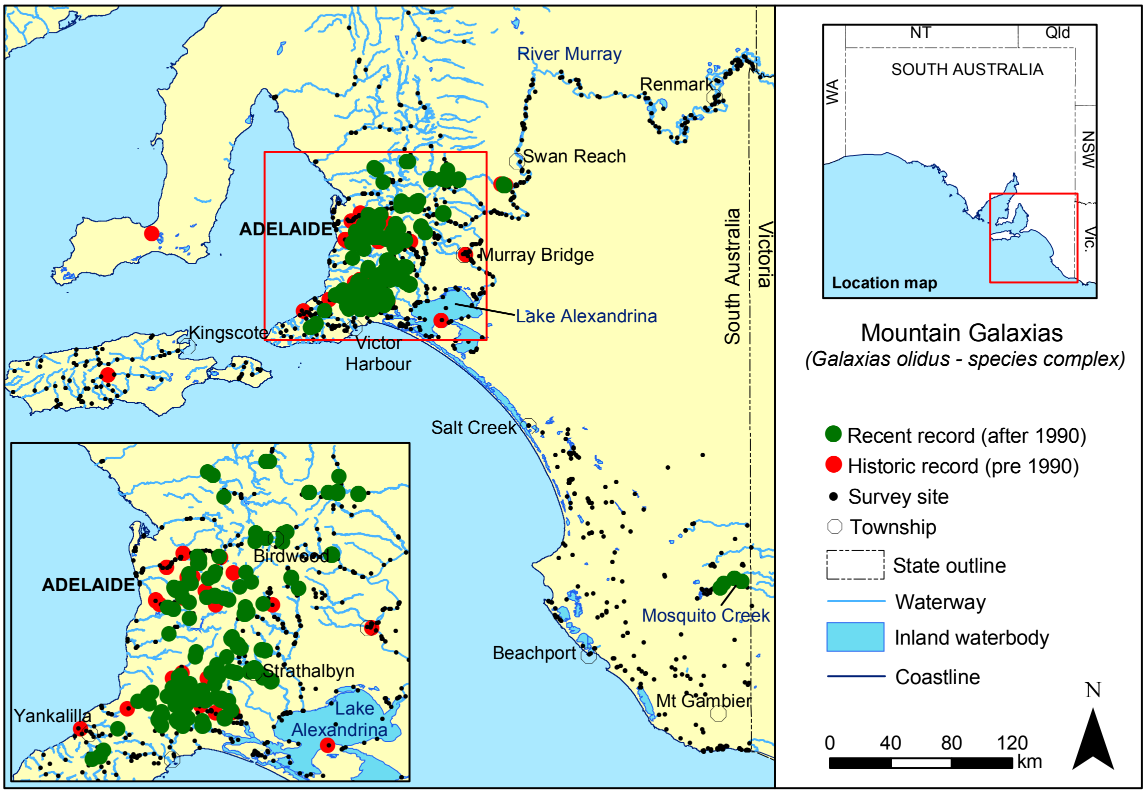
Conservation status South Australia: Vulnerable (VU B1ab(ii,iii)).
National & interstate: not listed (but certain forms are under consideration in Victoria - Data Deficient).

Taxonomy and identification A long slender fish to 14cm; more commonly 4-8cm. Mountain Galaxias can be distinguished from other galaxias by: (a) origin of the anal fin which is set behind the origin of the dorsal fin (used to distinguish between Common Galaxias – fins aligned, or Dwarf Galaxias – dorsal fin slightly in front of the anal fin), and (b) small pectoral and anal fins, equal length jaws and lack of a large black spot behind the gill cover (used to distinguish from Climbing Galaxias). Mountain Galaxias across southeastern Australia is currently under systematic review[15] with initial indications of multiple species including two distinct species in South Australia. Currently molecular (genetic) markers are used to separate the two species, with general differences in body shape and colouration (e.g. eastern form more robust and marbled[25,27]), with taxonomic keys still to be developed along with formal descriptions.

Former distribution A reasonable number of historic SA Museum records suggest that the Mountain Galaxias was once a widespread and common species in southern SA inland (cooler) freshwaters. It was predominantly known in the MLR (recorded catchments include: Gawler, Little Para, Torrens, Patawalonga (Sturt and Brownhill), Onkaparinga, Myponga, Carrickalinga, Bungala, Yankalilla, Hindmarsh and Inman (WMLR); Marne, Reedy, Bremer, Angas, Finniss, Tookayerta and Currency (EMLR)) with outlying records including swamps of the lower River Murray at Murray Bridge (during or prior to 1928) and at Lake Alexandrina (Point McLeay 1886). A distinct sub-section of habitat is known from the SE (records from Mosquito Creek) and there are unverified records from (a) Kangaroo Island - a single individual specimen from 1883 with no specific collection location, and (b) southern Yorke Peninsula, also based on a single record from 1934, although there is no remaining specimen to verify its identify (and it may well represent a record of Common Galaxias).

Current distribution The two species of Mountain Galaxias in SA have discrete ranges, with an approximate separation following the east-west divide of catchments in the Mount Lofty Ranges. Recent research sampling within the known range of Mountain Galaxias has been reasonably comprehensive. There has been a decline in the area of occupancy as it was not located in the historic catchment areas/regions of (a) Bungala River and Inman River (southern Fleurieu Peninsula[27]), (b) Scott Creek (Bremer Catchment), Murray Bridge and Lake Alexandrina (SAMDB[24,25,69,70]), and (c) Kangaroo Island[26]. Mountain Galaxias distribution is severely fragmented at broad (catchment) and local (stream reach) scales (VU B1a). This has been largely due to continuing declines in area of occupancy and abundance of isolated populations, especially with habitat change and the presence of alien predators in the Adelaide region (Torrens, Sturt and Onkaparinga catchments)[28], extensive recent pool drying, habitat degradation and introduced predators in the EMLR[25], and general habitat change on the southern Fleurieu[27]. Abundance and occupied area has also decreased at Mosquito Creek (SE) in the last five years due to pool drying and loss of flow[94,118] (VU B1bii,iii).

Biology and habitat While the presence of two distinct species of Mountain Galaxias in SA is recognised, there is as yet no differentiation of biological information for each, and hence a general account is provided. As the name implies, Mountain Galaxias occurs most commonly in areas with higher elevation including streams and swamps across a variety of environmental conditions, most commonly in areas with shallow flowing areas and moderate levels of instream cover. Cooler temperatures are preferred provided by stream flow and/or shade from edge riparian and terrestrial vegetation (this vegetation is also thought to provide habitat for invertebrates as an important source of food for Mountain Galaxias). Lowland areas are occupied where permanent springs occur (e.g. lower Marne and Angas rivers) and large pools can be habitat if alien predatory fish are absent; Brown Trout, Rainbow Trout and Redfin appear to restrict the distribution of Mountain Galaxias at microhabitat or stream reach scales when these larger growing alien predators are present. Fish in reproductive condition have been found in autumn through to spring. Mountain Galaxias does appear to undertake small scale movements within



stream sections for population expansion and recolonisation with the return of suitable conditions (if source populations remain)[23,25,27,28,200]. More detailed biology has not been investigated in distinct SA habitat, with interstate studies suggesting that: (a) diet includes a variety of terrestrial and aquatic insects and macroinvertebrates, (b) spawning occurs under solid objects such as rocks in flowing areas (riffles), and (c) longevity is unknown but most fish in a population are less than 2 years old, with sexual maturity reached within around a year[76].

Reasons for decline and threats The major threat to Mountain Galaxias in SA involves altered hydrology. Stream flow in upland areas of the MLR is heavily influenced by increasing levels of abstraction from water captured in farm dams and other storages, especially during naturally dry periods (potentially worsened with climate change). Abstraction impacts the presence and permanency of stream pools (thus determining the extent of Mountain Galaxias habitat) and causes changes to the nature and timing of flows, especially the loss of low flows or delayed onset of seasonal flows, both critical for maintaining water quality (e.g. oxygenation, reducing salt loads) and potential links to species biology (e.g. maintaining spawning habitat and eggs)[149,150,177]. The influences on vertical water sources (i.e. springs) is less obvious but groundwater extractions are likely to influence the availability of critical base flows. Cumulative to water stress, the reduction in the quality of stream banks and vegetation (e.g. stock grazing, urban development) is a threat to the quality of Mountain Galaxias habitat such as reduced shade, instream structure and increased silt loads. Introduced predatory fishes can reach larger sizes than native species and eliminate them from otherwise suitable habitat at local or regional scales, particularly in structurally and hydrologically simple systems (hence predation and competition from introduced fishes is a threat in its own right, potentially compounded by habitat change and water resource development)[25,27,28].

Land tenure and conservation Mountain Galaxias is known from numerous lands in the State Reserve system including: Montacute CP, Blackhill CP, Morialta CP, Cleland CP, Brownhill Creek RP, Belair NP, Sturt Gorge RP, Onkaparinga River NP, Scott Creek CP (Adelaide Hills), Myponga CP and Naracoorte Caves CP. Numerous stream sections on private property have been fenced and managed for conservation, others are linear reserves (e.g. Stirling), with populations also known from land managed by councils (e.g. Mt Barker, Strathalbyn) and SA Water.

Recovery objectives

- Secure and enhance existing populations by: (a) protecting and improving environmental flows, (b) protecting and restoring stream side habitat, and (c) reduce predatory and competitive effects of alien trout and Redfin.
- Promote research and monitoring on biology and environmental relationships.
- Improve awareness of the public, management and planning on the presence and requirements of Mountain Galaxias.

Conservation actions already initiated

- Broad baseline studies into distribution and status undertaken.
- Initial genetic investigations underway.
- Water resource allocation reviews are underway in key habitats (Marne and EMLR, Adelaide Hills (WMLR) and Mosquito Creek (SE).
- Environmental flows programs considering Mountain Galaxias requirements have been established in the lower Torrens and Onkaparinga catchments.
- Data sheets with pictures, identification keys and summary of biology are available[106,121,201].

Required conservation actions

- Determine taxonomic status and the genetic uniqueness of SA populations to inform management of distinct conservation units and priorities.
- Undertake environmental flow and water allocation processes across the range of Mountain Galaxias to ensure sustainable surface water and groundwater supplies, including provision for climate change scenarios.

- Further map the range of Mountain Galaxias, with specific reference to environmental conditions and the local influence of predatory fishes.
- Undertake research on local biology to better inform management, especially: (a) flow relationships for spawning and recruitment, (b) juvenile and adult tolerances, (c) age and growth, and (d) biological interactions with predatory fishes.
- Establish strategic riparian restoration zones at and near key populations, with before and after monitoring to quantify and document benefits. Disseminate findings and best practice guidelines to groups involved with on ground works.
- Assess and priorities sections where the control of introduced fishes will have benefits to biodiversity protection and expansion of important populations.

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, AMLR, SAMDB & SE NRM boards, DWLBC , SA Water, local councils.

Organisations or individuals involved

NFA (SA), SARDI Aquatic Sciences, AMLR, SAMDB & SE NRM boards, DWLBC, DEH, SA Water, numerous Catchment and Landcare groups (especially Upper River Torrens and Sixth Creek Landcare groups and Friends of Scott Creek CP).

Dwarf Galaxias *(Galaxiella pusilla)*

Other common names: Eastern Little Galaxias

Conservation status *South Australia:* Vulnerable (VU B1b(i,ii,iii)c(i,ii)).
National: Vulnerable (*EPBC Act 1999*). *Interstate:* listed as Threatened in Victoria (Vulnerable) and Tasmania.

Taxonomy and identification A tiny, bullet shaped species reaching a maximum size of only 4.8cm, commonly 2-3cm. Distinguished from juveniles of other species by a lack of scales (e.g. compared to Gambusia) and faint to iridescent body stripes and a small single dorsal fin with origin slightly in front of the anal fin (e.g. compared to Mountain Galaxias). Males have orange to red lateral body stripes during the spawning season, while females develop purple flanks.

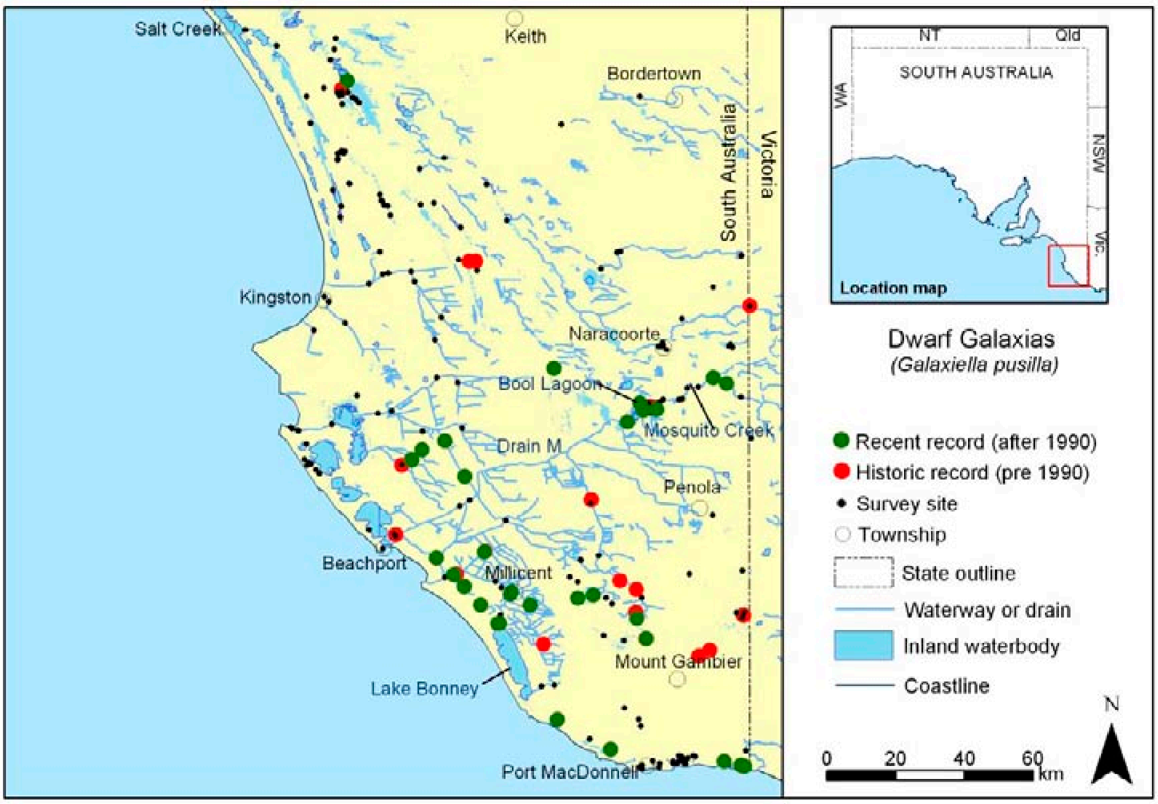
Former distribution Widespread in swamp and wetland habitat throughout SE SA including the Naracoorte Creek system (Mullinger Swamp), Mosquito Creek/Bool Lagoon system, Bakers Range Watercourse through to Cortina Lakes, Dismal Swamp Corridor through to Mt Burr, the Millicent/Lake Bonney area, and the Lower South East[23,40,101]. Due to its small size and lack of specific searches the species presence was not recognised until the 1970s (e.g. records from Bool Lagoon in 1974), but subsequent publications revealed earlier records (Mingbool area near Mount Gambier)[202].

Current distribution A reasonably comprehensive survey in 2001-2002 revealed the species to still be widespread in the region, but reasonably patchy and with limited natural (secure) habitat[23]. Strongholds appear to be in the areas of Bool Lagoon, coastal springs of the Lower South East, Millicent/Mt Burr area and Drain L system, with patchy records in the Bakers Range and Upper South East. The species was not located in the Mingbool area, Naracoorte Creek system or Deep Swamp system (east of Kingston) where there had been previous records. Recent assessment (2008) indicates further decline, with potential loss from the Upper South East[94] (VU B1b(i,ii)).

Biology and habitat Occurs in shallow swampy habitat amongst emergent and submerged aquatic vegetation, primarily in swamp and wetland habitat, but also in numerous artificial drains which represent the only available habitat in some areas, and with some records in stream habitat (Mosquito Creek) and flooded lake edges (Lake Bonney)[23]. The species has been documented to occur in seasonal habitats, surviving swamp drying by seeking refuge in Swamp Yabby (Geocharax spp.) burrows for periods of up to five months[202] but survival at a regional context is likely best provided within a network of populations (metapopulation) where core refuges exist for recolonisation. Recolonisation is aided by a strong ability to navigate shallow surface water connections between habitats[55,202]. This species appears to be short-lived (longevity 1-2 years) and hence successive failures in habitat condition could lead to local extinctions. They spawn during cooler conditions in aquatic vegetation from around April to November. Adults are known to eat small crustaceans and vegetative matter[202].

Reasons for decline and threats Habitat loss from cumulative and progressive effects of widespread drainage of wetland and low-lying areas is likely to have had, and continue to have, a great impact on this species (e.g. loss of 90% of SE wetland habitats and alteration of most others[23,203,204])(VU B1b(iii)). A short lifecycle, altered regional hydrology and shallow occupied habitats leaves the species susceptible to extreme fluctuations in area of occupancy during climatically dry period. In addition, such adverse conditions may become more frequent and severe with climate change. This species is concurrently exposed to threatening processes which reduce quality of refuges may affect their ability to recover from such periods of stress (VU B1c(i,ii)). Other threatening processes are likely to include:

- Localised habitat damage from stock trampling wetland edges and seasonally dry habitats[202].
- Altered groundwater hydrology (e.g. from irrigation and plantations) lowering water tables potentially influencing the water holding ability of surface habitat and the ability of Dwarf Galaxias to reach refuge in Swamp Yabby burrows.
- Altered surface water connections by creating artificial barriers to Dwarf Galaxias movement may inhibit dispersal and recolonisation. Barriers do not need to be large structures given the small size of the fish (e.g. elevated roads, culverts, and drain spoilings may be significant dispersal barriers).
- Alien species: while the distribution of introduced species in the SE is currently restricted, future spread of species, primarily competition and aggression from Gambusia, is a concern based on experience interstate.
- Chemical pollutants: population losses were noted in the 1960s in the Mingbool region following application of pesticide (Lindane)[202]. Investigation is required into the impacts of other pesticides and herbicides employed in agriculture and local management (e.g. weed spraying).



Land tenure and conservation Occurs at Piccaninnie Ponds CP, Bool Lagoon GR, Hacks Lagoon CP, Reedy Creek CP, on land owned by DEH for conservation at Picks Swamp, other private lands managed for conservation (e.g. Ellis Swamp north of Lake Bonney), Forestry SA land (e.g. Mt Burr and Mingbool regions), drains in the Millicent region and Drain L system managed by the SEWCDB, and other private land with stock access (e.g. Mosquito Creek, coastal swamps).

Recovery objectives

- Secure core populations and regional metapopulations.
- Establish monitoring to develop an understanding of relationships to environmental conditions and hydrology, especially with any changes in management and/or conditions.
- Ensure that all key stakeholders are aware of populations and potential threats and improve awareness, particularly regarding species presence and ability to occur in seasonally dry habitats.

Conservation actions already initiated

- Initial broad scale distributional surveys and habitat assessment undertaken[23].
- Published ecological account provides significant information for management[202].
- Fencing on selected habitats (Picks Swamp, Ellis Swamp[205], parts of Mosquito Creek).

Required conservation actions

- Continue to identify then protect or undertake restoration at core dry period refuges.
- Protect and restore other known habitats.
- Protect and restore corridors for dispersal (e.g. fencing, reviewing road infrastructure).
- Temporal monitoring programs at current and historic sites to help determine population dynamics under different environmental and seasonal conditions. Urgent priority to assess the impacts of landscape drying from a prolonged period of below average rainfall since 2005.
- Improve habitat conditions to assist long term persistence at drain sites through adaptive habitat management (e.g. section fencing, hydrological alterations).
- Active management to prevent new pest fish introductions to Dwarf Galaxias habitat.
- Establish long-term government and community support structures (e.g. plans, educative materials) to promote the Dwarf Galaxias within regional planning and management, and aquatic protection and restoration programs.

Organisations responsible for conservation of species

DEH, DEWHA, SENRM Board, SEWCDB, USE Program, Forestry SA, regional Councils.

Organisations or individuals involved

NFA (SA), DEH, private landholders.

Flyspecked Hardyhead *(Craterocephalus stercusmuscarum stercusmuscarum)*

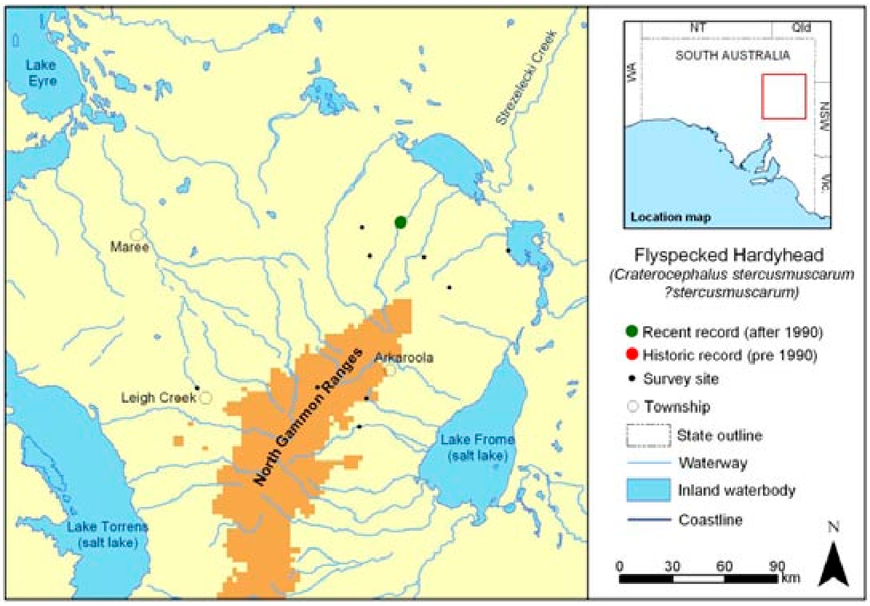
Conservation status *South Australia:* Vulnerable (VU D2).
National & interstate: not listed (the related subspecies Unspecked Hardyhead is listed as Threatened in Victoria and recommended Vulnerable in NSW[74]).

Taxonomy and identification A slender, silvery-gold coloured fish with thin black body stripes visible under certain conditions, maximum size is around 11cm, but is commonly 4-6cm. Occurs in the same region as Lake Eyre Hardyhead but is distinguished by being more elongated, having less transverse body scale rows (7-8 v. 1-14) and a faint black stripe through the head and mouth. The species is very similar to Glovers Hardyhead and Unspecked Hardyhead which occur in isolated habitats. There is currently taxonomic confusion surrounding the different subspecies in the 'Craterocephalus stercusmuscarum' group and hence the current identity of the South Australian population is tentative - initial genetic research indicates this form is distinct from those in the Murray (i.e. Unspecked Hardyhead) and is most closely related to fish in NE Queensland[206] but further research may prove the SA population to be an endemic subspecies.

Former distribution This species is known positively from MacDonnell Creek flowing from the northern Flinders Ranges. There have been historic reports from other locations in the SA Lake Eyre Basin[207,208], however these appear to be based on misidentifications or taxonomic confusion with Lake Eyre Hardyhead and Glovers Hardyhead as there are no verified records within extensive historic samples at the SA Museum[1].

Current distribution Recent records from large pool habitat on ~2km of MacDonnell Creek (1994-95 & 2003[55,101]) (VU D2). Could occur in other locations but appears to prefer habitats without Lake Eyre Hardyhead, a species which is common and widespread throughout most inland waters in the SA LEB (except perhaps for the Cooper Creek).

Biology and habitat Occurs in large deep pools fringed with emergent vegetation of Reeds (*Typha* and *Phragmites*), commonly in the edges or shallow areas of rock, algae or Pond Weed (*Potamogeton crispus*)[55]. The series of pools it occupies on MacDonnell Creek appear to be fed from local groundwater (not the Great Artesian Basin) which is relatively fresh (<1000µS, but this requires longer term quantification) compared to other more saline waters commonly encountered in the LEB which are occupied by Lake Eyre Hardyhead. There is no biological information currently known for the South Australian population. Data from NE Australia (tropical habitat) indicates the species to have a primarily carnivorous diet of aquatic insects and micro-organisms with occasional ingestion of vegetative matter (e.g. algae). The same data has found that spawning occurs on submerged and edge vegetation opportunistically over an extended period depending on temperatures and rainfall; that fish mature quickly and are relatively short lived (2 or more years); and that they are mobile within sections of stream systems[209].



Reasons for decline and threats There is no long-term data to assess population trends for the species, but its limited distribution, extreme isolation in desert habitat, and specific known habitat makes it susceptible to local losses – its status could quickly shift from the 'Vulnerable' to 'Critically Endangered' category if any indication or observed, inferred or projected decline or fluctuation in the habitat or population were observed. The hydrology of unique local freshwater habitat requires further investigation to ensure long-term sustainability and presence, with any major water extractions in the region a likely serious potential threat (e.g. mineral exploitation). Other local issues could include the introduction of alien fishes, both exotic (e.g. competition, disease and aggressive behaviour from Gambusia) and translocated Australian native species which do not naturally occur in the region (e.g. predation and disease from larger angling species). Additionally, high levels of stock grazing may be detrimental to water quality and edge habitat condition.

Land tenure and conservation

- Occurs on private land.

Recovery objectives

- Secure the known population through (a) improved knowledge and (b) acting to protect important aspects of population sustainability (especially water security).
- Further determine distribution in the SA LEB.

Conservation actions already initiated

- Genetic studies to determine species status (i.e. SA endemic) initiated.
- Current presence of species confirmed through research sampling.

Required conservation actions

- Undertake temporally replicated research into habitat dynamics, biology and potential threats at known habitat.
- Work closely with local land managers to provide water security and on-ground protective measures within a framework of existing landuse.
- Build broader awareness within planning and management of the importance of the local water resource (spring feeding).
- Undertake baseline sampling throughout the SA LEB.

Organisations responsible for conservation of species

DEH, SAAL NRM Board, DWLBC.

Organisations or individuals involved

NFA (SA), SA Museum, SAAL NRM Board.

Congolli *(Pseudaphritis urvillii)*

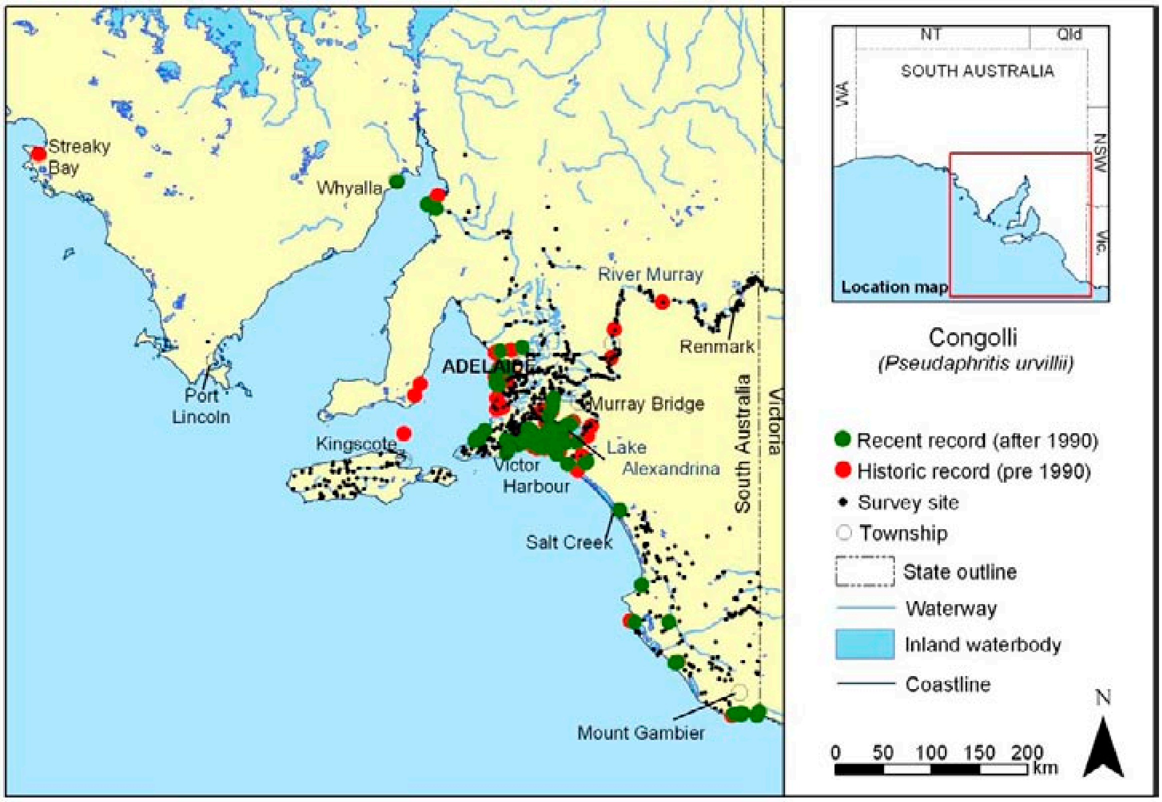
Other common names: Freshwater Flathead, Sandy and Tupong

Conservation status *South Australia:* Vulnerable (EN A2ac).
National & interstate: not listed.

Taxonomy and identification A small-medium sized species, highly variable in colour and reaching a maximum size of 35cm (females), more commonly 10-20cm. The Congolli is similar in appearance to gudgeons but can be distinguished by the very long second dorsal and anal fins.

Former distribution Relatively widespread in freshwater systems with coastal access and in estuaries stretching along the SA coast, although known records are quite patchy in the west of the State - limited to an old record from Streaky Bay (1903), Upper Spencer Gulf near to the outlet of the Broughton River (1988-2004) and from the foot of Yorke Peninsula (1931 & 1969). Core distributional records come from: (a) streams and estuaries in the Adelaide region (Gawler to Onkaparinga rivers), (b) the southern Fleurieu (e.g. Myponga, Bungala, Inman, Hindmarsh and Middleton catchments), (c) Lower River Murray region including the Coorong, Lower Lakes, EMLR and with intermittent records stretching upstream along the River Murray to the SA border, and (d) a coastal fringe of freshwater habitat in SE SA. Surprisingly no records have come from streams and estuaries on Kangaroo Island despite reasonable searches there over time. Congolli was formerly reported as abundant in the River Torrens near Adelaide[172], and a commercial fishery existed for the species in the Lower Lakes[176].

Current distribution Recent records have been made throughout core habitat in the Adelaide region, southern Fleurieu, Lower Lakes and coastal habitats of SE SA[23,24,25,27,28,67,141,210,211], with no recent records despite suitable sampling in wetlands and the main channel of the River Murray[69,70,155,212] and on Kangaroo Island[26]. An early disappearance was noted from the River Torrens[28] although they have recently returned to lower freshwater sections due to the installation of fish ladders. Similarly the distribution in lowland streams of the EMLR and north of Adelaide has declined (range and abundance) with loss of previously permanent pools and reduced flow connecting to the Lower Lakes (e.g. Bremer and Angas rivers[25,67]). The status of Congolli in the west of the SA requires further investigation with the only recent records being from Port Davies and Whyalla[55,66].



Biology and habitat Some details of Congolli biology have been documented for SA, however a general life history model is still to be developed with the species appearing to exhibit complex and varying behaviour across its range. Congolli appears to occur in a variety of habitats from purely marine to the mid sections of lowland streams (and it has the ability to tolerate a direct transfer from marine to freshwater[213]), but often occurs in or near areas of freshwater discharge and reaches its highest adult abundance at the interface of fresh and salt water. This species occupies habitat with soft silt or sand (especially lakes and estuaries) in which it can bury itself, or in stream situations with reasonable levels of instream cover (rocks and snags) and edge vegetation such as Bullrush. The congolli is an ambush predator, with diet from the Lower Lakes found to include fish, fish eggs, molluscs, crustaceans and aquatic vegetation. There appears to be pronounced size differences between males and females, with larger individuals invariably reported as females. Reproduction occurs from May to September in the lower River Murray, and likely takes place in freshwater - large congregations of females in roe (presumably spawning) were historically netted from around Reed islands in Lake Alexandrina. Its longevity is unknown but it probably lives for 4-5 years. Congolli has traditionally been known as a diadromous species (i.e. its lifecycle involves movement between fresh and salt water for different life stages), but such movements appear flexible and need to be better understood in SA[24,25,27,142,176,214,215].

Reasons for decline and threats Threatening processes for Congolli require greater documentation, however the species seems most susceptible to hydrological change and instream barriers to dispersal (e.g. Barrages, numerous weirs in the Adelaide region) blocking access to freshwater habitat. Reduced river discharge such as the 2/3 loss of flow of the River Murray leads to reduced available area of habitat, weakens connections for upstream and downstream movement, and results in an overall deterioration in the quality of habitat and food webs (e.g. reduced water quality, decreases in edge vegetation). Habitat loss through land clearance (e.g. changes to stream channel shape, loss of snag input) and local changes (e.g. stock damage, development of stream banks) could reduce the suitability of lowland stream habitats, and industrial/stormwater pollution to some estuaries may be significant. Netting of spawning aggregations in the Lower Lakes may also have contributed to regional declines.

While the species remains reasonably widely distributed there is evidence to suggest a significant decline in abundance across its range. Most significant is the major recent changes to habitat in the lower Murray, the largest and likely core population in South Australia. Access to freshwater habitat in the SAMDB has been blocked since 2007 denying a migration pathway in or out (a 96% decline in congolli juveniles was observed between 2006/07 and 2007/08[151]), and major water level lowering has greatly reduced vegetated edge and off-channel habitats with matching declines in records[102]. This decline is predicted to continue if environmental conditions degrade further (EN A2ac).

Land tenure and conservation There are known records of Congolli from the following State Reserves: Lower Glenelg River CP, Piccaninnie Ponds CP, Ewens Ponds CP, Lake Frome CP, Coorong NP, land managed for conservation at Wyndgate, Tolderol GR, Onkaparinga NP and Port River/Barker Inlet Aquatic Reserve. Also occurs on a variety of public and private land including managed habitat in drains and Lake George in the SE.

Recovery objectives

- Improve understanding of Congolli (a) biology under different SA conditions, and (b) potential threats.
- Secure and restore environmental flows, and the general condition of lowland and estuarine habitats including unimpeded access for fish movement.

Conservation actions already initiated

- Distributional surveys within most of the known range of Congolli have been undertaken.
- An environmental flow program has been developed for significant habitat on the lower Onkaparinga
- River (reservoir releases), with initial moves to secure water requirements in the EMLR. The Living Murray Initiative also aims to restore flow regimes to key ecological assets including the Lower Lakes and Coorong.
- Fishways have and continue to be constructed and monitored on major barriers to fish movement on the River Murray.
- A new fishway has been installed at the mouth of the River Torrens.
- An initial pilot biological study on Congolli in SA has been undertaken[215].

Required conservation actions

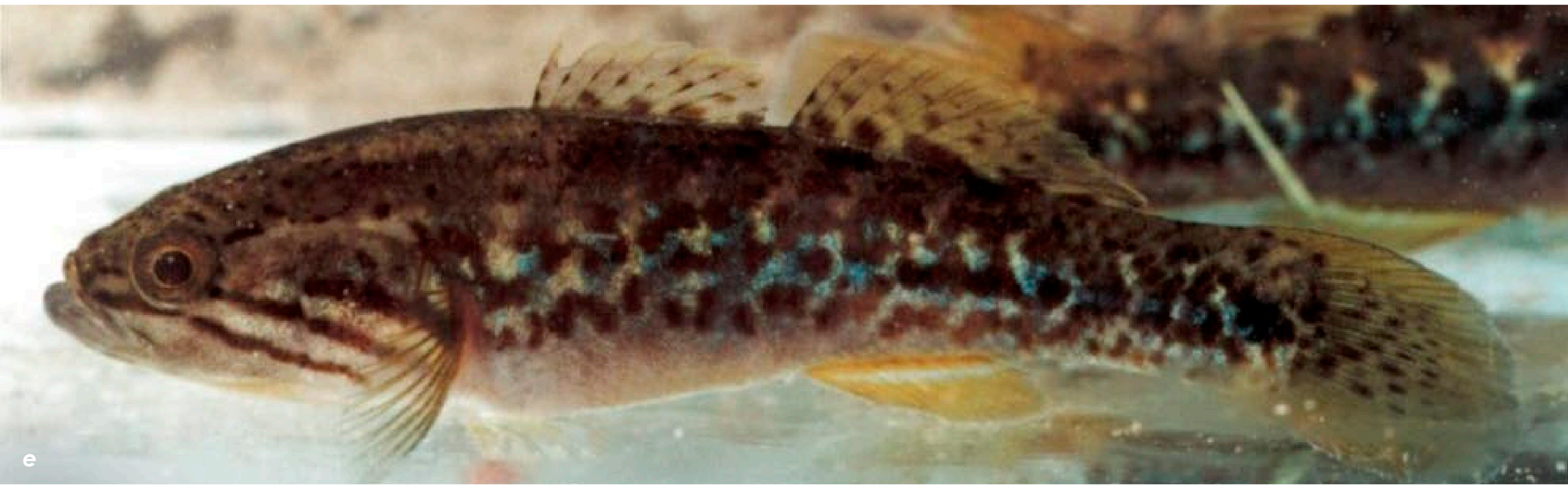
- Initiate long-term biological studies across various habitat types and regions of SA to monitor the status of populations, and concomitantly investigate movement, spawning behaviour/biology, recruitment and habitat use across different life stages, and link this to required environmental conditions.
- Specifically undertake environmental flow assessment and restoration programs to ensure sustainable surface water and groundwater supplies, including provision for climate change scenarios (especially MLR, plus broader improved management of water resources in the MDB).
- Assess and prioritise barriers potentially impacting migration, then investigate fishway options including studies to test their effectiveness.
- Undertake projects to protect and restore lowland stream reaches (and monitor their effectiveness).
- Investigate the status of Congolli in the western portion of SA through targeted surveys at known historic habitat and likely estuaries.

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, DWLBC, SEWCDB and the SE, SAMDB, AMLR, NY & EP NRM boards.

Organisations or individuals involved

NFA(SA), DEH, SARDI Aquatic Sciences, the SE, SAMDB and AMLR NRM boards, MDBA, DWLBC, SA Water, Goolwa to Wellington LAP.



a Dalhousie Catfish (*Neosilurus gloveri*) ***b*** Dalhousie Goby (*Chlamydogobius gloveri*)
c Glover's Hardyhead (*Craterocephalus gloveri*) ***d*** Dalhousie Hardyhead (*Craterocephalus dalhousiensis*)
e Dalhousie Purple-spotted Gudgeon (*Mogurnda thermophila*)

Dalhousie Springs Endemic Fishes

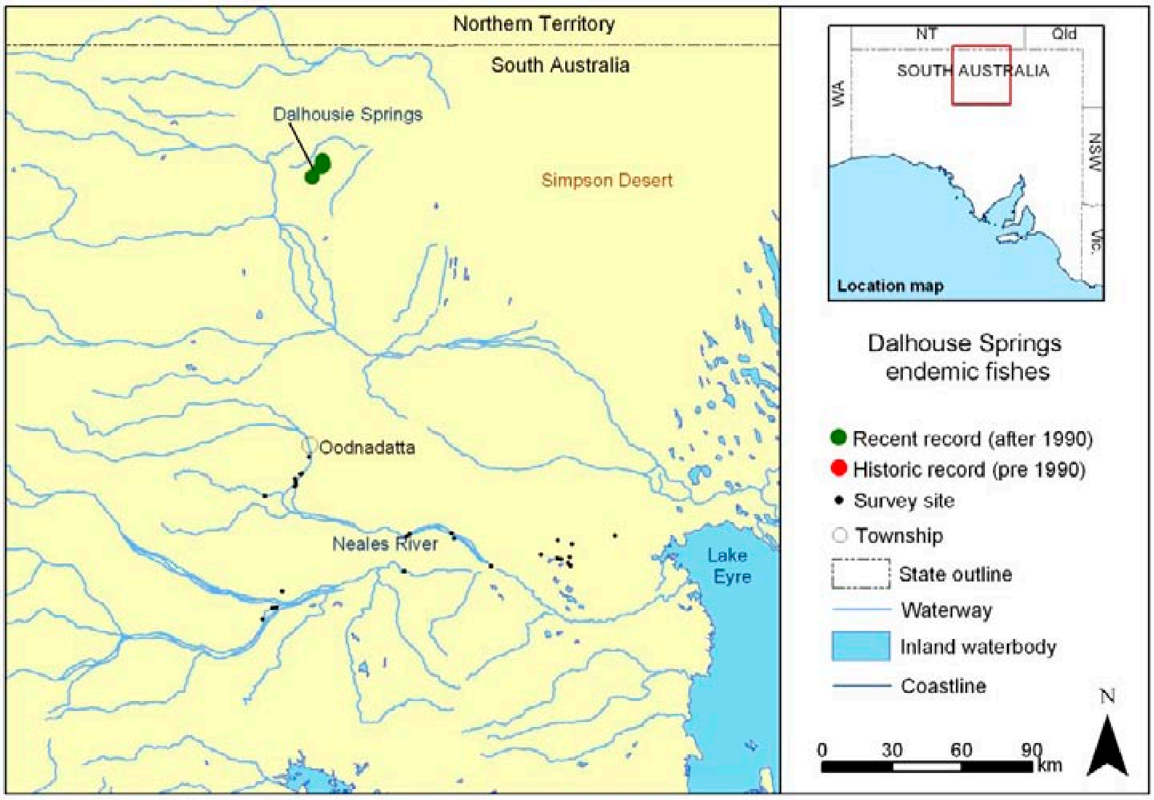
Conservation status *South Australia:* Vulnerable (VU D2), the Dalhousie Purple-spotted Gudgeon is also Protected (*Fisheries Management Act 2007*).
National: individual species are not listed but fall within the 'community of native species dependent on natural discharge of groundwater from the Great Artesian Basin' listed as an Endangered Ecological Community (*EPBC Act 1999*) (three species are considered Vulnerable on the IUCN Red List[6]).

Taxonomy and identification All five of the Dalhousie Springs endemic fishes are small reaching a size no larger than 15cm. Each species group exhibits major differences in body form (e.g. streamlined hardyheads, eel-tail of catfish, cupped pelvic fin of goby and robust spotted form of the gudgeon: see photos). The two species of hardyhead are difficult to identify and require further investigation into species boundaries. The five endemic species have been distinguished and described in the last 30 years and in addition to geographic isolation, other keys are available to distinguish them from similar species elsewhere[31,136,216,217,218,219,220].

Former distribution The Dalhousie Springs complex is situated in northern SA occupying a relatively small area with an extent around 70km^2. Fish were reported from Dalhousie Springs as early as 1894-95, but it was not until 1968 that they became known in scientific circles (mainly from a major spring group). The first study across the various spring groups was completed in 1985[30] forming the best available historic data on occurrence at a fine scale. The study found fishes at about half of the 80 active springs which occur as isolated springs or as small clusters or groupings of springs. The Dalhousie Goby was the most widespread species (30 springs) followed by Dalhousie Purple-spotted Gudgeon (11 springs), Dalhousie Catfish (5 springs), Dalhousie Hardyhead (7 springs) and Glover's Hardyhead (4 springs).

Current distribution A second major study on the fishes of Dalhousie Springs was undertaken in 1991 documenting 77 populations of fish, distributed among 28 isolated springs[49]. Data was similar to patterns observed in the 1980s with only minor loss of populations due to drying of one spring in what appeared to be natural cycling. The study also recorded additional sites for Dalhousie Catfish and Dalhousie Purple-spotted Gudgeon due to more comprehensive sampling (14 and 19 sites total respectively)[221], but hardyheads were not identified to species level in this study. A more recent assessment of species distributions was undertaken by the same researchers in 2003[222]. The latest study identifies major changes in the fish community in recent times, especially the loss of twelve of 30 (40%) occurrences of Dalhousie Goby sites (VU A2ac), due to a change in local grazing regime (feral animal control) leading to proliferation of Common Reed (*Phragmites australis*) subsequently encroaching and reducing shallow aquatic habitat.

Biology and habitat Dalhousie Springs represents a restricted and isolated ecosystem that has been in existence for several million years[220], fed by water rising from the Great Artesian Basin. Hence, the primary habitat requirement for Dalhousie endemic fishes is water to maintain highly isolated refuges in an otherwise inhospitable habitat. The endemic fishes show clear patterns of spring occupancy – each species appears to occupy a particular distribution among different sized springs or microhabitats (i.e. gudgeon and goby generally in shallow edges and spring tails; catfish and hardyhead in deeper habitat). Distributions may be influenced by the only other fish species recorded at Dalhousie, Spangled Perch (native) which occupies larger and deeper springs[49]. While no detailed studies have been undertaken, opportunistic observations on diet, behaviour and biology have been compiled for the different fish species at Dalhousie Springs[30,31]. Of note is the high thermal tolerance of many species allowing them to occur in warm groundwater at the source of discharge in many springs; nocturnal behaviour in Dalhousie Catfish; wide variation in diet within and between species; and difference in basic spawning modes between species (e.g. broadcast spawning of eggs over the bottom (catfish), scattered on vegetation (hardyheads) and fixed to solid objects and guarded by the male (gudgeon and goby). Other information on spawning periods, lifespan and dispersal remain to be studied.



Reasons for decline and threats A limited extent of occurrence, extreme isolation in desert surrounds, and specific known habitat makes the community of Dalhousie endemic fishes susceptible to local losses (VU D2). The primary potential threat is hydrological change and spring drying due to aquifer water drawdown and/or reduced artesian pressure. Recent observations of fish declines associated with habitat change and vegetation dynamics (Reed and Date Palms *Hoenix dactylifera*), indicates altering grazing and habitat management may also be a key threatening process. Other potential threats include habitat damage associated with tourism which needs further quantification of long-term influence. The introduction of fishes, especially Gambusia, poses potential competition, aggressive interaction and disease introduction. Wildlife research poses a minor threat, mainly for the potential introduction of disease with via contaminated equipment.

Land tenure and conservation

- Dalhousie Springs occurs within the Witjira National Park (established 1985).

Recovery objectives

- Undertake proactive efforts to protect the high conservation values of Dalhousie Springs including (a) ensuring the long term sustainability of source aquifer water, (b) providing appropriate fish related habitat management, and (c) controlling other human impacts such as physical and biological pollution (e.g. fish introductions).

Conservation actions already initiated

- Establishment of a National Park incorporating Dalhousie Springs.
- Initial biological investigations undertaken and documented, more detailed investigations of fish distribution have occurred and have been repeated through time.
- Date Palm control is currently been undertaken with aquatic monitoring associated with the removal (but not directly targeting changes in fish communities).
- Improved facilities to minimise the impacts of tourism have been installed (e.g. restricted access for vehicles and camping).
- Terrestrial feral animal control is being undertaken to aid terrestrial vegetation. Resultant changes to aquatic habitat need careful monitoring and potential alternate disturbance to protect fish habitat.

Required conservation actions

- The exact dynamics of the Great Artesian Basin water source needs to be better understood. The potential impact and lag times of water extraction should be assessed and built into proactive water resource management (e.g. creation of mineral exclusion zones, bore capping).
- Establish regular long-term monitoring points to help build biological information (recruitment and demography) linked to changes in environmental conditions, especially to help adaptive habitat management. Investigating the role of fire and fire management on fish habitat condition and availability would also be beneficial.
- Research into the genetic structure of species across different spring groups would be useful to assess if multiple conservation units are present which need individual management.
- Unlike many desert springs elsewhere in the world, Dalhousie Springs contain no introduced fishes. To maintain this status awareness within management and active local vigilance is required.
- Increased awareness of the uniqueness and importance of Dalhousie Springs may help long term conservation of the area and resource allocation, but needs to be balanced against the related increase in potential for visitation and deliberate acts. Improved awareness of presence of unique fishes may encourage an increase in such activity.
- All fish and aquatic research equipment must be sterilised before arrival at Dalhousie and between usage in different spring groups.

Organisations responsible for conservation of species

DEH, SAALNRM Board, PIRSA Fisheries, DEWHA.

Organisations or individuals involved

DEH, SAALNRM Board, SA Museum, traditional owners.

One of the many thermal pools at Dalhousie Springs, North East SA

2.5. **RARE**

taxa that are in decline or that naturally have a limited presence in South Australia

Shortfinned Eel *(Anguilla australis australis)*

Conservation status *South Australia:* Rare (RA d(ii)).
National & interstate: not listed.

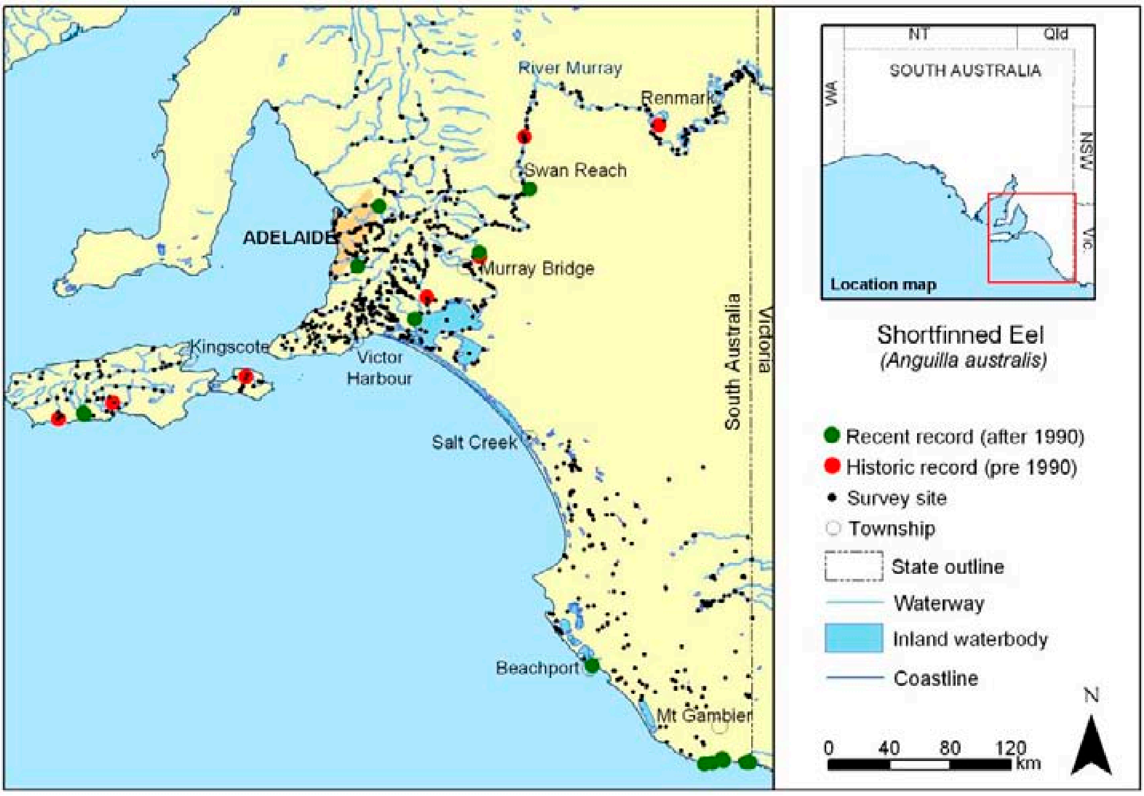
Taxonomy and identification The Shortfinned Eel has the characteristic elongated eel body shape, reaching a maximum size of around 1.2 metres, commonly 40-60cm. Shortfinned Eel can be distinguished from Longfinned Eel (a species from the east coast of Australia) and Conger Eel (a marine species) by the length of the dorsal fin which reaches only half way along the top of the body and is aligned with the origin of the anal fin.

Former distribution Early details of the distribution of Shortfinned Eel in South Australia are vague, but suggest the species was once common in SA freshwaters particularly prior to the construction of the Barrages on the Lower Murray[44,107,152]. A specimen (1.1m and 3 kg in weight) taken at Sunnyside on the River Murray in 1961 was the first documented record for some time, and there has been a slow trickle of reports since from coastal areas including southern catchments of Kangaroo Island (records from the Willson, Eleanor and South West River in the 1980s), SAMDB including main channel, wetlands, lower tributary streams and Lower Lakes (e.g. Blanchetown 1973, Barmera 1982, Bremer River 1988), and SE, particularly with more intensive sampling in streams using fyke nets in recent times. The species may have occurred in the Adelaide region (e.g. Torrens and Patawalonga catchments) but there are no verified records (but see current distribution)[28].

Current distribution Most recent records of Shortfinned Eel in SA have come from the SE which houses a reliable population concentrated in the area of groundwater discharge near Port MacDonnell (Eight Mile Creek and Piccaninnie Ponds areas[23,55]). There is a sprinkling of documented records further west in systems with coastal access (e.g. Lake George 2002[155]) including the Lower River Murray region (recent records from Milang 1996[101], Devon Downs 2003[59], Mypolonga[101], Goolwa[101]) and Kangaroo Island (two records from the Stunsail Boom River in 2005[26,101]). The first verified records of Shortfinned Eel have recently come from the Adelaide region (WMLR streams) including one found at the Salisbury Wetlands (interconnected with the Little Para River) by Waterwatch in 2005 and an adult from the Onkaparinga River in 2006[155]. Given the location close to urban areas it is unknown whether these are natural occurrences or translocations (e.g. discarded aquarium fish).

Biology and habitat The Shortfinned Eel is a diadromous species (i.e. it has different life stages in both marine and freshwater habitat). Juveniles grow to maturity for as long as 10-20 years in upper estuaries and freshwater habitat types such as streams and rivers, springs, wetlands, sinkholes. A predatory

species, diet interstate is known to include insects, molluscs, crustaceans and fish. Adults migrate out to sea on full moons in late winter with seasonally high discharge and undertake a long spawning migration to spawning grounds thought to occur somewhere NE of Australia in the Coral Sea (around 3000km!). Larvae (leptocephali) are carried back towards the coast on the East Australian Current where they metamorphose (change form) into the glass eel stage which move into freshwater in winter and spring[87,223](an upstream migrant was recorded in December 2006 at Eight Mile Creek in SE SA[55]). Recruitment (colonisation) of Shortfinned Eel into streams becomes less regular and reduced west of Cape Otway in Victoria as juveniles need to contend with opposing current directions across Bass Strait and along the SA coast in winter and spring[224,225]. Hence, as the western most distribution of the species, long distances and unfavourable conditions likely limit the abundance of the species in SA.
In addition, a late summer arrival will rarely coincide with significant discharge, further limiting penetration inland.



Reasons for decline and threats The species is threatened in SA as it is naturally rare in abundance and has a restricted and divided area of occupancy (RA d(ii)). However, other potential threats which may be ongoing might have caused declines from historic distribution and abundance. Changes in catchment hydrology, especially loss of perennial (permanent) flow and early cessation of seasonal flows (e.g. from farm dam abstraction, water storage in reservoirs and upstream regulation on the River Murray) would lead to limited opportunities for colonising freshwater habitat and a reduction in the availability and quality of suitable habitat. Migration barriers (such as large dams, the Barrages and smaller weirs) would act to limit the numbers of individuals accessing freshwater and cause bottlenecks exposing fish to predation and deleterious conditions. Loss of instream and riparian habitat would be significant in small streams (e.g. known habitats on Kangaroo Island) and general ecosystem change could influence required trophic linkages for populations[226]. The local and regional impacts of fishing are unknown. For example a small recreational fishery exists for Shortfinned Eel in the SE and larger numbers are harvested in eastern states. Reduced adult spawning biomass may for example, influence the numbers of juveniles available to migrate to SA.

Land tenure and conservation Shortfinned Eel is known from or moves through the following conservation reserves: Lower Glenelg River NP, Piccaninnie Ponds CP, Ewens Ponds CP, Kelly Hill CP, Coorong NP and Onkapringa River NP. It occurs on other private and public lands including drains managed by the SEWCDB.

Recovery objectives

- Gain a detailed understanding of status and biology in SA through targeted research.
- Improve access to freshwater habitat by addressing artificial barriers to fish movement and altered flow regimes.
- Undertake habitat restoration projects on strategic habitat areas.
- Link conservation of Shortfinned Eel in SA to broader management of interstate fisheries.

Conservation actions already initiated

- Initial assessments of distribution undertaken opportunistically from surveys occurring throughout much of the known range of Shortfinned Eel.
- Fishways have been installed at the Barrages and some Locks and Weirs as part of a large MDBA project aiming to restore fish passage between the sea and Hume Weir. Initial[227] and more detailed SARDI study has been initiated at these fishways.
- A fishway has recently been installed at the mouth of the River Torrens (AMLR NRM Board).
- Pilot movement studies have been undertaken in the SE[55] and at the Onkaparinga as part of an environmental flows project[155].

Required conservation actions

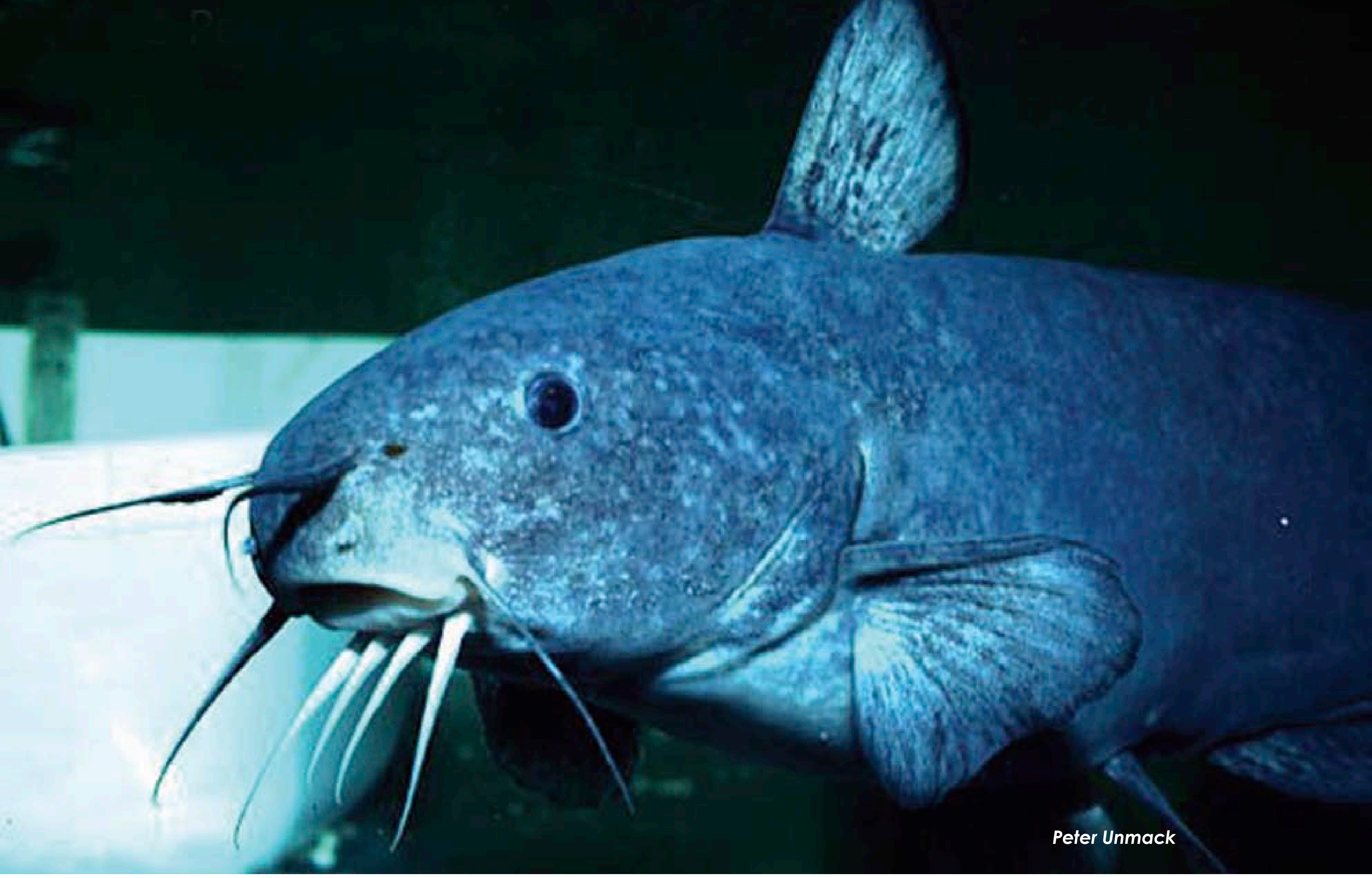
- Continue to monitor adult distribution with targeted surveys, and undertake long term movement studies at key habitats (e.g. Eight Mile Creek, Murray Mouth, SW Kangaroo Island, Onkaparinga River) to determine the scale and timing of juvenile upstream migration so that requirements for upstream colonisation can be catered for (e.g. environmental flow restoration programs).
- Assess and prioritise barriers potentially impacting migration, investigate fishway options, including studies to test their effectiveness[228].
- Undertake genetic and/or otolith studies to assess the origin of fish in the Adelaide region and whether any homing of juveniles to rearing grounds exists (and hence further identify the importance of protecting and enhancing local populations).

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, DWLBC and the KI, AMLR, SAMDB & SE NRM boards.

Organisations or individuals involved

NFA(SA), SARDI Aquatic Sciences, DEH, AMLR & SAMDB NRM boards, KI Community Education, MDBA, SA Water.



Cooper Catfish *(Neosiluroides cooperensis)*

Other common names: Cooper Creek Catfish, Cooper Creek Tandan

Conservation status *South Australia:* Endangered (RA d(ii)).
National & interstate: not listed.

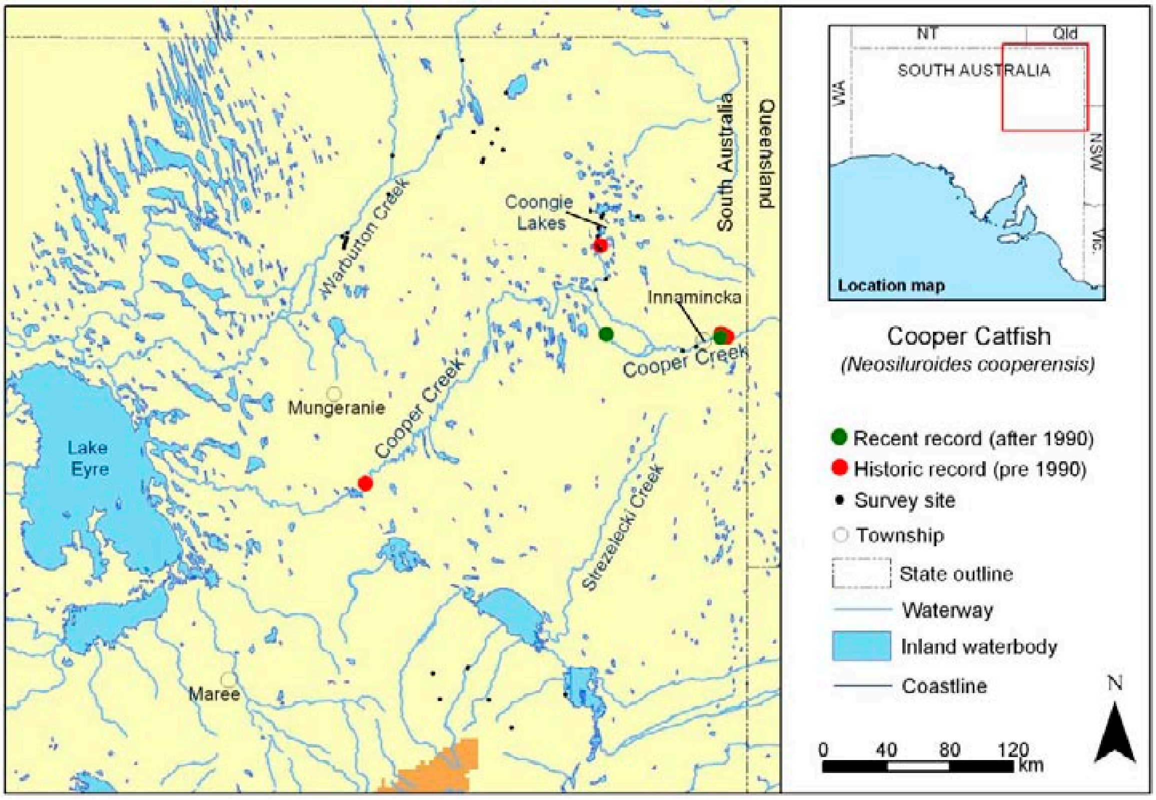
Taxonomy and identification The Cooper Catfish has a stout, tapered body and is large growing to around 60cm. Catfishes can easily be distinguished by the four pairs of barbells around their mouth and by the eel-like tail. The Cooper Catfish can be distinguished from Freshwater Catfish by the tail fin occurring only on the underside of the fish compared to extending along the dorsal surface (top) in Freshwater Catfish. It also has an underslung mouth, and a bulbous rounded head and small black eye when compared to Silver Catfish and Hyrtl's catfish.

Former distribution There are only a handful of documented records for the species in SA, and over its range which is limited to the Cooper Creek river system of the LEB. The Cooper Catfish has been historically overlooked due to rarity, a lack of research within its known range and by confusion with other co-occurring catfishes. It was first reported in the 1970s and not formally described until 1998[216,229] and hence there is little information from before this time. Most records are from Cullyamarra Waterhole, a large permanent pool on the Cooper Creek near Innamincka (1971-2003). Other records include Coongie Lakes (1988, location details may be inaccurate) and Lake Warrawarinna (1974).

Current distribution Remains poorly known, with only a few recent records from Coopers Creek – Cullyamarra Waterhole[64,230] and Embarka Waterhole[101,231]. Expected habitat includes any larger permanent waterholes along Cooper Creek proper and its North West branch which splits off and heads towards Coongie Lakes.

Biology and habitat The Cooper Creek Catfish is poorly known. The little available data suggests the species is restricted to permanent waterholes and does not disperse widely to areas inundated during flooding unlike many other species in the LEB. They are known to eat snails, and probably also prey upon other invertebrates, shrimps and fishes. No information is known on spawning times or habits, although they appear to produce a relatively low number of eggs. Juveniles have not been recorded to date and maximum age is unknown[31,64,232]

Reasons for decline and threats The current status and population trends for Cooper Catfish cannot be determined due to a current lack of information. They have a limited range which appears to include specific habitat which would become highly fragmented and contracted during the long periods without flow common to Central Australia (RA d(ii)). Cooper Creek is currently one of the very few unregulated (i.e. without major dams or extractions) river systems in SA, and any change from this status may threaten localised species like Cooper Catfish by reducing the permanency of pools and lengthening the duration between flow events. Similarly climate change may have serious implications. The potentially highly restricted and fragmented occupied habitat of Cooper Catfish leaves them susceptible to local losses and range contraction which may have occurred in the past or be occurring, but remains undetected. Potential threats include: (a) local habitat loss from pool pumping or instream works, (b) fishing pressure either direct or incidental, especially during dry periods, (c) deterioration in water quality due to pollution from human use or stock access, and (d) the introduction or establishment of alien species which may bring threats from disease, changes to aquatic food chains, competition and predation (for example Murray Cod have been reported[180] and Tilapia is an ever present threat).



Land tenure and conservation

- Most known records fall within the Innamincka Regional Reserve, with remaining sites on private grazing properties or public water reserves.

Recovery objectives

- Provide a significant increase in available knowledge of Cooper Catfish distribution and biology in SA.
- Use acquired knowledge to implement appropriate conservation initiatives as required.

Conservation actions already initiated

- Recent research sampling has occurred at several sites (potential habitat) on rivers in the SA LEB[64] although little published information exists for Cooper Creek directly.
- Recreational fishing restrictions have been introduced.

Required conservation actions

- Determine distribution through time at identified permanent pools via targeted sampling. Undertake concurrent biological studies as pilot for more in-depth investigations of spawning, recruitment and movement.
- Review information on recreational fishing catch and vulnerability to overharvest to inform fisheries management and species conservation (e.g. investigate moratoriums during drought).
- Initiate community driven programs to protect habitat at isolated populations and to help improve awareness of the presence and uniqueness of the Cooper Catfish plus threats to the species and related habitat.
- The lack of information regarding the Cooper Catfish means that the general public can help by reporting any past or present sightings (www.nativefishsa.asn.au).

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, DWLBC, SAAL NRM Board.

Organisations or individuals involved

University of Adelaide, DWLBC, PIRSA Fisheries, traditional owners.

Cullyamarra Waterhole on Cooper Creek, a large desert refuge for Cooper Catfish (Photo Dylan Sortino)

Climbing Galaxias *(Galaxias brevipinnis)*

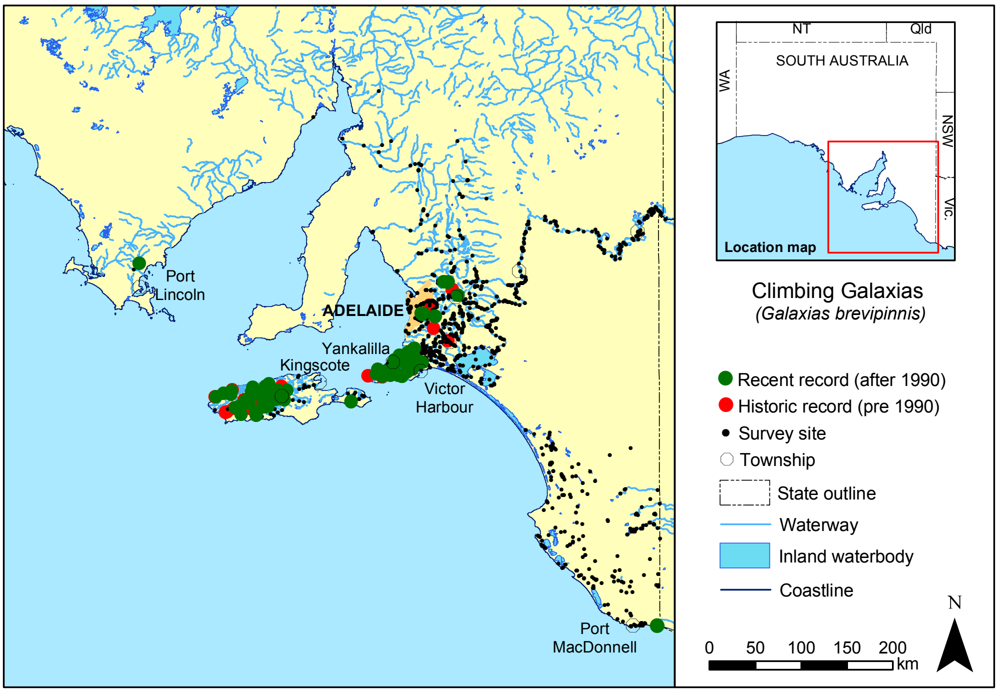
Other common names: Broadfinned Galaxias, Muddies and Slipperies.

Conservation status *South Australia:* Rare (RA b).
National & interstate: not listed.

Taxonomy and identification Climbing Galaxias is a stocky, scaleless fish reaching a maximum size of around 25cm, but is more commonly 10-18cm. Small individuals can be confused with Mountain Galaxias, but Climbing Galaxias have an undercut lower jaw, dark spot behind the gill cover, and larger pelvic and anal fins. Adults are similar to Spotted Galaxias which have jaws equal in length and uniform large spots on the body. Climbing Galaxias are often quite dark and could be confused with River Blackfish which have a long single dorsal fin and small finger-like pelvic fins. Transparent juveniles (whitebait) can be identified by the anal fin beginning behind the origin of the dorsal fin and the lack of a black band at the base of the tail.

Former distribution The historic distribution of the Climbing Galaxias is poorly documented with only sparse and patchy records held at the SA Museum. Early records include four distinct areas: (a) Adelaide region - Morialta Gully (Fourth Creek, prior to 1928), (b) Southern Fleurieu Peninsula - Myponga River and Deep Creek (1949), (c) Kangaroo Island - Cygnet River (1883, 1912) and Breakneck and Rocky rivers (1948-50), and (d) EMLR – Angas River, Strathalbyn (1914). Additional records between 1950 and the 1980s expanded known localities in three of the four regions listed above including: (a) Watts Gully (Gawler Catchment) and Jupiter Echunga Creek (Onkaparinga Catchment), (b) Cape Jervis and Hindmarsh River, and (c) the western half of Kangaroo Island including the Middle, Western, De Mole, Ravine des Casoars, South West, Stunsail Boom, Harriet and Eleanor rivers.

Current distribution Baseline sampling across much of the known range of Climbing Galaxias since the 1990s (mostly concentrated in the period 2001-2005) has revealed significant new information. A fifth distinct range section has been identified from the Tod River on Eyre Peninsula (1995)[101], with numerous new records or location confirmations from other regions: (a) Adelaide region – Victoria Creek (Gawler Catchment)[55,67,101], upper River Torrens[28], Brownhill Creek[28,101] and the Onkaparinga Catchment including Scott Creek and the main channel of the Onkaparinga River between the upper Gorge and above Mt Bold Reservoir[55,155,233], (b) most streams with permanent pools on the Southern Fleurieu[27], and (c) most streams on Western Kangaroo Island, plus another small population in Willson River (eastern KI)[26,27]. Distribution within known catchments is quite patchy, and with the exception of KI and some streams of the Southern Fleurieu, abundances are quite low (especially in the Adelaide region, with the current status on the Eyre Peninsula unknown). Although there are only a few historic records, at least two locations where the species was previously known appear to no longer support populations: Fourth Creek[28] and the EMLR, where despite extensive sampling no individuals have been found[25]. The species was likely to have been more commonly recorded in the EMLR prior to construction of the Barrages around the Murray Mouth and reductions in stream discharge. The first South East record was made in September 2007 during monitoring at the Piccaninnie Ponds fishway[169].



Biology and habitat Climbing Galaxias occur in mid to upper catchment sections in deeper, cool pools that are often spring fed and have high levels of instream cover (rock) and a good buffer of riparian (stream side) vegetation (shade, edge cover and source of food). They also move into flowing areas between pools (riffles) when this habitat is available. Environmental flows appear important in maintaining the cool and oxygenated required habitat, and also to aid dispersal of the species within systems. Climbing Galaxias is generally thought to be a diadromous species where, after spawning in autumn and winter (spawning site documented as streamside vegetation above the normal water levels in Victorian streams[234]), larvae are swept out to sea where they develop for several months before returning to freshwater in spring as small transparent juveniles (whitebait). This lifecycle has yet to be confirmed in SA, and may occur wholly within some stream catchments, especially for a few populations landlocked above reservoirs (e.g. Mt Bold, Middle River, above Kangaroo Creek Reservoir). Population demographics and age of Climbing Galaxias is little known, and diet from studies outside SA is known to be opportunistic including aquatic and terrestrial invertebrates. Their large downward facing pectoral and pelvic fins combined with a flattened body assist the Climbing Galaxias to move through streams and negotiate waterfalls and instream structures. Its distribution and abundance appears to be significantly negatively influenced by the presence of predatory Brown and Rainbow Trout as they share similar habitat requirements in small streams[26,27,28,76,87].

Reasons for decline and threats Climbing Galaxias are likely to be influenced by altered catchment hydrology affecting the permanency and quality of pools (e.g. loss of spring feeding and delayed onset of seasonal flows due to water abstraction, which is likely to become even more pronounced with climate change), and habitat change especially land clearing and loss of stream side vegetation through stock access. Major barriers or disruptions to dispersal such as reservoirs, vertical weirs, road culverts and dry lower stream reaches are likely to impede the colonisation of juveniles and cause aggregations which are then susceptible to other impacts like predation and exposure to poor conditions. Competition for space and food, plus predation from trout (and also possibly Redfin) is a known threat in SA. Some catchments in the Adelaide region have lost connectivity to the sea and Climbing Galaxias must now rely solely on variable conditions in reservoirs to survive (and hence may now be fragmented). Fish from eastern Australia translocated into the MDB are currently invading downstream[89] and may pose a risk of genetic pollution to SA stocks.

There is little evidence for recent declines of Climbing Galaxias in SA although this is likely to be masked by a lack of previous data. While a large portion of the species' extent of occurrence seems relatively secure in less modified streams of the Southern Fleurieu and Kangaroo Island, this situation could easily change with increasing water resource development or changes in landuse. Indeed some smaller modified catchments and/or areas with trout have restricted distributions compared to that which would have naturally occurred. Further, based on: (a) a deterioration in the extent and quality of suitable adult habitat, (b) some presumed local extinctions from the few populations that were historically documented, and (c) the seemingly precarious position (low abundance and extent) of some populations especially in the Adelaide region and Eyre Peninsula, the abundance of Climbing Galaxias in >50% of known habitat is predicted to have declined significantly and both abundance and area of occupancy is predicted to continue declining from existing and potential threats (RA b).

Land tenure and conservation Known conservation reserves where Climbing Galaxias occurs include: Para Wirra RP, Morialta CP (historic record), Brownhill Creek RP, Scott Creek CP, Onkaparinga NP, Deep Creek CP, Western River WA, Ravine des Casoars WA, Flinders Chase NP, Kelly Hill CP and Seddon CP. The species also occurs on other land managed by SA Water and Forestry SA, council reserves (e.g. Cox Creek at Bridgewater, Hindmarsh Falls) and private property including some properties managed for conservation (e.g. Bungala and Carrickalinga creeks).

Recovery objectives

- Improve knowledge of Climbing Galaxias biology and fine scale distribution in SA.
- Protect and restore environmental conditions including water regimes for maintaining habitat, spawning and migration.
- Protect terrestrial vegetation buffers around known populations and undertake targeted stream side restoration projects extending from core habitats.
- Provide appropriate management and control of introduced fish species.
- Improve access into and within freshwater habitat by assessing and addressing where appropriate artificial barriers to fish movement

Conservation actions already initiated

- Baseline surveys conducted in a large portion of the known range of Climbing Galaxias, providing a significant increase in available knowledge on the species.
- Climbing Galaxias has a reasonable representation in the State Reserve system and on a few properties managed for conservation.
- Fishways have been installed at the Murray Mouth region and at the River Torrens mouth.

Required conservation actions

- Initiate long-term monitoring programs and specific biological studies to examine the life history of Climbing Galaxias across different regions and habitats, especially focused on spawning, recruitment and movement in relation to flow, introduced predators and climate change.
- There is a strong need for fine scale mapping of distribution to better understand the status of Climbing Galaxias in the Eyre Peninsula and Adelaide regions.
- Secure key populations with immediate conservation management such as habitat restoration, managing introduced fishes, addressing barriers to fish passage and implementing environmental flow programs (e.g. Brownhill Creek, upper River Torrens, Tod River, Willson River).
- The interesting anatomy and biology, requirement for good stream side vegetation, and threatened status of the Climbing Galaxias make the species a good icon for the protection and restoration of waterways in SA (e.g. Landcare Programs), especially the Southern Fleurieu and KI regions – this needs to be fostered through improved education and natural resource management within government and community groups.

Organisations responsible for conservation of species

DEH, PIRSA Fisheries, DWLBC, Forestry SA, and the EP, AMLR, KI & SAMDB NRM boards.

Organisations or individuals involved

NFA(SA), SARDI Aquatic Sciences, DWLBC, AMLR, KI & SAMDB NRM boards, KI Community Education, Bungala Restoration Committee, and Landcare groups from the Southern Fleurieu.

2.6. **NON LISTED SPECIES**

should not necessarily be
considered secure

The future of the 26 native fishes not included on the conservation list should not necessarily be considered secure. Some species may be in historic or recent decline but with trends masked by a common lack of information on distribution and abundance or other issues such as inadequate taxonomy where additional cryptic species could occur. Several 'near threatened' species which narrowly missed qualifying for the conservation list are prime candidates for proactive approaches to secure populations before they indeed become threatened (Table 2). The near threatened species include several from the River Murray system which are suspected to have declined (eg. Figure 12), and also some little known fishes from the Lake Eyre Basin. Species have also been considered based on the warning signs of similar members of their Family being threatened.

Left to right. Northwest Glassfish, Lagoon Goby and Murray Rainbowfish

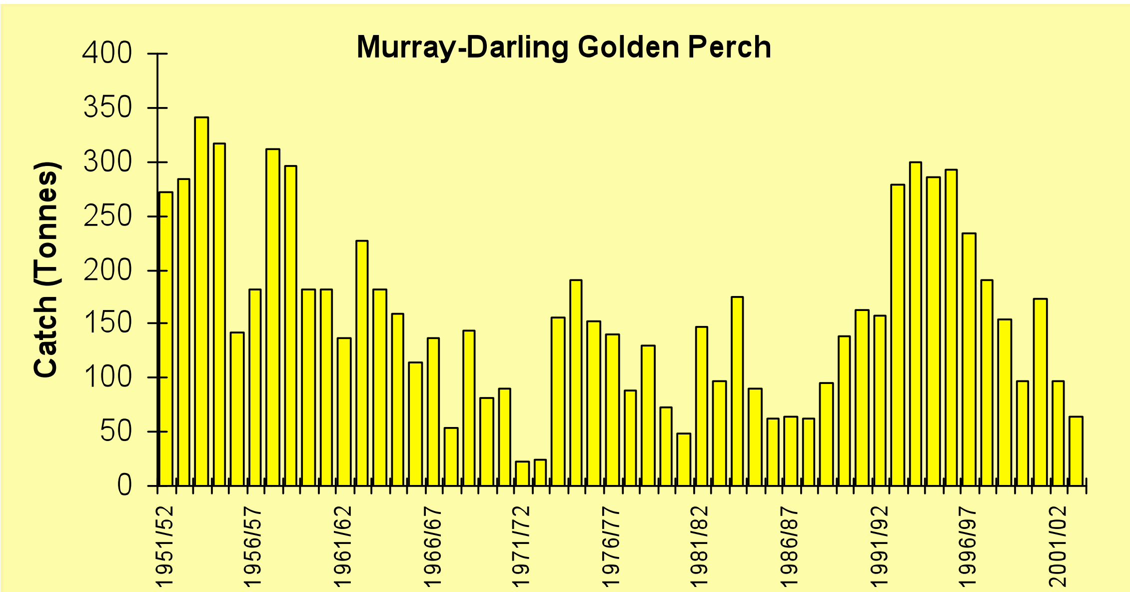


Figure 12. Catch data for Murray-Darling Golden Perch from the SA River Murray Commercial Fishery (between 1951-2003) based on SA Fisheries Statistics[163,165,189,235].

Table 2. List of ‘near threatened’ freshwater fishes (unofficial category) for South Australia.

Family	Species	Common name	Conservation concerns
Galaxiidae	*Galaxias maculates*	Common galaxias	Widespread in coastal systems, but potential to be listed due to due to blocked access and deterioration of the Lower Lakes.
Melanotaeniidae	*Melanotaenia fluviatilis*	Murray Rainbowfish	Patchy distribution, minor decrease in extent of occurrence (Finniss River), possibly subject to major fluctuations in abundance.
Atherinidae	*Craterocephalus stercusmuscarum fulvus*	Unspecked Hardyhead	Uncommon in 1980s, appears to have increased in recent years, but could fluctuate rapidly.
Ambassidae	*Ambassis* sp.	Northwest Glassfish	Poorly known species, with a limited distribution. Related species is presumed extinct in the SAMDB.
Percichthyidae	*Macquaria ambigua ambigua*	Murray-Darling Golden Perch	Populations fluctuate but seem secure (Fig. 10), however susceptible to further changes (degradation) in the condition of River Murray, especially reduced flooding and with loss of Lower Lakes habitat. Most other members of the Family are threatened.
	Macquaria sp.	Lake Eyre Golden Perch	Vulnerable to over harvest and habitat change depleting refuge populations in isolated pools during dry periods. Most other members of the Family are threatened.
Terapontidae	*Scortum barcoo*	Barcoo Grunter	Poorly known species, with a limited distribution. May be susceptible to over harvest and habitat change depleting refuge populations during dry periods.
Eleotridae	*Philypnodon macrostomus*	Dwarf Flathead Gudgeon	A patchy distribution, generally in low abundance. May have declined concurrent to altered conditions in the River Murray. Small populations in MLR streams susceptible to local extinction.
	Hypseleotris sp. 3	Murray-Darling Carp Gudgeon	Poorly known due to taxonomic confusion, initial SA Museum research suggest a patchy distribution that may be susceptible to further changes (degradation) in the condition of River Murray wetlands and EMLR streams.
	Hypseleotris klunzingeri	Western Carp Gudgeon	Poorly known due to taxonomic confusion. Initial SA Museum research suggests a patchy distribution that may be susceptible to further changes (degradation) in the condition of the River Murray.
Gobiidae	*Tasmanogobius lasti*	Lagoon Goby	Limited number of known locations within a limited area of occupancy.

Section 3 Overview of potential threats

Freshwater systems require special consideration in regards to threats, as it is not only local and obvious changes to habitat and species introductions that can cause impacts. The fluid nature of water means that freshwater habitats are often connected within broader networks (e.g. streams) and with terrestrial habitat. As a result threats from one area can be transmitted elsewhere, especially downstream, such that the cumulative result of practices in or around waterways or catchments can impact aquatic habitats in an area (e.g. Figure 13).

A range of documents provide background on threats to freshwater fishes and habitats in different parts of Australia[12,22,31,74,87,236,237]. The intention of this section is to summarise and develop a list of potential threats relevant to South Australia (Table 3), reinforced with local examples and as a summation from individual species accounts. While a list of threat categories is provided, a particular process rarely acts on its own and will likely have consequences of species decline interlinked with other threats overlapping on different spatial and time scales. For example habitat degradation, introduced species and local pollution would become more severe with loss of flow and during warmer periods. Some threats may have obvious and immediate impacts, while others take time to become evident (i.e. lag time) or are masked until a particular threshold is reached. The list of threats is not necessarily reflective of an order of severity. However, hydrological alteration is considered the primary or underlying threat to fish habitat and communities across South Australia.

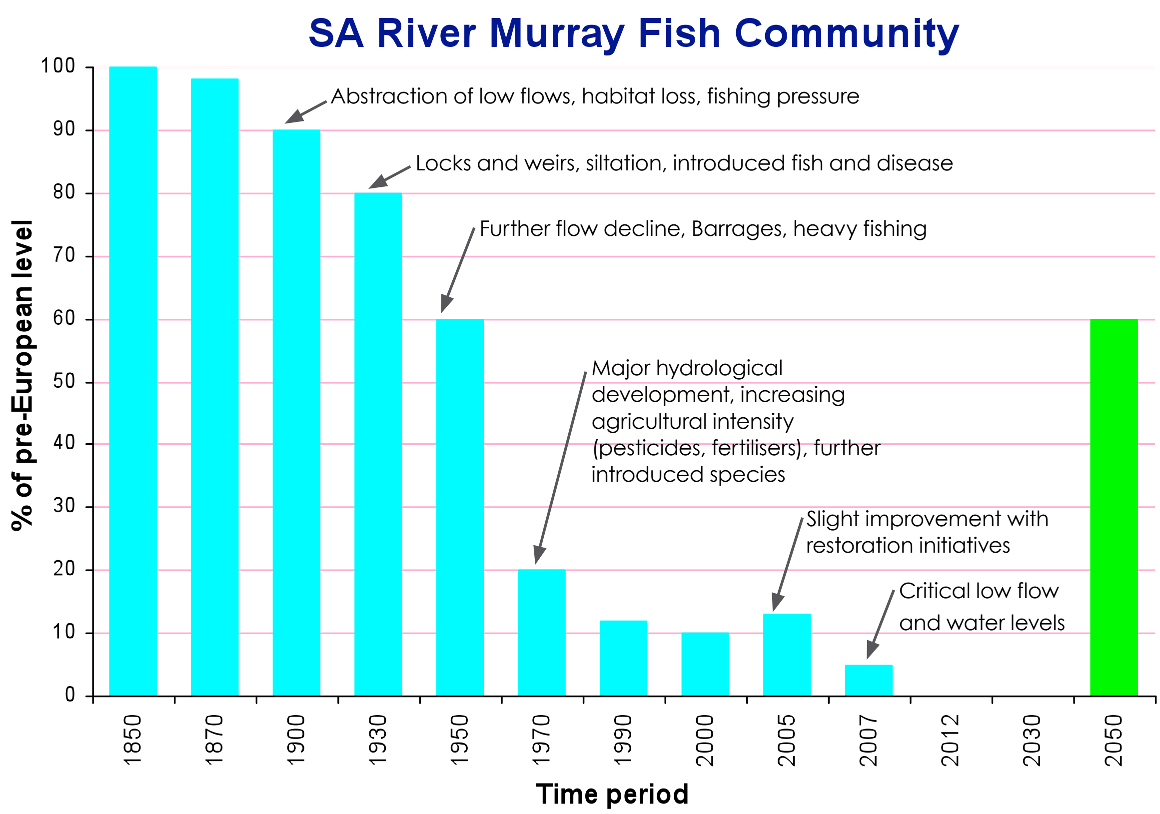


Figure 13. Decline of the SA River Murray fish community since European settlement. The model is developed after the MDBA Native Fish Strategy which considered decline in species diversity and abundance of native fish to have reached 10% of pre-European levels for the MDB by 2003. The green bar represents the target for restoration under the same strategy[236].

Table 3. Potential threats to freshwater fishes in South Australia.

Threat category	Examples causes (processes)
1. Hydrological (flow) alteration	
a) Loss of water from a system/habitat Reservoirs,	Farm dams, pumping surface and groundwater, drainage, climate change, plantations
b) Altered flow seasonality and variability	Provision for irrigation (i.e. seasonal reversal), dams (e.g. delay the onset of flow periods), land clearance, climate change
2. Habitat loss and degradation	
a) Removal and alteration of habitat (broad)	Reduced flow, drainage, damming, channelisation, river engineering, levees (floodplain loss), urbanisation
b) Removal and damage of riparian vegetation	Land clearance, stock access, urban/rural development
c) Loss of instream cover	Desnagging, dredging, siltation & overgrazing, altered hydrology, removal of aquatic vegetation, exotic plants, algal growth (nutrients)
d) Artificial barriers to fish movement and gene flow	Physical structures (e.g. weirs, dam walls, road culverts), biological barriers (e.g. loss of intervening habitat, predators, water quality, high velocity)
3. Lowered water quality	
a) Fish kills	Toxic substances (e.g. chemicals & pollutants), reduced flow, eutrophication, suspended sediments, temperature
b) Sub-lethal responses (e.g. reduced spawning or feeding ability)	Salinity, reduced dissolved oxygen, altered temperature (e.g. thermal pollution, loss of flow and shade, climate change)
c) Reduced habitat quality	Sedimentation, nutrient input (algal growth)
4. Alien species & stocking (biological pollution)	
a) Biological impacts (competition, predation, aggression, habitat modification)	Introduction and/or establishment of exotic and translocated native species
b) Transfer of disease and parasites	Introduction of exotic and translocated native species, discarded aquarium fishes and plants, inter-basin transfer and movement of materials, equipment and vegetation
c) Genetic impacts	Inappropriate translocation and stockings (e.g. mass releases, hybridisation)
5. Exploitation or use	
a) Reduced abundance and reproductive potential	Past and present fishing pressure and aquarium trade (recreational, commercial and illegal)
b) Trophic cascades and altered states	Selective removal of a keystone or prey species.
6. Population decline	
a) Loss of genetic diversity & reduced ability to adapt to change	Previous unnatural range contractions, ongoing population bottlenecks (e.g. exotic predatory species), fragmentation
b) Restricted range and/or small populations	Restricted range and/or small populations Vulnerable to lag effects, new threats, change and stochastic events, genetic problems (e.g. inbreeding)
c) Failure to include fishes in management and planning	Lack of: knowledge, monitoring/research, awareness (government & community) and appropriate legislation
7. Climate change	
a) Change in habitat and flow	Temperature increases, decreased and altered rainfall

3.1. HYDROLOGICAL (FLOW) ALTERATION

Hydrology (processes involving water) is the main driver to the presence, nature and dynamics of aquatic habitats. The hydrology of different habitat types or systems can vary considerably, depending on the source of water, position in a landscape and local climate and geology. Sources of water include (a) local rainfall and runoff, (b) linear or longitudinal flows (e.g. stream flow from headwaters to the sea), (c) lateral (outward) linkages such as the inundation of edge, wetland or floodplain habitat, and (d) vertical interactions with groundwater. All of these linkages can vary in their frequency, magnitude, duration, timing and rate of change to be temporally variable. Aquatic biota may also rely on particular aspects like flow for breeding, movement and survival, or have innate responses to components of natural water regimes such as flooding and disturbance[238,239].

Given the generally warm climate combined with low to moderate or variable rainfall in South Australia, the presence and dynamics of water is considered of primary importance in maintaining habitats for fishes. Many important fish habitats or critical summer refuges would simply not exist if not for river flow from higher rainfall areas or expression from groundwater sources (e.g. springs). Hydrological alterations relate to two main problems: loss of water and altered flow patterns.

(A) LOSS OF WATER Loss of water can result from any practice which removes water directly or impacts a source of water and thus eliminates or alters habitat at large and/or micro scales (e.g. the drying of a stream reach and loss of pools). A significant problem occurs with drying of habitat for small populations, and is most critical when water is already scarce during dry seasons or extended periods where human use tends to exacerbate already low levels. For example recent (last 10 years) widespread drying of once permanent fish habitat in streams and springs has been witnessed in areas of the Eastern Mount Lofty Ranges[25,51]. The recent prolonged period of low rainfall has also highlighted critical deficiencies in water management to maintain fish habitat in the Lower Murray[114,129] and South East[94].

In addition to drying of habitat, reduced flow volume can lead to reduced flushing of salts, altered geomorphology (e.g. reduction in channel depth, encroachment of reeds), reduced aquifer recharge and direct ecological implications. Loss of water can also reduce the magnitude of particular flow events limiting the size of floods and the amount of wetted habitat. For example, floods on the River Murray are now much fewer in frequency and smaller than which occurred naturally[185].

Direct removal can include:

- Drainage and conversion to alternative uses is a special problem for wetlands and floodplains either altering hydrology by limiting or removing wetting (see examples in Habitat loss).
- Deliberate drying of wetlands for management or during works along or in streams aquatic habitat (fish need water).
- Direct pumping from aquatic habitat impacts overall water availability and can increase the risks of habitat drying eliminating local flows and habitat components (i.e. lower water levels) or lead to total habitat loss. Again this can be an especial problem in dry periods and for localised populations.

Loss of water sources (linkages) can be caused by:

- Large dams and reservoirs capture water and limit the volume received by downstream environments (and alter the nature of flows and habitat downstream –see altered variability). Large dams impact most major river and stream systems in South Australia with the current exception being the unregulated Lake Eyre Basin. The River Murray now only receives one third of its natural flow volume into South Australia due to upstream dams and diversions (e.g. irrigation[186,241])and there is an extensive water supply network in the Western Mount Lofty Ranges involving numerous reservoirs including Myponga, Millbrook, Warren, South Para, Mt Bold, Kangaroo Creek and Little Para.
- Farm dams can have local and cumulative impacts within catchments contributing to overall loss of water from a system through capturing (abstracting) surface water. For example there are moderate to very high levels of farm dams in most areas of the Mount Lofty Ranges, with this form of water resource development escalating rapidly (e.g. doubling of storage volume in some catchments) in the last 10-15 years. In the Marne River Catchment for example, more than 640 dams capture on average

20% of water destined for stream flow, with this percentage of capture much higher in drier years and at certain times of year like summer when important small flows are virtually eliminated[149.] Similarly farm dams have been calculated to reduce the median summer flows, important for maintaining habitat presence and condition (e.g. cool oxygenated pools in Mediterranean type climates), by up to 72% in some years[150] (see also flow seasonality).

- Groundwater extraction is an underestimated and latent problem because groundwater sources (aquifers) are not directly obvious and in many cases not well known. Consumptive use of groundwater may lead to one or a combination of rapid extermination of small reserves, interception of flows destined for other areas or broader lowering of water tables, all of which may lead to reduction or loss of groundwater expression to the surface (e.g. flow discharging from springs) or lowered surface water levels where the two are interconnected. Because groundwater processes are often complex interactions between historic influences and surface water recharge, such processes may operate over long timelines. There is a particular danger of lag effects where impacts may not be evident for some time, nor be readily reversible once problems are evident. Groundwater is often relied on by aquatic biota during dry periods or in dry regions (e.g. desert mound springs, core refuges in the Mount Lofty Ranges and unique spring fed habitats in the South East) and there is thus a high potential for conflict with human consumptive use.
- Plantations are an emerging issue of water use due to the high density of trees (pine or Tasmanian Bluegum) and high water demands by mature trees especially in small catchments/waterways and areas of groundwater recharge. Water loss occurs through two processes: (1) plantations can act as an umbrella capturing rainfall and reducing aquifer recharge or runoff into streams and wetlands depending on the scale of the plantation relative to catchment area, and (2) plantations can be water pumps that use groundwater with subsequent lowering of groundwater levels (e.g. by as much as 9-10m depending on rainfall, plantation location and soil type). There is also potential habitat and water quality issues from plantation processes including erosion, runoff and chemical use. Leaf litter from plantations may have detrimental effects on water quality and in-stream processes when it enters waterways.
- Climate change will result in altered patterns of rainfall, runoff and drought (see later).

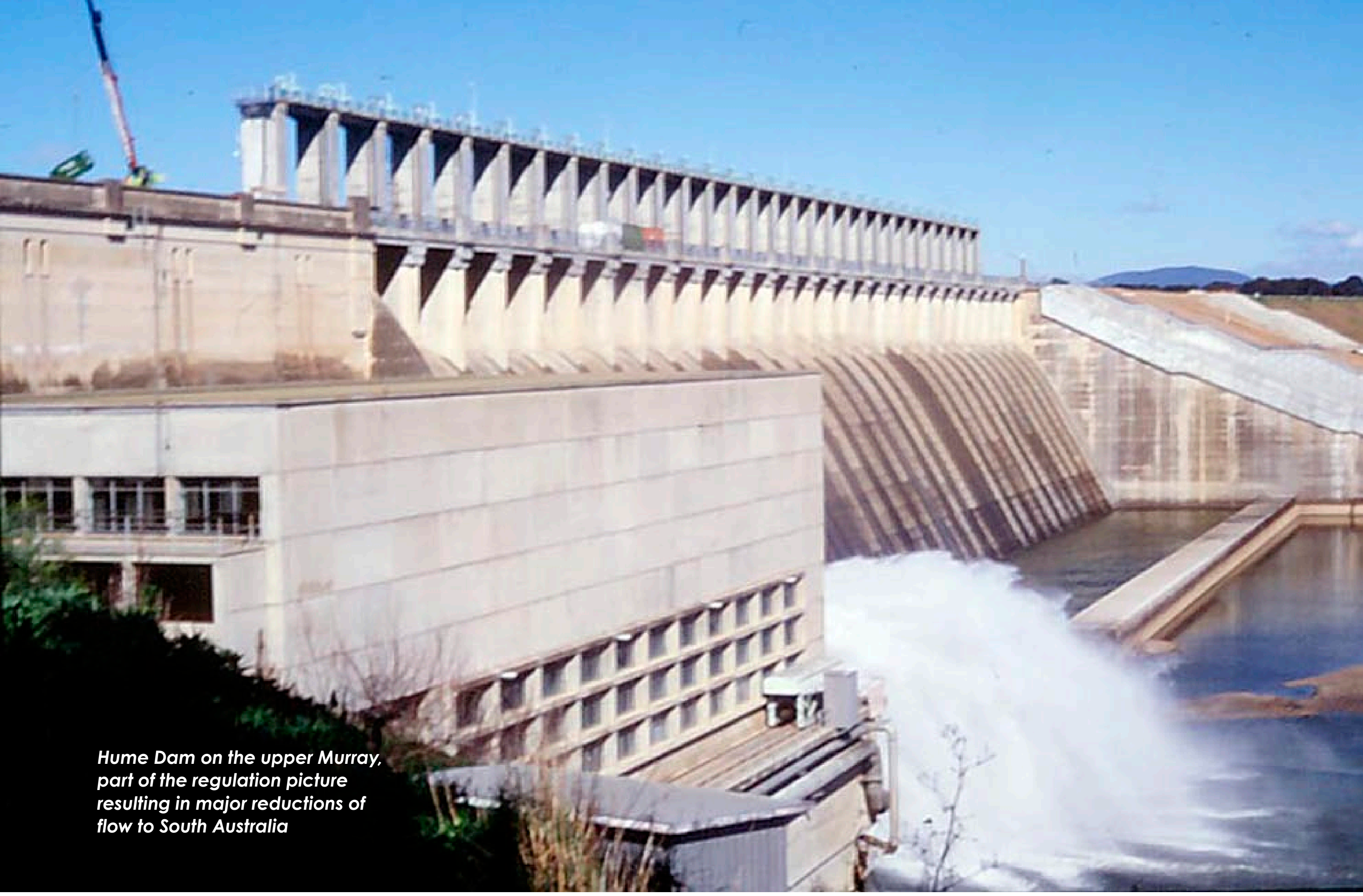
(B) ALTERED FLOW PATTERNS Altered flow patterns are interlinked with water loss, but involve more subtle hydrological alterations which change the nature of flow. Alterations of flow patterns can affect flow seasonality or timing and variability. This in turn can affect habitat suitability and directly interfere with species lifecycles.

Flow seasonality refers to the time of year flows occur, and local animals and plants are often tuned to natural cycles by having seasonal cues for breeding and movement. Alterations in flow seasonality may mean that flows start much later and do not link with appropriate times for fish spawning and movement for example, and lead to longer periods of exposure to low water levels and reduced water quality (e.g. temperature, dissolved oxygen, salt, pollutants). Altered timing of flow events (e.g. a shift from winter dominated flow and floods may also be out of synchrony with natural cycles or biological response impacting fish breeding and survival.

Natural variability in flows and water levels over time forms a part of ecosystem function and is thought to promote higher native species diversity. Shifts away from natural rates of variation can thus be a threat. Flows and flooding generates physical disturbance or fluctuation in habitats which can be important for ecological function, and involve processes such as flushing sediment and cleaning underwater surfaces, preventing the encroachment of reeds and diluting salts. Most native species have adapted to natural variability (e.g. they move outward into riparian vegetation during floods, utilise different habitat at different times of the year) while some exotic species like Gambusia and Carp are discouraged by variability or alternately favoured by stable conditions. Rapid water level fluctuations could lead to stranding of eggs or larval stages and unreliable habitat or cover for adults. At the other extreme stable environments might encourage or favour habitat generalists and invasive species over rare species[240].

Major causes of altered flow patterns include:

- Regulation (weirs, barrages, large dams/reservoirs) provide the plethora of impacts relating to altered flow patterns. Flow releases or overflow from large storages is unpredictable, commonly occurs during unnatural times when irrigation demand is high (e.g. summer along the River Murray), and is often 'all or nothing' where large bursts of water suddenly occur as an extreme disturbance (e.g. reservoir overflow). The series of Locks and Weirs along the River Murray and Barrages maintain highly stable weir pools as opposed to river habitat.
- Farm dams can have a large impact on seasonality by holding back or capturing runoff at the break or end of seasons and thus delaying flows until dams can overflow.
- Instream works such as dredging, modifications of river banks, road crossing and other structures, can drop water levels rapidly[57] thus stranding eggs or juvenile stages and removing access to important types of habitat (e.g. for spawning).
- Climate change may lead to altered rainfall patterns and timing reducing the onset of flow and altering the timing and frequency of larger flow events for which biota might be unaccustomed to (see later).
- Direct pumping (bottom left of photo) during a dry period, combined with reduced environmental flows from abstraction in the catchment led to the drying for the first time of this pool on Dawson Creek (2004) in the Mount Lofty Ranges, previous habitat of threatened Southern Pygmy Perch and Mountain Galaxias.



Hume Dam on the upper Murray, part of the regulation picture resulting in major reductions of flow to South Australia

Direct pumping during a dry period, combined with reduced environmental flows from abstraction in the catchment led to the drying for the first time of this pool on Dawson Creek (2004) in the Mount Lofty Ranges, previous habitat of threatened Southern Pygmy Perch and Mountain Galaxias

3.2. **HABITAT LOSS AND DEGRADATION**

Fish habitat can range from broad scale suitability (e.g. stream, river, wetland) to local or microhabitat requirements. Different species require habitat for a variety of reasons including:

- Cover from predators and competitors.
- Shelter from environmental conditions such as high flow velocity.
- Spawning structure or sites (e.g. hollows, submerged vegetation, gravel benches).
- Shade to maintain cool temperatures over warm periods.
- Food sources (e.g. aquatic and terrestrial invertebrates).

Cover or habitat components include submerged structures such as rocks, snags (woody debris) and aquatic plants, fringing or emergent vegetation such as reeds and sedges, and overhanging terrestrial vegetation.

Some species have more specialised requirements or reliance on cover than others, with differences also within a species at different stages of their life cycle (juveniles and small species normally need higher densities of cover). Habitat requirements can vary through time depending on different water levels and types of flow, especially during floods when normally dry habitats are utilised to escape dislodgment and unfavourable conditions (e.g. cover on river banks, floodplains).

Considering the different uses and roles of habitat, then not surprisingly habitat loss and degradation can take many forms and vary greatly in impact severity. Impacts can be obvious from processes which visibly directly alter habitat, but other changes may have more subtle impacts on the structure and connectivity of habitats or alter conditions relied upon by fishes.

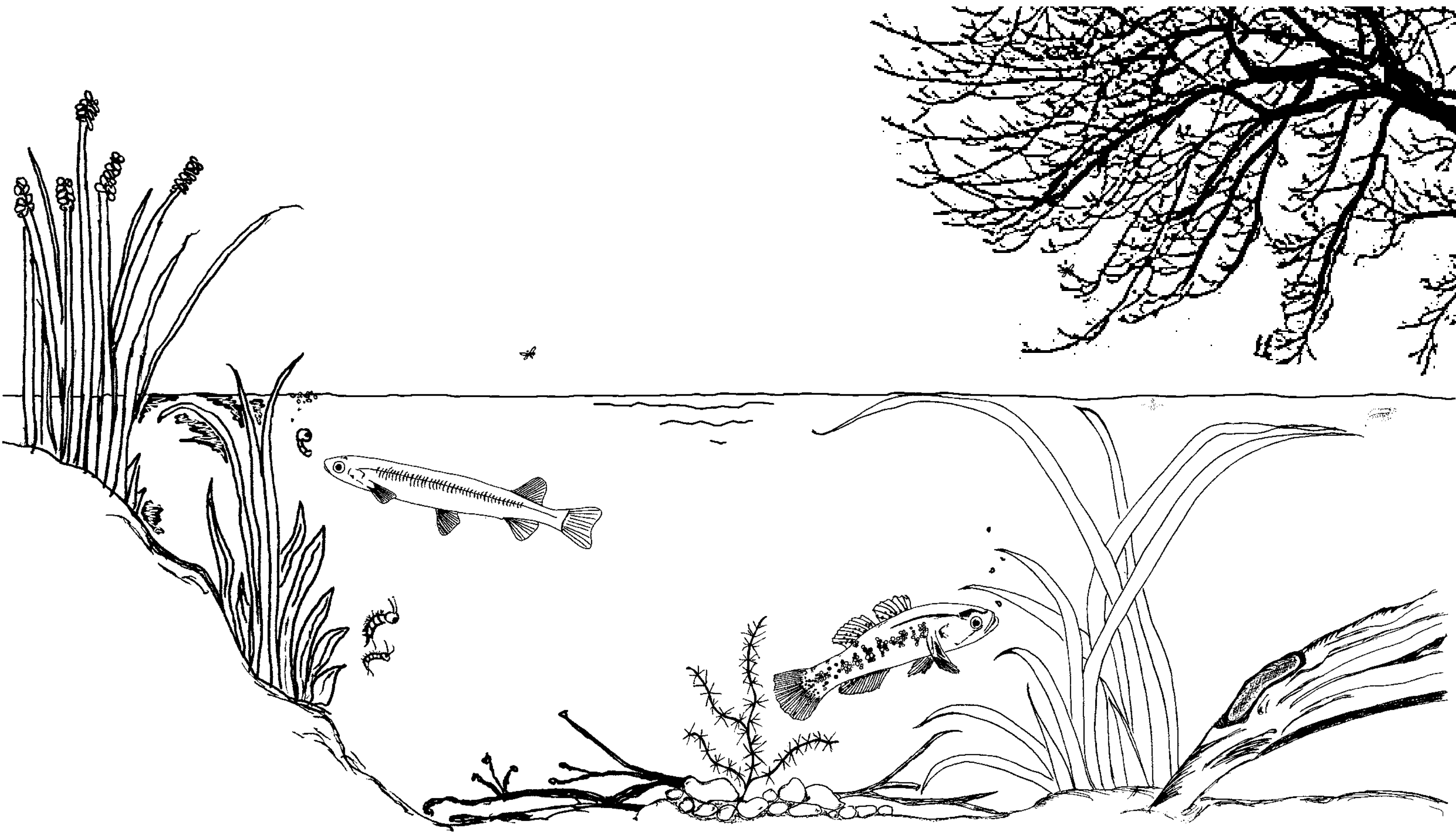


Diagram depicting different types of fish habitat: emergent and submerged aquatic vegetation, large and small woody debris (snags) and overhanging vegetation (shade, input of organic matter, future snags and source of terrestrial invertebrates) (B. McKenzie)

(A) REMOVAL AND ALTERATION OF HABITAT (BROAD) Much broad scale change to river systems has occurred since the advent of European settlement, whereby large areas of catchments have been progressively cleared. Subsequent changes to the nature of flow and sediment inputs have occurred with stream channel erosion, incision and siltation and are large scale issues transforming habitats in the Mount Lofty Ranges for example.

A change in landuse to urban and semi-urban environments transfers parts of catchments to artificial structure that changes the character and nature of waterways. Extensive changes have occurred in the Adelaide region (Figure 14), as well as other regional centres.

Other landscape level changes include drainage and river transformation.

Prime examples include:

- A comprehensive and still expanding network of drains in the South East which has resulted in the loss of over 90% of wetland habitats and alteration of most others[23,203,204].
- The loss (>40% total) or alteration (at least 50% or remaining) of a large percentage of swamps on the Fleurieu Peninsula (e.g. conversion to pasture)[242].
- Levees along the River Murray between Wellington and Mannum which have transformed (removed most swamp and wetland habitats.

Many aspects of habitat change can be related to altered hydrology (see 3.1) such as stream drying, loss of flooding and access to fringing and wetland habitats.

(B) RIPARIAN VEGETATION Fringing terrestrial vegetation such as trees, shrubs and fringing water plants (e.g. sedges and rushes) can provide the base of habitat and food chains via the input of woody debris and living structure at both varying water levels. Hence buffers around streams and wetlands are important. Vegetation can also influence physical conditions such as water quality via shade (cooler temperatures in summer) and nutrient uptake or trapping silts.

Unrestricted stock access, land clearance and modifications for rural and urban development can significantly alter stream habitats[22,243]. During dry periods, stock can reduce cover and also affect water quality (especially oxygen levels) through wading and waste. In addition to the direct loss of cover, loss of riparian and terrestrial vegetation can also alter the structure or geomorphology of areas. For example trampled stream edges are unstable and more easily eroded leading to channelised environments with high velocity and little cover. Stock access to aquatic habitats is still common place in most areas of South Australia and heavy unregulated access is particularly likely to impact small sensitive habitats. Many urban habitats are stripped of riparian vegetation when they are transformed or channelised, especially in the Adelaide region (Torrens and Patawalonga catchments).

(C) LOSS OF INSTREAM COVER A decrease in the amount of instream cover available to fishes is often related to the level of land clearing and local riparian clearance (i.e. decreased input of woody debris). For example an extensive program was undertaken along the River Murray to remove large woody debris (snags) and thus improve navigation conditions. Siltation (build up of fine silts and sand) can smother underwater surfaces reducing physical cover such as rocks and suppressing plant growth. Similarly, leaf fall from exotic trees and high nutrient levels, encouraging growth of filamentous algae or dense floating plants (e.g. Duck Weed) which can also smother underwater surfaces.

Some physical activities are extremely disturbing to instream cover such as construction of road crossings, removal of aquatic vegetation undertaken for improved recreation or industry, instream dams or other works, dredging, and stream side development (e.g. infilling with dirt and rubbish). In the South East, the maintenance of natural streams as drains provides regular physical disturbance to stream beds, vegetation and banks[57]. Heavy stock access could also disturb instream cover, especially with large hoofed animals in small or fragile environments. The highest likelihood of impact from the loss of instream cover is in areas where sedentary and sensitive native fish occur, or for species that have particular requirements for cover such as hollows for spawning and guarding eggs.

Unrestricted stock access can reduce instream and bank cover and lead to water quality problems, especially during dry periods (photo taken in the Lake Eyre Basin)

(D) BARRIERS TO MOVEMENT AND MIGRATION Fish need to move between habitat sections for a variety of reasons and at a variety of scales. Large scale movements are undertaken by diadromous species, which require access between freshwater and estuarine/marine habitats at particular life stages (see Figure 15), and potamodromous species, which undertake large movements within freshwater. For example Murray-Darling Golden Perch tagged in South Australia around Renmark in the 1970s moved hundreds and even thousands of kilometres upstream and downstream during periods of river flow[162]. Other species may make smaller unidirectional or return movements for events such as spawning and feeding to particular habitats (e.g. floodplains, stream headwaters) or dispersal and recolonisation from refuges as part of regional populations. Even tiny species such as Carp Gudgeons and Dwarf Galaxias are known to move upstream and between wetlands[23,25,202].

Artificial barriers to fish movement are common in parts of South Australia and examples include:

- Reservoirs, dams and other major instream structures (e.g. barrages, locks and weirs).
- Instream farm dams or other structures.
- Smaller weirs including flow gauging stations.
- Levees (wetlands and floodplains).
- Elevated roads, culverts and crossings.
- Behavioural barriers such as darkened areas or inappropriate habitat (from habitat change).
- Physiological barrier such as high velocity flow or poor water quality areas.
- Biological pollution – presence of introduced predatory or aggressive fish.

In addition to direct blockage of upstream or lateral movement, fish concentrated below barriers are exposed to predators, stress and disease. Downstream passage can also be affected or result in high mortalities associated with falls over spillways or through highly turbulent areas.

While in the main artificial barriers to dispersal have a negative effect, it is worth noting that some fauna rely on barriers to escape other threats such as predatory introduced fish. Natural barriers provide long-term isolation for some species free from competition with both native and introduced species and introduction of fish into such areas can have impact on species biology, genetics and survival.

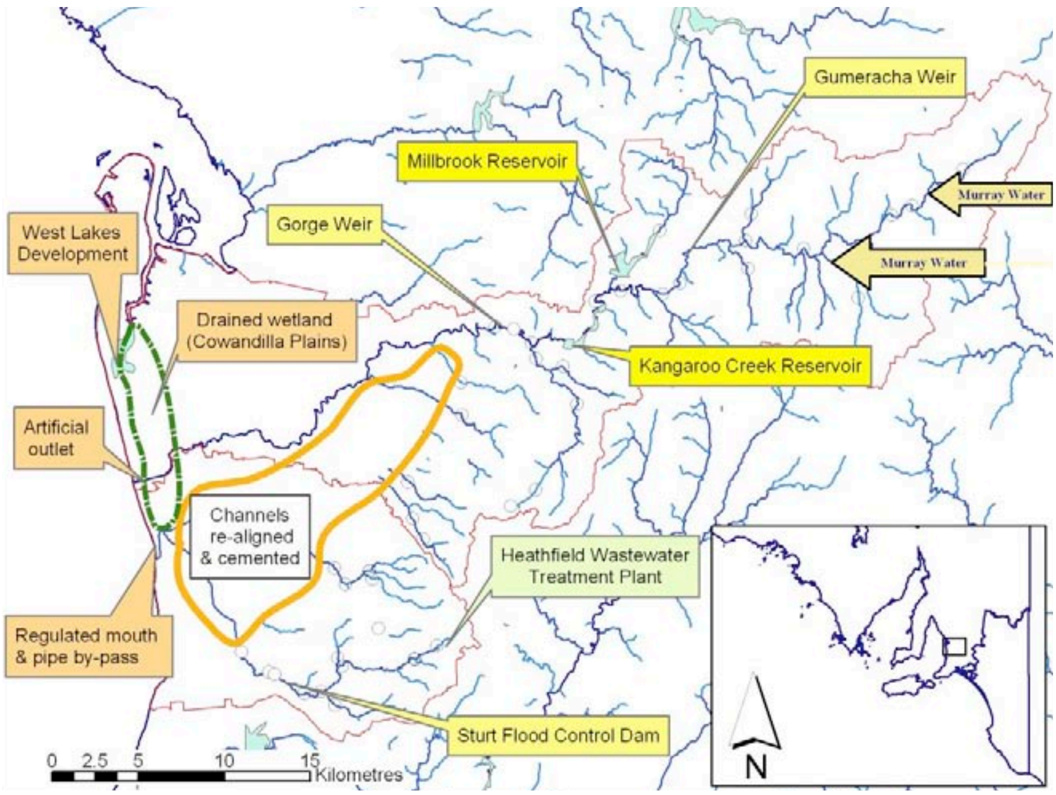
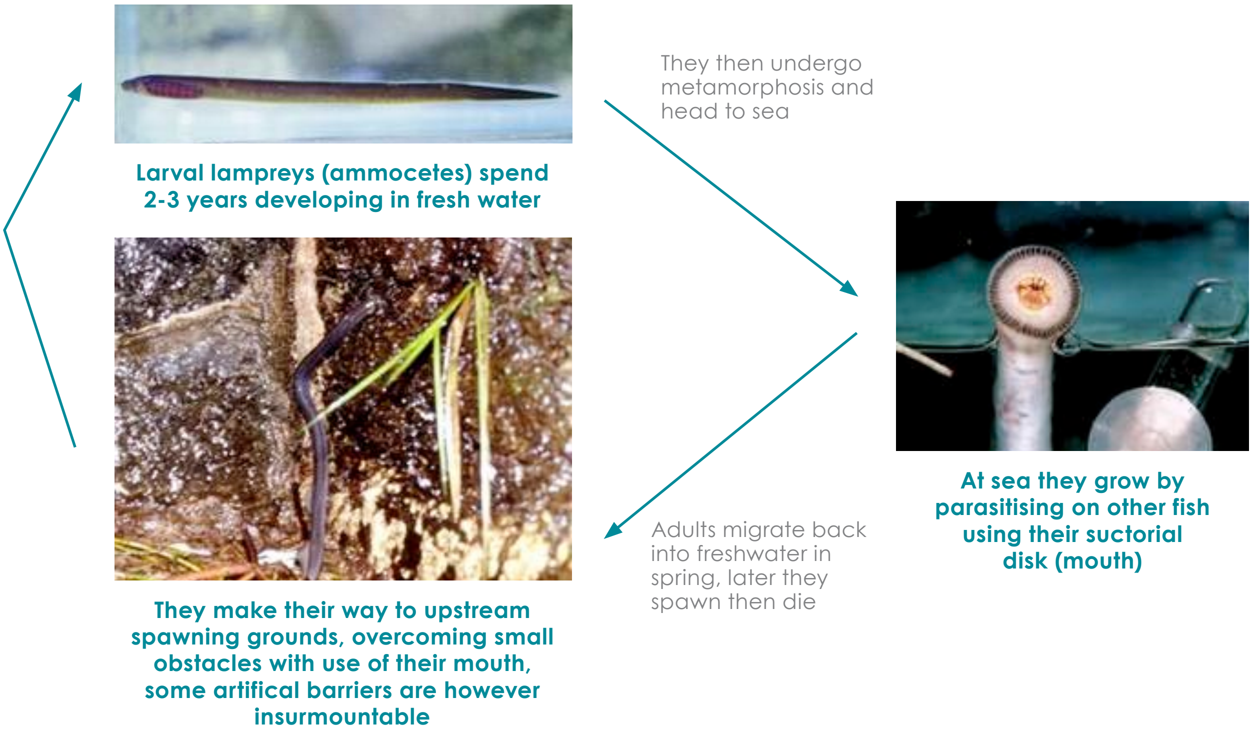
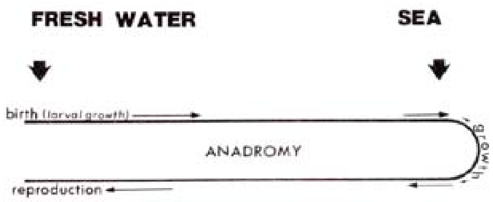
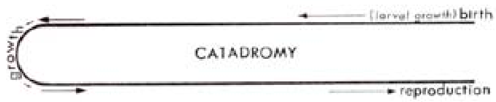


Figure 14. Example of major anthropogenic habitat changes to the Torrens and Patawalonga catchments[28].

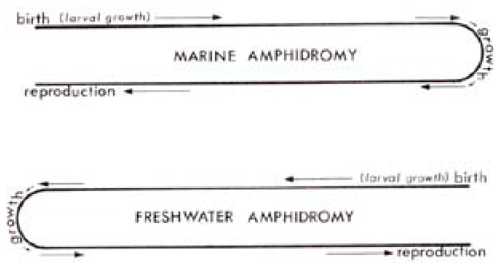




Spend most of their lives in the sea and migrate to fresh water to breed as adults



Spend most of their lives in the fresh water and migrate to the sea to breed as adults



Migration to or from fresh water is not for the purpose of breeding but occurs regularly at some life cycle stage

Figure 15. Schematic lifecycle diagram for diadromous species in South Australia, illustrated with the example of the anadromous Pouched Lamprey. Figure and text adapted from McDowall (1988)[244].

3.3. **LOWERED WATER QUALITY**

Water quality is a relatively complex combination of chemical and biological interactions in a local environment with broader influences. For example, levels of dissolved oxygen, one of the key water quality parameters, can be influenced by things like temperature, flow (aeration), suspended solids, concentration of organic carbon, and biological/chemical oxygen demand (fish, plants, algae, bacteria). Temperature in turn is governed by a variety of factors such as climate, water source, local radiation or shade and pool characteristics such as depth and surface area. Flow is further linked to water quality by diluting or distributing pollutants. Lowered water quality will have different implications or act as triggers for different processes such as fish mortality (fish kills), sub-lethal responses, and generate flow on effects to habitat quality. Negative effects will vary widely depending on fish condition, stress, species and age (size).

(A) FISH KILLS There are various potential causes of fish kills including natural events associated with habitat drying (e.g. temporary fish populations die as Lake Eyre recedes after flooding). Anthropogenic change can alter natural cycles of drying and water chemistry exacerbating natural events. In particular loss or reduction in base flow which might buffer oxygen or temperature levels, which can lead to suboptimal and ultimately lethal conditions[25].

Other inputs (pollutants) in isolation or combination are potential causes of fish kills:

- Pesticides such as Endosulfan (an organochlorine) are known to be toxic to fish[245]. Historically the pesticides Dieldrin and DDT were thought to harm fish populations in South Australia[176,202].
- Herbicides – in addition to impacting habitat (i.e. aimed to kill aquatic plants), these chemicals may be toxic, particularly the wetting agents used to help dispersal.
- Other toxic substance include heavy metals, acidic conditions[60,246], ammonia, hydrogen sulphide, winery waste and various industrial chemicals.
- High salinity and or temperatures can be above the tolerance of certain fishes.
- Turbidity (suspended solids) from runoff, instream or near stream works, can clog fishes gills and reduce oxygen availability.
- High nutrient levels from urban or agricultural runoff combined with warm still conditions promote blooms of algae and cyanobacteria (blue-greens) which can have a high demand for oxygen resulting in eutrophication.
- In urban environments toxic substances, organic load and large bacterial loads (high oxygen demand) occur with stormwater after rainfall, especially following dry warm periods. Both aforementioned problems could be linked to irregular fish kills observed in the Torrens Lake in the centre of Adelaide and Patawalonga Lake at Glenelg.

Disease may also cause mass mortality in fishes (see later).

Fish kills should be reported to the 24 hour FISHWATCH hotline on 1800 065 522.

(B) SUB-LETHAL RESPONSES The same factors involved in fish kills, but at sub-lethal levels, can impact on the condition of fish and the ultimate survival or successful breeding of individuals or populations in a chronic or cumulative way. Fish may be stressed, use extra energy or be unable to feed or breathe normally when exposed to certain substances. The potential consequences include poor fish condition and health (e.g. susceptible to disease and predators), increased abnormalities, poor growth and shorter lifespan, reduced or failed spawning, and low survival of eggs and larvae.

(C) REDUCED HABITAT QUALITY Other aspects of water quality may influence the structure or nature of aquatic habitats, linking together various other threat categories. For example un-naturally high turbidity limiting light penetration may inhibit plant growth, fish feeding, fish behaviour and water quality. Filamentous algae and suspended solids that settle may smother surfaces including food sources and breeding substrates. High salinity may affect other ecosystems components such as plant or macroinvertebrate composition and abundance having indirect impacts to fish feeding and habitat.

Fish kill of Flathead Gudgeon after pollutants entered a creek from a winery along the North Para River at Tanunda in April 2000[247]

Silt laden runoff from a roadway entering the Onkaparinga River Gorge

3.4. ALIEN SPECIES & STOCKING (BIOLOGICAL POLLUTION)

Alien species is used here to describe species exotic to Australia (SA *Fisheries Management Act 2007*) and Australian native species translocated outside their natural range. The introduction of organisms (biological pollution) outside their natural range is a worldwide problem in aquatic systems with serious impacts to ecosystems and biodiversity in numerous cases, particularly in small isolated habitats[248]. Fish translocated into one area have the potential to disperse more widely through connected waterways. The problem then escalates when these established species are more frequently encountered and further dispersed by humans. This is well illustrated by the rapid range expansion of Common Carp in Australia which included dispersal along river systems but has also many new isolated river basins and catchments including isolated wetlands around Adelaide.

Fish translocations can occur from a variety of mechanisms including deliberate releases (legal or illegal) or accidental movements (list adapted from a recent Australian review[249] with local examples provided where available):

- Deliberate legal stocking (recreation or conservation): permits for trout stocking in the Mount Lofty Ranges; attempts to form refuge populations of threatened native fishes.
- Contaminants of fish stocking (i.e. generally smaller fish that colonise aquaculture ponds and are then transported with juveniles of angling species): species such as Carp Gudgeon and Gambusia are potential candidates.
- Bait bucket introductions (i.e. live animals discarded after use at a different place to where they were captured): Goldfish were suspected to be introduced via this method in the Lake Eyre Basin[250].
- Transfers via water diversions (e.g. pipelines between river systems): several species which occur in the River Murray may have been introduced to the Torrens and Onkaparinga catchments via this linkage.
- Discarding of aquarium fish (and plants): Goldfish commonly occur in urban and rural centres[23,27,53].
- Escape from aquaculture facilities: marron on Kangaroo Island.
- Deliberate introductions for (a) pest control (e.g. Gambusia was distributed widely after WWII under the perception that it was a good mosquito control agent) and (b) biodiversity enhancement (e.g. wetland stockings[251]).
- Deliberate illegal stocking: many larger Australian native species including Murray Cod and Golden Perch have been stocked into waterways outside their natural range[1].
- Escape from outside ponds and farm dams close to waterways or that overflow during winter or storms.
- Transfer on commercial fishing gear.
- Deliberate release for cultural reasons.
- Contaminants of ballast water (shipping): estuarine/marine species that can colonise freshwater[141].

A variety of fishes, invertebrates and plants have been introduced into aquatic habitats of South Australia. This includes at least 27 alien fish species, fourteen of which have established populations and/or are regularly stocked (Table 4). The majority of such species have been introduced in and around Adelaide and in the Murray system. Problems with introduced organisms can be categorised as including (a) biological interactions, (b) transfer of disease and parasites, and (c) genetic implications. It is important to recognise that any species, exotic or native, introduced to areas where they do not naturally occur could cause one or more of these problems.

Table 4. Alien species recorded in South Australia by Drainage Division[1,252]. Alien fishes in natural waterways are regarded as established species (x) if their populations are self-sustaining or if they are continually stocked, and as introduced species if records are few and isolated (I) or confined to artificial (A) waterbodies (and potentially could become established); (*) recorded in marine habitat; (?) unverified record.

Family	Taxon	Common name	SEC	MD	SAG	LE	WP
Exotic species							
Cyprinidae	*Carassius auratus*	Goldfish	x	x	x	x	A
	Cyprinus carpio	Common Carp	I	x	x	A	
	Tinca tinca	Tench	x	x	x		
Cobitidae	*Misgurnus anguillicaudatus*	Oriental Weatherloach		I			
Salmonidae	*Oncorhynchus mykiss*	Rainbow Trout	I	x	x	I?	
	Salmo salar	Atlantic Salmon		I			I*
	Salmo trutta	Brown Trout	I	x	x		
	Salvelinus fontinalis	Brook Trout		I	I		
Poeciliidae	*Gambusia holbrooki*	Eastern Gambusia	x	x	x	x	I
	Phalloceros caudimaculatus	Speckled livebearer			x		
Percidae	*Perca fluviatilis*	Redfin Perch	x	x	x	I	A
Translocated Australian native species							
Plotosidae	*Tandanus tandanus*	Freshwater Catfish	I	A	x		
Galaxiidae	*Galaxiella pusilla*	Dwarf Galaxias			I?		
Melanotaeniidae	*Melanotaenia fluviatilis*	Murray Rainbowfish	I?	I	x		
Centropomidae	*Lates calcarifer*	Barramundi			I		
Ambassidae	*Ambassis agassizii*	Agassiz's Glassfish		A			
Percichthyidae	*Gadopsis marmoratus*	River Blackfish			A		
	Maccullochella peelii peelii	Murray Cod	I	A	x	I	
	Macquaria ambigua ambigua	Murray-Darling Golden Perch	I	A	x	A	
	Macquaria novemaculeata	Australian Bass		I	I?		
	Nannoperca australis	Southern Pygmy Perch		A	A		
Terapontidae	*Bidyanus bidyanus*	Silver Perch	I	A	A	A	
Eleotridae	*Hypseleotris* sp. 1	Midgley's Carp Gudgeon			x		
	Hypseleotris sp. 3	Murray Darling Carp Gudgeon	x				
	Mogurnda adspersa	Southern Purple-spotted Gudgeon		A	A		
	Philypnodon macrostomus	Dwarf Flathead Gudgeon			x?		
	Oxyeleotris lineolata	Sleepy Cod		I			
TOTALS		27	13	20	22	8	4
		known established	5	7	13	2	0

Drainage Divisions: SEC = South East Coast, MD = Murray-Darling, SAG = South Australian Gulf, LE = Lake Eyre, WP = Western Plateau

(A) BIOLOGICAL INTERACTIONS Direct and indirect problems associated with the biology of introduced organisms include those listed below, and are especially problematic during periods when habitats contract and native fish are confined. Impacts may be directed to sensitive groups or be manifested as ecosystem level impacts following the removal of certain species or resources (trophic cascades):

- **Predation:** many native fishes in South Australia are small species that have evolved in stream, spring, wetland and waterhole environments without exposure to large active predators. The introduction of large predatory fish into such areas poses a high risk to native fish, tadpoles and frogs, and macroinvertebrates especially decapod crustaceans (e.g. Spiny Crayfish and Yabbies). Smaller introduced species could also prey on the eggs or larvae of native fishes.
- **Competition:** juveniles of larger species or smaller growing species can compete for the same resources as native species including food but also available habitat (e.g. forcing a greater exposure to predators).
- **Aggression:** territorial or aggressive behaviour can impact native species through competition for space/habitat (above) and physical damage to individuals such as damage mucosal coat and fins (and hence increased risk of disease or reduced condition for spawning or growth).
- **Behavioural changes:** the presence of introduced species may alter the behaviour of native species feeding or foraging periods or force the use of suboptimal or non-preferred habitat.
- **Habitat alteration:** the feeding ecology or behaviour of introduced species may disturb environmental conditions required by some species or ecosystems (e.g. Carp disturb sediments and increase turbidity, remove of aquatic plants)

(B) TRANSFER OF DISEASE AND PARASITES Australia's long evolutionary isolation (tens of thousands to millions of years) has limited exposure to diseases (i.e. viruses, bacteria and fungi) and parasites. Therefore local native species may have a low immunity to new forms or strains introduced from oversees or interstate. Pathogens or disease causing agents can be primary or secondary in nature, causing disease in healthy or minimally stressed fish and fish with compromised health respectively. In the later case, poor environmental conditions or stress increases the susceptibility of populations to new or existing disease which may compromise survival of remnant or refuge populations[129].

Potential pathways for the introduction of diseases and parasites include:

- **Fish stocking:** the movement or introduction of fishes to regions, catchments or stream sections where they do not naturally occur, especially fish that have been apart from the natural environment, poses significant risks. This is especially true for exotic species that could carry disease or parasites which native fish have no acquired immunity for.
- **Discarded aquarium species:** a multitude of tropical and temperate freshwater species are utilised within the aquarium trade, and desired fishes are selected from around the world, facilitated through international exchange (importation). In the order of 8-10 million fishes are imported into Australia each year and with this comes an associated risk of importation of other micro-organisms (disease and parasites) including 'hidden' infections which may avoid detection[253,254]. The intentional or accidental release of fish, water or materials from aquariums and ponds into natural waterways thus provides an avenue for introducing disease and parasites to native fish (and is illegal).
- **Inter-basin transfers:** movement of water and organisms between areas provides another mechanism for dispersal of disease or disease carrying organisms. Pipelines such as those between the River Murray and catchments on the western Mount Lofty Ranges are an example.

Movement of materials such as unsterilised or not thoroughly cleaned fish sampling equipment, construction and maintenance machinery, and aquatic vegetation are all potential avenues for transportation of disease (plus potential introductions of fish and plants).

Current and potential diseases and parasites of native fishes in South Australia are poorly studied with little routine monitoring for new outbreaks. Potential problems include viruses such as EHNV and Gourami Iridovirus[253,255], fungal infection (e.g. *Saprolegnia, Aphanomyces*), bacterial infections such as Goldfish Ulcer Disease (linked to *Aeromonas salmonicida*)[256] and Fish Tuberculosis (*Mycobacteria*), and parasites such as tapeworm (*Bothriocephalus acheilognathi*) and Anchor worm (*Learnea* spp.).

(C) GENETIC IMPACTS

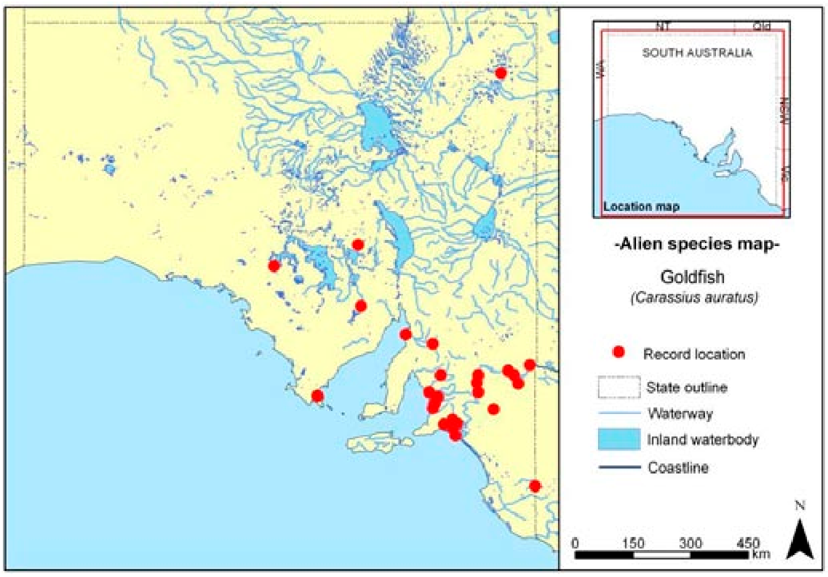
Two main categories of genetic impact can be considered in relation to fish introductions:

- Decline and fragmentation due to the direct impacts of introduced species. Biological interactions may lead to reduced population size (e.g. continual predation, exclusion from habitat, disease), population bottlenecks during critical periods, altered natural selection, and poor connectivity and gene flow within populations – all serving to reduce genetic diversity and uniqueness within a population.
- Reproductive interaction of local and stocked fishes. Mostly an issue with the translocation of Australian native species where mixing (reproduction) of different genetic strains or closely related species could lead to: (a) hybridisation and introgression (contamination with foreign genes) interrupting natural evolutionary trajectories and having other issues such as infertility and outbreeding depression, (b) the loss of distinct local genetic types (diversity) through swamping with new foreign genes[257,] and (c) reduced genetic diversity through swamping with genetically similar hatchery reared fish. Some relevant local examples include the risk of mixing fish from isolated regions such as distinct species of Golden Perch occurring in the Murray-Darling system and Cooper Creek, swamping the local genetic diversity of Murray Cod in the SA River Murray due to stocking fingerlings, or small distance translocations across catchment boundaries eliminating distinct genetic strains of smaller native fishes like Southern Pygmy Perch and Mountain Galaxias.

(D) SPECIES PROFILES Brief synopsis on the range, status, history of introduction and potential problems for introduced species in South Australia are detailed in family order (see Table 4). More detailed information on these species can be found in broader texts or reports[89,258,259,260,261,262].

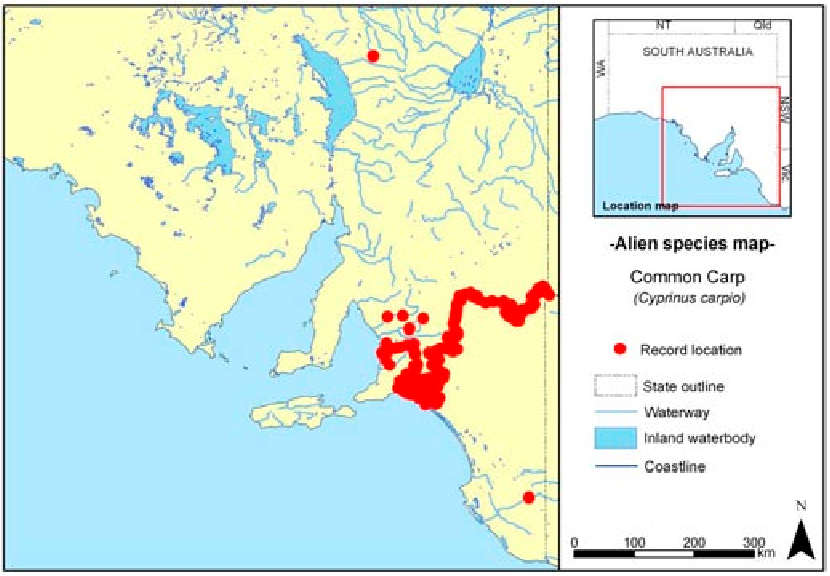
Goldfish

The species has been established in South Australian waterways for some time (at least early 1900s) with evidence of continuing introductions due to a close association with humans through culture (e.g. aquariums and ponds). Goldfish are common in the Murray and urban Adelaide but are also spread patchily throughout all major SA Drainage Divisions. While goldfish appear harmless, there is a potential to compete with native species for food (zooplankton, invertebrates), to modify habitats (e.g. suspend sediments in confined habitats; feed on and remove aquatic vegetation), and most importantly for the introduction of disease and parasites carried with their importation into Australia. The illegal use of Goldfish as live bait poses a high risk of introducing disease to native fish stocks, potentially ruining fishing opportunities and impacting biodiversity.



Common Carp

A species well known and much maligned by the general public, commonly referred to as European Carp. Carp became established in the Murray system in the late 1960s where it is now abundant and has since become established in other streams of the Western Mount Lofty Ranges (e.g. Onkaparinga, Torrens and Light rivers) as well as numerous local wetlands in the Adelaide region. Only isolated reports have been made from the South East and Lake Eyre Basin. The impacts of this species appear to be interlinked with broader environmental change, as they have a high tolerance for stable, stagnant habitats. Nevertheless, potential impacts are thought to include their high densities providing competition with small native species for food (zooplankton) and space, increased turbidity and loss of submerged aquatic vegetation due to their large adult size and feeding mode, and as vectors for disease and parasites. Any impacts are most noticeable in confined areas such as wetlands or stream pools.



Weatherloach and other potential exotic invaders

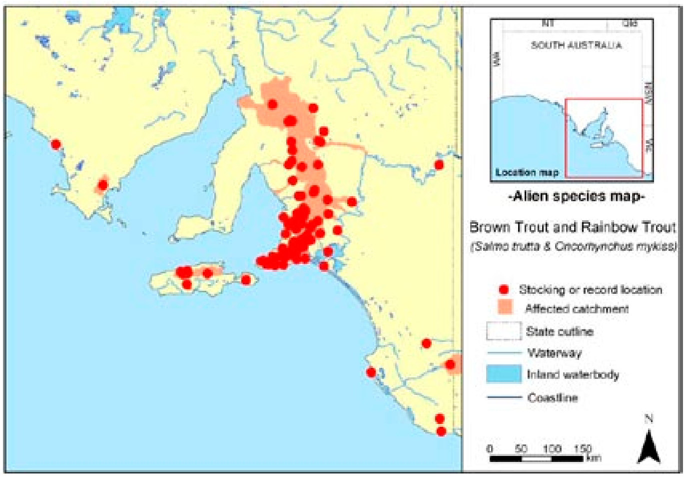
Only a few unverified records of Weatherloach have so far been made in South Australia, however the species (a small eel like fish reaching ~20cm) has become established in the eastern states and has undergone a rapid proliferation in the last 20 years. It is now advancing down the Murray River in Victoria towards the South Australian border. Potential impacts from species which is highly tolerant of environmental extremes include competition and potential predation on eggs and larvae of native fish[263], posing particular danger to species in the Mount Lofty Ranges and Lake Alexandrina. Other potential pest species that are established in other parts of Australia that could be a threat to local native species and ecosystems include Tilapia, Rosy Barb, and numerous aquarium species.

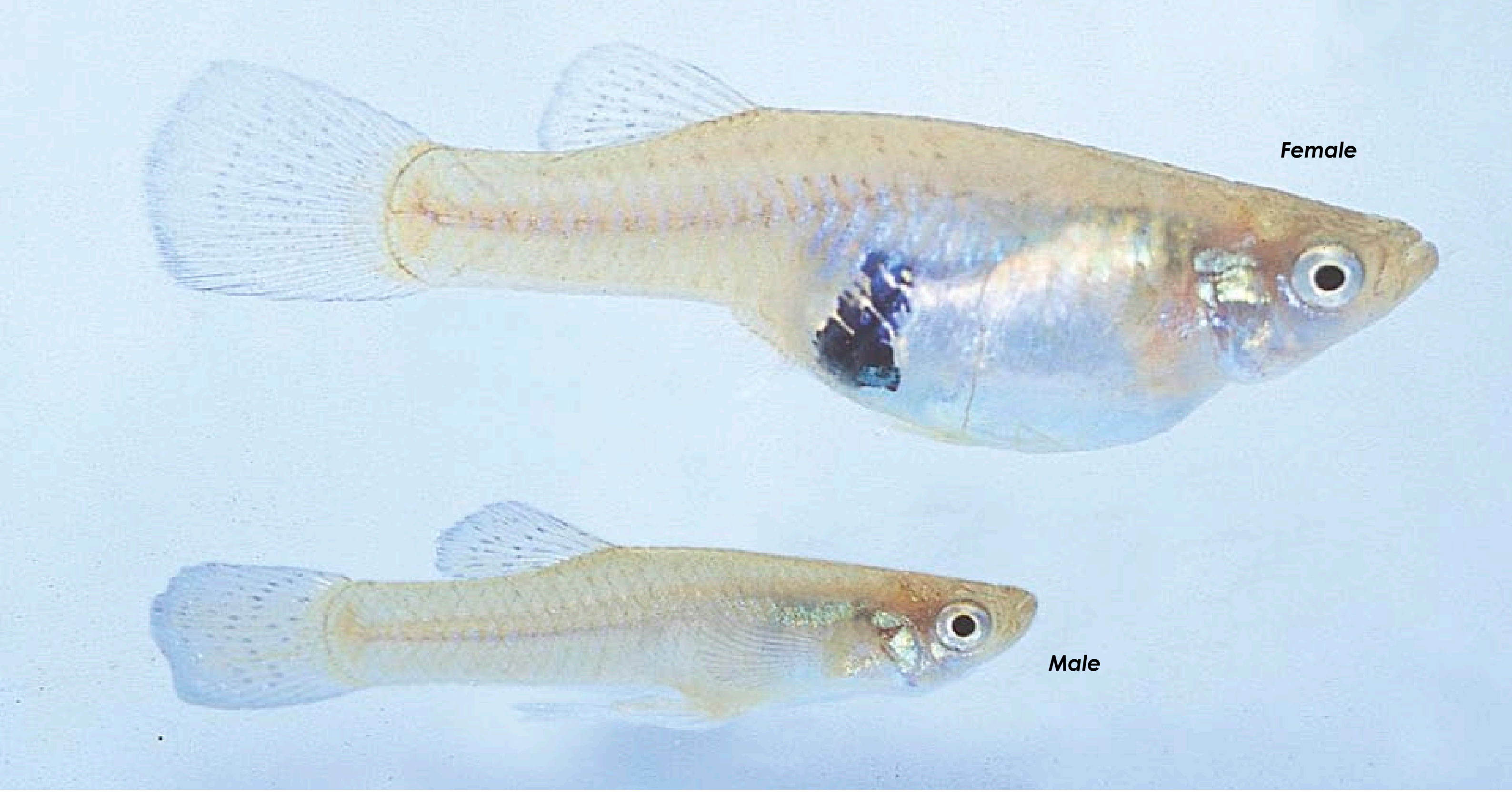
Stomach contents of a Brown Trout in the Finniss River catchment which includes 15 fish (Flathead Gudgeon and Mountain Galaxias) and numerous Glass Shrimp

Brown and Rainbow Trout

Trout have been systematically stocked into the South Australia's waterways since the late 1800s, especially after the 1950s. Given documented stocking locations, plus the likelihood of considerable other releases, it is fair to say that essentially any waterbody in temperate regions of the State (and some warmer regions) has probably received trout fingerlings at some stage. Several systems like the Broughton, Light, Torrens, Onkaparinga, Finniss, Hindmarsh and Currency catchments (Mount Lofty Ranges) and Mosquito Creek (SE) have each received hundreds of thousands of fingerlings over time[264]. Some populations appear to recruit in the wild but many are topped up with stockings under a PIRSA Fisheries permit system. The number of catchments stocked in recent times has been reduced mainly due to decline in environmental conditions to the point that areas are no longer suitable to carry trout signalling broader environmental problems, but tighter control is also being implemented.

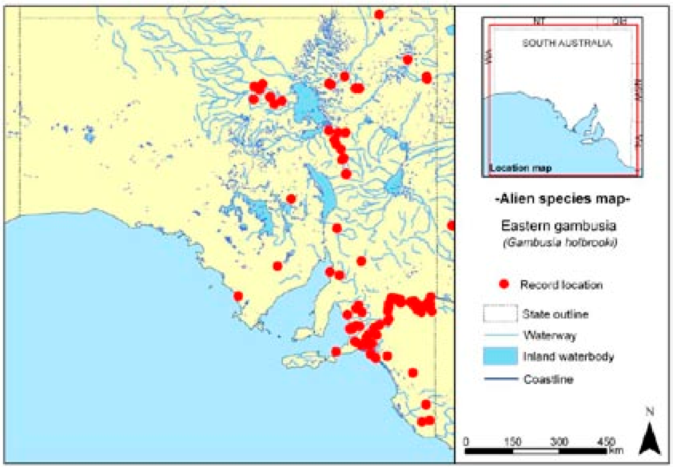
Both Brown and Rainbow Trout are active predators, often being much larger than species native to systems where they are stocked. Many of the impacts of trout probably occur upon initial stocking (e.g. loss of native fish populations in the Torrens[265]), however there is evidence of ongoing impacts to native species such as Mountain Galaxias, Climbing Galaxias and Southern Pygmy Perch. These native species have restricted fragmented distributions at some sites in the Mount Lofty Ranges likely attributable to the presence of trout[25,27,28,51]. Trout tend to occupy stream regions or pools with better water quality and flow and thus are in direct conflict with optimal habitat and refuge areas of native species. Trophic cascades are also possible due to heavy feeding on invertebrate fauna and possibly tadpoles.





Eastern Gambusia

The Eastern Gambusia (Gambusia for short) is a small fish that attains a length of less than 5cm. It is able to rapidly expand populations, giving birth to live young. It was originally introduced for mosquito control (especially around World War II), but is now known to be no better at controlling mosquito larvae than the native fish and macroinvertebrates which naturally fulfil this role. The species can negatively impact on these natural mosquito predators (hence use of the name Mosquitofish is discouraged). It occurs widely in South Australia and is considered a threat to many native fishes because it is aggressive, nipping at fins and the body of other fish, can predate on eggs and young fish, and can compete for food and space (e.g. aggressively defends shallow pool margins[39]). The largest impacts are likely to occur in confined habitats such as mound springs or isolated stream pools, or areas with sensitive small species such as Dwarf Galaxias and Pygmy Perches. The species has high tolerance of environmental extremes and hence can be favoured by declining environmental flows and habitat degradation.



Speckled livebearer

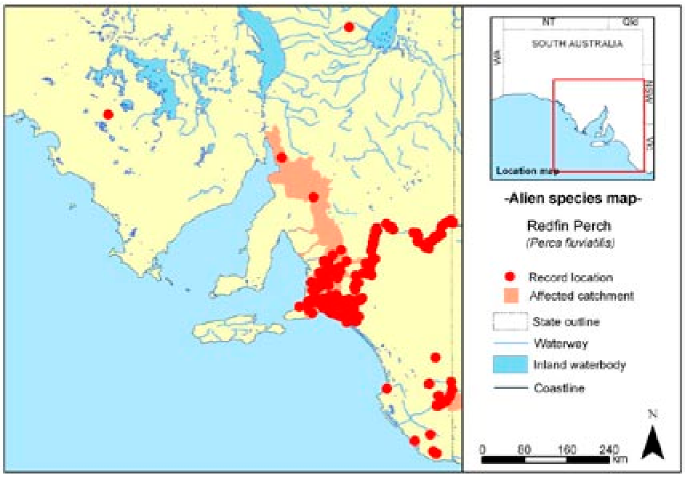
This species, a relative of the Gambusia, represents a newly documented invasion in South Australia (southern Adelaide)[252]. Like its cousin it is known to be aggressive and compete with native species. It has likely become established through escape or release from captive fish, and highlights the need for vigilance with regard to alien species introductions.

Redfin are an introduced predatory species which threaten populations of small fish such as Pygmy Perch and Galaxias

Redfin

Redfin have been spread widely in South Australia, particularly in the Adelaide region and South East of the State. Introductions occurred soon after settlement with records of the species becoming established in major areas such as the River Torrens and River Murray by the 1920s. They are most common in streams of the western Mount Lofty Ranges such as the Torrens, Onkaparinga rivers, Lake Alexandrina and some tributaries (Finniss and Angas rivers), and waterholes and streams of the South East including Bool Lagoon (when wet). Interestingly, harsh environmental conditions in recent years appear to have resulted in a decline in distribution and abundance in Mosquito Creek suggesting certain vulnerabilities or intolerances[118].

Compared to most small native fish, Redfin are large growing and are highly predatory (with a large mouth). The species can breed and grow rapidly with impacts likely to include competition for space and food (as juveniles), predation or behavioural shift forcing loss or exclusion of native fish from important habitat. A Western Australian study found diet of Redfin between 50-200mm comprised mostly small aquatic invertebrates, and Redfin >200mm preyed almost entirely on decapod crustaceans and fish. The study concluded that Redfin were believed to have played a significant role in the local extinction of three native fish species[266]. This matches local observations of potential impacts to species such as Southern Pygmy Perch, River Blackfish, Mountain Galaxias, Yarra Pygmy Perch and Murray Hardyhead in their respective distributions in the Mount Lofty Ranges, Lower Lakes and Mosquito Creek[13,23,25,113,260]. Impacts are likely to extend to Yabbies, Spiny Crayfish and tadpoles.

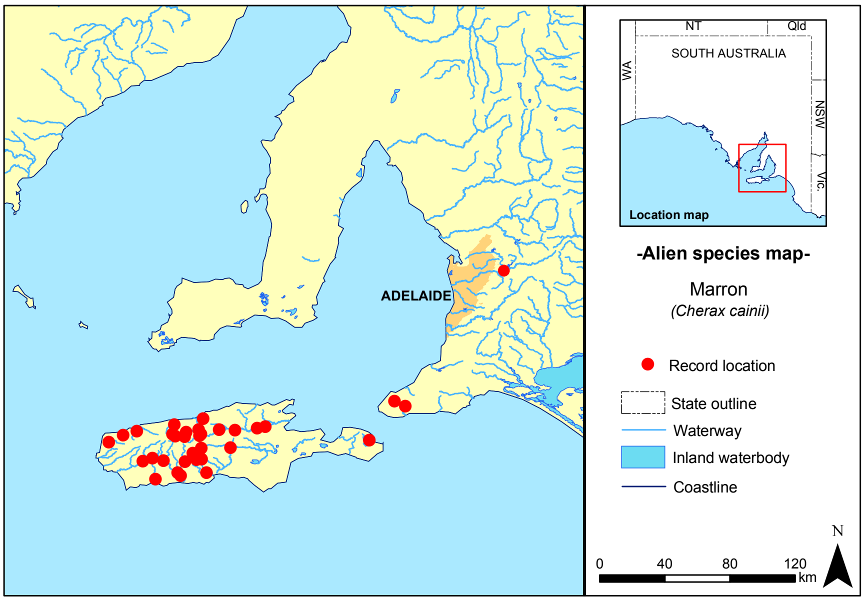


Native fish species

Large predatory species such as Murray Cod, Golden Perch and Freshwater Catfish are increasing used for stockings (angling purposes) with some records of translocated fish from South Australian waterways[1]. However, just because such species are native to Australia, does not mean that they will not pose a threat to areas where they do not naturally occur. Their potentially large adult size and predatory nature threaten small native species and invertebrates (especially Spiny Crayfish) in areas where they are stocked or escape to (e.g. from farm dams that overflow into natural waterways). Further, stocked fish may also carry disease from hatcheries or other areas, and there are potential genetic implications such as hybridisation or genetic swamping of native populations. Similarly, small native species stocked outside their natural range could compete for food and habitat with local species, transfer disease or parasites and have implications for mixing of different genetic strains. Stocking is seen as a way of improving declining fish populations, however it is often a band-aid solution which fails to address the underlying threats to species such as loss of habitat. Further, if undertaken incorrectly, stocking can cause its own problems through genetic impacts, disease introduction, impacts to other ecosystem components and increased competition pressures for natural populations.

Marron

Marron, native to Western Australia, is now widely established on Kangaroo Island and some sections of the Fleurieu Peninsula. In these areas they reach a very high biomass during concentrated conditions, and are likely to be impacting fish directly as a large aggressive animal (e.g. predation) or alter the food-chain (e.g. competition or replacement of natural invertebrates). The species has established over the last 20-30 years with mechanisms such as escape from ponds or dams and illegal movements and stocking probable. There has to date been little research or management undertaken on control of prevention of spread.



Willows

Willows comprise a number of species of deciduous water loving trees which can spread to line and choke small waterways and exclude native plants. Willows also have a heavy rapid leaf drop with fast decomposition which can lead to deoxygenation and poor water quality and smothering of underwater surfaces and vegetation. However, in some cases Willows now represent the only shade and sources of cover at some degraded sites and actually provide important habitat for species with requirements for cool conditions such as River Blackfish, Southern Pygmy Perch, Mountain Galaxias and Climbing Galaxias in the Mount Lofty Ranges. The sometimes crude methods used to control Willows involving heavy physical disturbance to stream edges and a subsequent transition from full to no shade can be a threat to native fish populations and a more gradual transition to native riparian vegetation is recommended.

3.5. **EXPLOITATION (USE)**

Catch and use of fishes occurs for a variety of purposes including recreational, commercial and cultural reasons (e.g. food, angling), for research, biodiversity enhancement projects (e.g. collecting fish for stocking wetlands) and for personal enjoyment or observation such as keeping native fish in aquariums. These uses can provide an appreciation of the intrinsic value of native species and a greater awareness and knowledge of their natural history and biology. However, the inappropriate or excessive use of native fish populations could provide an additional stress to threatened species and those with temporarily restricted distributions.

(A) REDUCED ABUNDANCE Use can ultimately reduce the abundance of species at a point in time or progressively. This has the potential to impact on the number of fish or critical mass required to sustain a population or basic levels of genetic diversity (e.g. appropriate number of spawning fish). Species vulnerable to exploitation include those with highly restricted ranges (e.g. desert fish[32], Pygmy Perches), which spawn infrequently or are slow growing, and species which occur in concentrated refuges during dry periods (e.g. larger fish of the Lake Eyre Basin in systems like Coopers Creek and the Neales River). Other species are susceptible to over harvest during spawning aggregations or migration.

(B) TROPHIC CASCADES Fish play a variety of roles in ecosystems such as being an important part or link in food chains. Nearly all small native species and juveniles of larger native species are carnivorous and hence consume aquatic and terrestrial macroinvertebrates and crustaceans. A particular aspect of this predation includes a role in mosquito control (by predation on wrigglers or adult mosquitoes). Small fish are in turn consumed by predators such as birds, water rats and larger fish. Larger predators potentially control the dynamics of other species (keystone species). Such food chains exist in a fine balance with environmental conditions, and hence the selective removal of certain species, especially larger predatory species like Murray Cod, may indirectly alter the composition of a local fauna by allowing the proliferation of certain smaller species ('top-down' ecosystem effects). Alternately the introduction of larger predators could eliminate small species but leave the food they previously were feeding on (for example leaving no natural predators of mosquito wrigglers in pools as has been observed with trout in the Mount Lofty Ranges[25]. The selective removal of a species through legal or illegal fishing effort could mean that another species takes its role in a system, so that efforts to recover the exploited species later on are less successful as it has been functionally replaced. This is an example of an altered ecosystem state.

Preparing a large catch of Murray Cod, a top order predator, caught at Renmark 1898. Photo courtesy of the State Library of South Australia (SLSA: B45136)

3.6. POPULATION DECLINE

A grouping of other potential threats relate to the current characteristics of populations and social and political factors. These are very much cumulative or interlinked with problems such as hydrological alteration or habitat loss but warrant specific inclusion and highlight.

(A) LOSS OF GENETIC DIVERSITY Genetic diversity is the backbone to biodiversity or the number of unique animals and plants that have evolved and occupy habitats in South Australia. Genetic diversity can be expressed on a number of levels including phylogenetic (deeper relationships such as Families and Genera), species boundaries, and within species variation. Within species variation can provide an ability to adapt to changing environmental conditions, and can relate to variability both between and within different populations of a species. For example, the Southern Pygmy Perch has distinct genetic lineages in the South East and Murray regions of the State, and individual catchments in the Mount Lofty Ranges harbour unique genes and frequencies of different genes (heterogeneity). These distinguish each pygmy perch lineage and form the basis of potential adaptation or evolution in their isolated habitats[13,22]. Processes that can erode genetic distinctness or within population/species variation include local extinctions or range contractions (e.g. from habitat loss), bottlenecks from low numbers of fish at a point in time (e.g. over harvest during drought), fragmentation (e.g. artificial barriers), and swamping with hatchery reared fish.

(B) RESTRICTED RANGE Many species or populations of threatened species have a limited area of occurrence. This can be due to natural isolation such as desert fish restricted to a particular stream (Flinders Ranges Purple-spotted Gudgeon) or group of artesian springs (e.g. Dalhousie endemics), or alternately species which were formally more widely spread but have contracted due to human related impacts like hydrological alteration. Good examples include River Blackfish in the River Murray drainage, a once widespread species that now occurs as four small populations, including one which is restricted to two refuge pools[25,267]. Spatially restricted species and populations face a variety of challenges for long-term survival. Any change in their habitat could be devastating, and changes to small areas could happen quite easily and quickly through both chance natural conditions (e.g. floods and drought) and threatening processes such as habitat change, species introduction, pollution events and water quality issues[247], and loss of flow. Any new small change cumulative to existing threats may push a population past sustainable limits.

(C) MANAGEMENT AND PLANNING Being hidden below the waters' surface, most native fish do not have a high profile in the community or among planners, land and resource managers, and developers. This is particularly the case for small, rare fish with no recreational fishing value. A general lack of awareness of species or regional faunas is a threat to South Australia's freshwater fishes because:

- **Lack of action:** a failure to address the specific conservation requirements or actions for threatened species or communities could lead to species loss.
- **New threats:** the requirements and conservation of native fish may not be considered during new developments or changes in landuse, and in restoration programs.
- **Limited funding:** fish may not receive the same levels of attention or priority in restoration and management, leading to few dedicated actions and a greater risk of species loss from the State.
- **Limited research:** there may be a tendency for limited research and monitoring leaving knowledge gaps on the presence or condition of ecological assets as targets for conservation and management and biological information available for management.
- **Legislative protection:** the importance of protecting fish populations, their habitat and flow processes has been (and is currently) poorly represented in State laws and regulations. This has particularly been the case for small species that tend to fall between the gaps of terrestrial species conservation and fisheries management.

3.7. CLIMATE CHANGE

The projections of climate change as a result of current and increasing world-wide green house gas emissions have considerable relevance for South Australia. Exact predictions are difficult given large temporal variations in climatic conditions, and with variations for different parts of the State, but the overall trend based on average seasonal and annual conditions suggests South Australia will become hotter and drier, with a change in the nature of rainfall events[268].

Notably in time, the prevailing low pressure systems from the south west which produce rainfall in the southern areas of the State, are projected to decrease in number but increase in intensity with an overall effect of less rain in more concentrated events, particularly in spring. The northern half of the State is predicted to become warmer (e.g. between 1 to 6°C) with an increasing frequency and magnitude in summer rainfall events (e.g. more floods). A summary of predicted changes in rainfall and temperature are contained in Figure 16. Broader changes are also likely to affect South Australia especially in the Murray-Darling Basin where with less rain, flow to South Australia could be further reduced.

Climate change has the potential for direct impacts along with an overarching role in exacerbating many existing threats. A change in climate could mean aquatic habitats are increasingly influenced by disturbance events of large floods and longer periods of drought, and overall warmer water temperatures and lower average flows (the latter could also result in increased concentrations of salt, nutrients and pollutants). This pattern is likely to be further intensified in developed regions as humans react to secure water supply with cumulative additions to existing abstractions (e.g. dams, groundwater pumping). All fishes will be susceptible to changes in their habitat extent and conditions (e.g. habitat loss, water quality tolerances), but those living in currently cooler and more predictable seasonal environments will be hardest hit (e.g. cool water species from the Mount Lofty Ranges and South East).

Sights like this concentrated refuge pool could become more common with reduced rainfall and higher temperatures, combined with existing water use

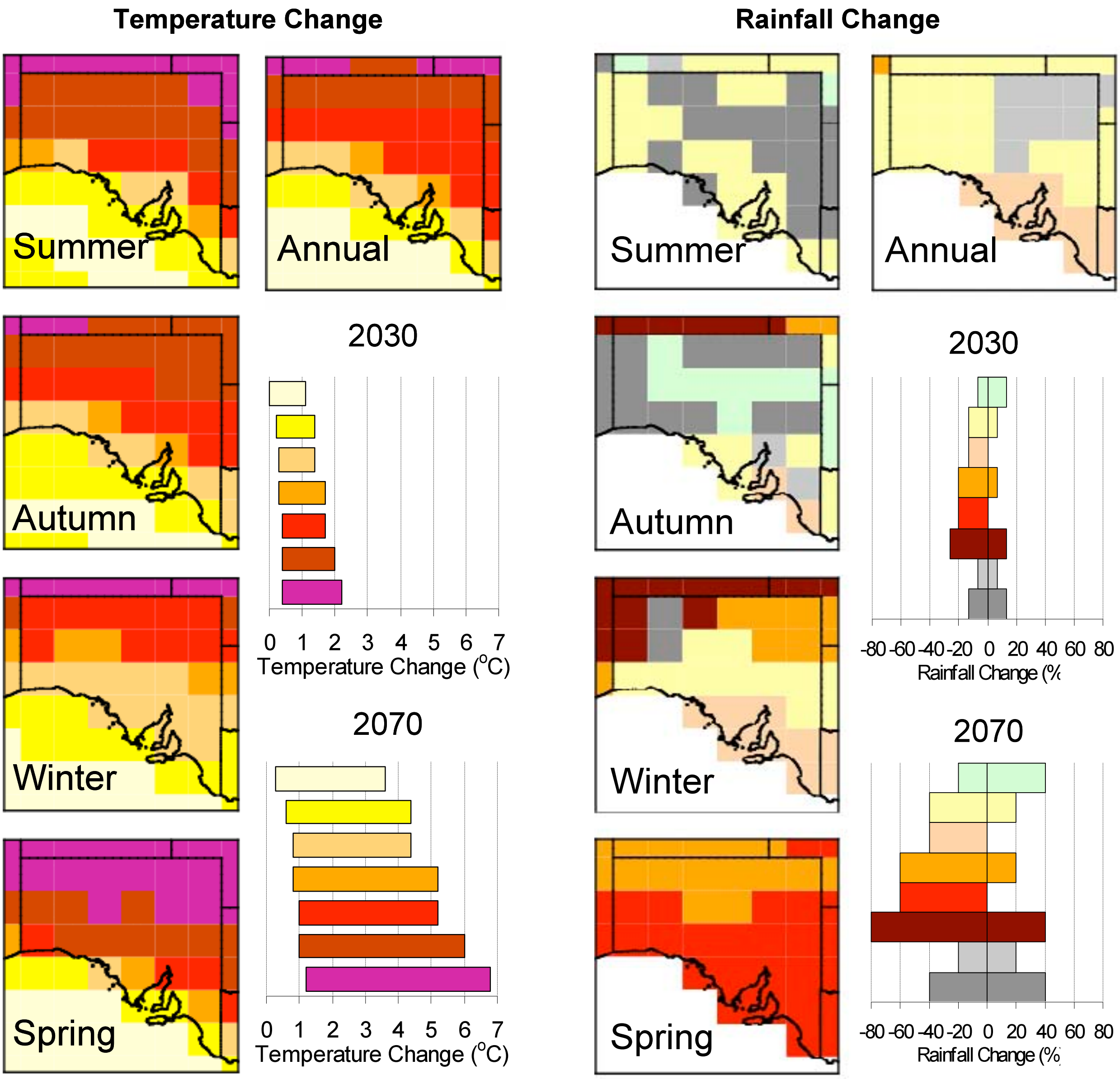


Figure 16. CSIRO climate change projections for South Australia covering (a) average seasonal and annual warming ranges (oC) for around 2030 and 2070 relative to 1990 and (b) average seasonal and annual rainfall change (%) for 2030 and 2070 relative to 1990. The coloured bars show ranges of change for areas with corresponding colours in the maps (reproduced with permission from McInnes et al. 2003[268]).

Section 4 Summary actions for conservation

Conservation of South Australian freshwater fishes requires recognition of current and future threats and actions to ameliorate them. Proactive measures are likely to be most effective in preventing further serious fish declines and minimising potential threats. Effective fish conservation is also most likely to be achieved when an ecosystem level approach is taken to ensure the survival of groups of species by protecting underlying habitat and environmental functions (flows). With historic neglect, ever increasing pressures from human development, and over half the States freshwater fishes already threatened with extinction, the reality is that urgent reactive measures are required in many cases involving hard decisions and decisive actions to prevent population or species loss.

Specific threats to species and counter actions have been detailed in species Recovery Outlines (Sections 2), and Table 5 provides example actions which could be used against the broader threats detailed in Section 3. This section provides a combined perspective of proactive and reactive measures, with an overall summary of higher recommendations for stakeholder consideration and involvement.

Table 5. List of possible actions against potential threats to freshwater fishes in South Australia.

Threat category	Examples Actions
1. Hydrological (flow) alteration	
a) Loss of water from a system/habitat **b)** Altered flow seasonality and variability	Adequate and proactive Water Allocation Planning (environmental water provisions); improved hydrological knowledge; government and community flow restoration programs; NRM/Catchment Management plans; improved Legislative Protection
2. Habitat loss and degradation	
a) Removal and alteration of habitat (broad) **b)** Removal and damage of riparian vegetation **c)** Loss of instream cover	Catchment scale restoration projects; flow restoration; targeted stream improvements of riparian and instream habitat (e.g. stock control, revegetation, resnagging, stormwater treatment); improved and considered environmentally sustainable development guidelines; tighter habitat protective measures (legislation and local planning); NRM/Catchment Management plans
d) Artificial barriers to fish movement and gene flow	Research and implement fishways; address biological pollution (e.g. control of introduced predators) and water quality issues
3. Lowered water quality	
a) Fish kills **b)** Sub-lethal responses (e.g. reduced spawning or feeding ability) **c)** Reduced habitat quality	Improve and protect environmental water provisions; increase stormwater treatment and industrial safeguards (e.g. winery waste disposal, saline water discharge, chemical spills); promote best catchment management practices (e.g. reinstating riparian buffers and revegetation, minimise agricultural runoff and nutrient/ sediment inputs). Prompt reporting and action.

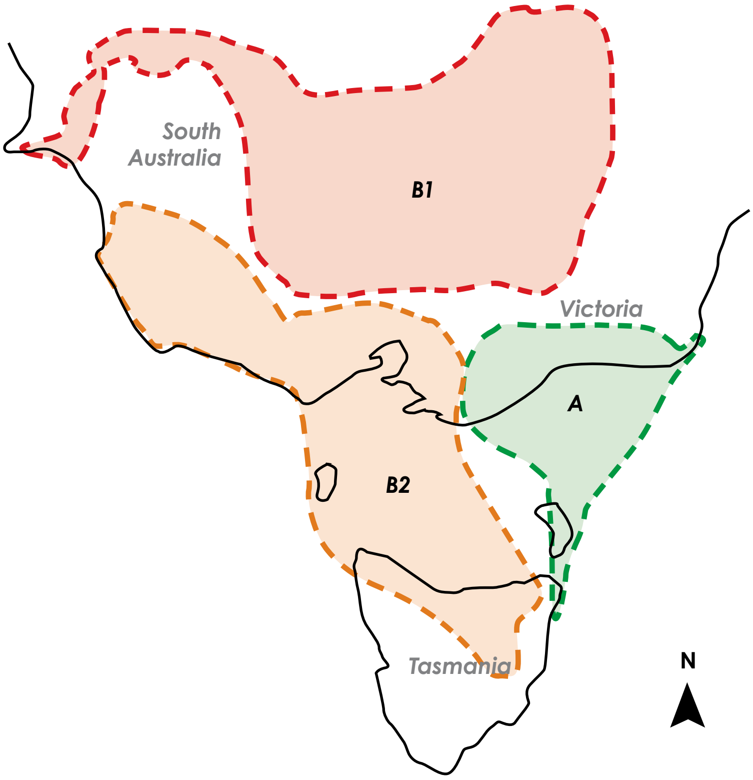
Table 5 continued....

Threat category	Examples Actions
4. Alien species & stocking (biological pollution)	
a) Biological impacts (competition, predation, aggression, habitat modification)	Identify and control impacts in key areas and habitats through physical removal, control of stocking or environmental manipulation/restoration; promote the environmental requirements of native species to increase their resilience; legislation and education for proactive measures to prevent new introductions or expanded translocations); develop a sound translocation policy
b) Transfer of disease and parasites	Research to increase understanding of the occurrence, frequency and impacts of disease and parasites in wild populations; develop a process for routine and responsive disease testing of native and introduced fish (wild and translocation); education to prevent aquarium fish discards; assess quarantine procedure and risk (importation of fish, movement of equipment); prevent inter-basin transfer of organisms (e.g. alternate water supplies/transport methods, water treatment, screens)
c) Genetic impacts	Develop a sound translocation policy and legislation; education within government and the community to improve awareness of impacts (preventative control)
5. Exploitation	
a) Reduced abundance and reproductive potential **b)** Trophic cascades and altered states	Carefully research and regulate sustainable harvest; promote community ownership and involvement to prevent overfishing, ecosystem impacts and illegal harvest
6. Population decline	
a) Loss of genetic diversity & reduced ability to adapt to change **b)** Restricted range and/or small populations	Recognise and protect threatened species and populations; minimise threats to already restricted population (reactive and proactive); undertake flow and habitat restoration to allow natural expansion; devise contingency plans for urgent conservation measures if required (e.g. captive maintenance)
c) Failure to include fishes in management and planning	Improve awareness of the presence, plight and requirements of freshwater fishes; promote and distribute Action Plan information and recommendations for incorporation into the activities and thinking of those undertaking activities (doers), decision makers, researchers and funding bodies;
7. Climate change	
a) Change in habitat and flow	Encourage and promote appropriate renewable energy sources; act to reduce energy and water consumption; build resilience to native populations through water allocation planning and habitat improvement

4.1. **SOME IMPORTANT FIRST STEPS**

Systematic frameworks A prerequisite for conservation, research and management of threatened species is a sound systematic framework which involves an understanding of species boundaries and spatial genetic structure. Freshwater fishes in general show high levels of cryptic species (i.e. species awaiting detection) and genetic diversity. Undetected species have the potential to confound biological information or worse result in the loss of species yet to be recognised. There are several examples of recent studies demonstrating multiple species either at one location or within distinct aquatic systems of South Australia: Carp Gudgeons, Smelt, Southern Pygmy Perch (see Figure 17), and Golden Perch[13,16,269,270]. Spatial genetic structure and information on species/population genetic diversity helps to determine the scale and priorities for management and thus protect distinct or unique evolutionary or management units (e.g. stream catchment, wetland or spring system, Drainage Divisions)[271]. The few freshwater fishes in South Australia so far investigated show strong patterns of spatial genetic structure (River Blackfish, Southern Pygmy Perch, Yarra Pygmy Perch, Mountain Galaxias, Smelt[13,16,55,130]).

Systematic frameworks should be investigated for all freshwater fish species in South Australia, even for 'common' species that may actually have more complex genetic patterns. Section 2 contains priority recommendations for threatened species including resolving taxonomic relationships with species and populations interstate. Taxonomic research is urgently required to describe and provide characters to distinguish cryptic species particularly as it forms a critical link to field identification, research and conservation management.



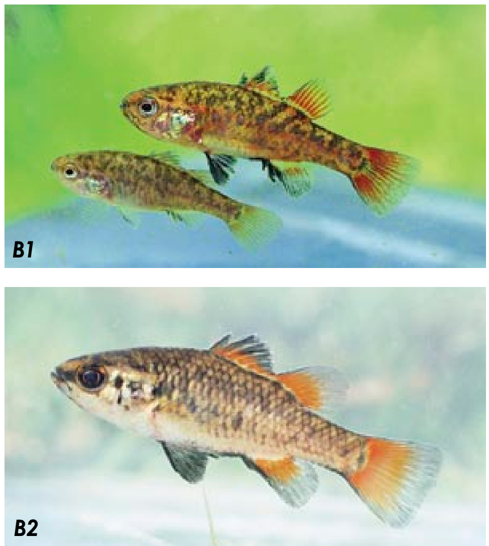


Figure 17. Systematic framework for Southern Pygmy Perch in south eastern Australia. Formerly considered a single wide-spread species, we now know that two distinct species exist. An eastern species (A) occurs in Gippsland, Flinders Island and north eastern Tasmania. The western species has two distinct genetic and geographic groups (likely sub-species): (B1) Murray-Darling Basin including the Mount Lofty Ranges and (B2) south east South Australia, western Victoria and northern Tasmania. Hence the new systematic framework identifies several different manage units in South Australia, with special relevance to declining population in the lower River Murray region[13,22].

Distributional data Information on the number of fish species and their distribution is critical to assess priorities for management and planning, and also links to assessing population trends. Freshwater fishes have been poorly surveyed in many areas of South Australia. For example, we know very little about the species occurring in the River Torrens that runs through the heart of Adelaide. Only opportunistic historic records occur, and early cataloguing and modern programs such as biosurveys across the State did not include fishes. Most of the available data is thus from more recent specialised fish surveys (see Section 1 and Appendix 3). A readily searchable database of State wide distributional information is required to incorporate existing data and highlight knowledge gaps.

Examples of data gaps include:

- Southern Fleurieu Swamps and waterways (only broad scale assessment conducted to date).
- Western Mount Lofty Ranges - survey intensity is patchy but it is an important region considering the amount of habitat present and levels of development.
- North Eastern Mount Lofty Ranges.
- River Murray wetlands – still a number of areas to be sampled for smaller species, especially with wetland drying occurring.
- Flinders Ranges – important refuge habitats and species to be mapped.
- Eyre Peninsula - limited data for systems including Todd River.
- Lake Eyre Basin – many regions need to be mapped and compared to historic data, especially important dry period refuges in the Cooper Creek and review of status of mound spring habitats and fishes.

Urgent conservation measures Many species with restricted and/or severely fragmented distributions and numerous near and present threats will require immediate action to secure sustainable populations into the future. The potentially short lifecycles of smaller species also heightens the need for action as one or successive years failed recruitment could have serious impacts. Species such as Yarra, Southern and Variegated pygmy perch, Flinders and Southern purple-spotted gudgeon, Murray Hardyhead and River Blackfish appear particularly at risk. The range of urgent conservation measures available will be specific to the location and habitat conditions locally and the broader catchment but could include:

- Special Environmental Water Provisions.
- Localised habitat management such as fencing or engineering works.
- Temporary captive maintenance or translocation to other suitable habitat[272].
- Regular monitoring.

Targeted awareness raising Given the low level of current available knowledge and awareness surrounding native fishes, some information should be targeted to highlight the presence and requirements of key threatened species or populations to ensure that relevant stakeholders are fully aware of their presence and implications of their actions/in-action. To some extent this has occurred through the invitation of input from key stakeholders on draft versions of this document. Regional or species workshops would be a valuable way to bring stakeholders together, present background information and build capacity to identify species, their conservation requirements, and scope and initiate actions and resources.

More general publicity of the plight of native fish could also generate some initial actions that can create momentum behind a more comprehensive approach to future protection, and may also help to engage the community and managers to provide new information to their knowledge of threatened species.

4.2. ADDRESSING HYDROLOGY, HABITAT AND WATER QUALITY

Environmental Water Requirements and Provisions Water is a primary consideration for securing threatened freshwater fish species. If appropriate hydrology is provided so that water is not a limiting factor, a sound platform for other restoration and conservation is secured. Management of surface and groundwater sources can take two basic approaches: (a) proactive or preventative measures to secure existing water sources (especially for unregulated systems like Coopers Creek and for catchments, sub-catchments or wetlands with less altered hydrology), and (b) restorative measures which is typically the more difficult task of returning environmental water to systems with heavy water resource development (e.g. areas with lots of farm dams or plantations, large reservoirs, high groundwater use and those that have been drained).

Options for returning environmental water include specific allocations in larger systems such as the River Murray and from reservoir releases in the Mount Lofty Ranges. For smaller systems, the management of farm and irrigation dams (e.g. adjusting overall capacity and adding low flow diversion), careful forestry planning and regulation/management of groundwater use are the main avenues. It is important that the methods of water return are not simplified to focus on flow volume alone, but should consider various other aspects of natural flow regimes (e.g. smaller flows over summer which are critical for protection of core refuge habitats, flow events with the appropriate timing and duration to allow fish migration, or flood peaks which mimic the natural rates of rise and fall).

Environmental Water Requirements (EWR) are delivered as provisions through the Water Allocation Planning (WAP) process. In the past, arbitrary and often small targets have been set for the amount of water to be retained or provided for the environment (10-30% of natural runoff or volume). However, studies investigating flow components and related processes required to meet environmental objectives (e.g. self sustaining fish populations, protection of core refuges) are likely to be much more appropriate and effective. Key challenges for future EWR assessments and reviews of existing WAPs will be to protect critical flows or refuges and to incorporate climate change scenarios as part of changing human and environmental needs in the future.

The establishment of truly effective environmental water provisions is likely to require an improved understanding of our freshwater ecosystems, freshwater fish biology/ecology, hydrological interactions between surface and groundwater sources, and models which account for variable South Australian climates (e.g. identify critical lows). Programs will require sufficient resources for education and enforcement, and importantly, water allocation planning requires support and commitment from community groups, business and government. Effective environmental water provisions can only be achieved if there is greater awareness of the problems facing our rivers and native fishes (see Brisbane Declaration below). An appreciation of the cultural, recreational, environmental and commercial importance of freshwater fishes is also needed to ensure a concerted commitment is made towards their conservation.

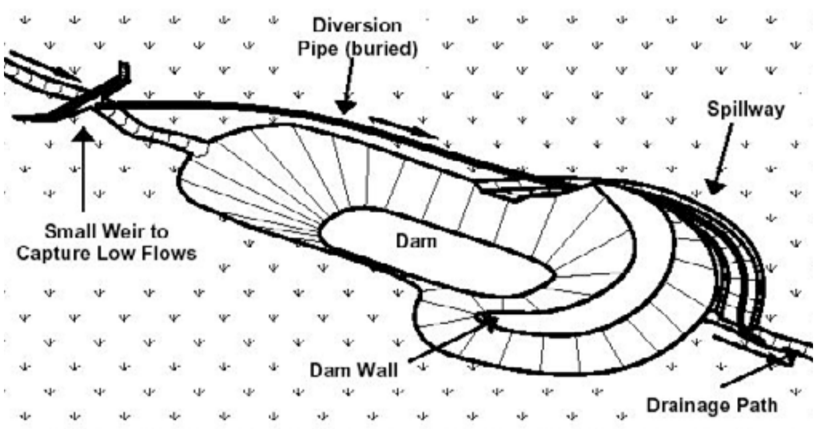


Diagram of a low flow diverter – designed to pass smaller flows critical to sustaining aquatic systems

The Brisbane declaration is a succinct summary of the need for understanding and providing Environmental Water Requirements. It is derived from summary findings and a global action agenda that address the urgent need to protect rivers globally, as proclaimed at the 10th International River symposium and International Environmental Flows Conference, held in Brisbane, Australia, September 2007. The conference was attended by more than 750 scientists, economists, engineers, resource managers and policy makers from more than 50 countries.

The Brisbane Declaration: Environmental Flows are Essential for Freshwater Ecosystem Health and Human Well-Being, key findings include:

- Freshwater ecosystems are the foundation of our social, cultural, and economic well-being. Healthy freshwater ecosystems – rivers, lakes, floodplains, wetlands, and estuaries – provide clean water, food, fiber, energy and many other benefits that support economies and livelihoods around the world. They are essential to human health and well-being.
- Freshwater ecosystems are seriously impaired and continue to degrade at alarming rates. Aquatic species are declining more rapidly than terrestrial and marine species. As freshwater ecosystems degrade, human communities lose important social, cultural, and economic benefits; estuaries lose productivity; invasive plants and animals flourish; and the natural resilience of rivers, lakes, wetlands, and estuaries weakens. The severe cumulative impact is global in scope.
- Water flowing to the sea is not wasted. Fresh water that flows into the ocean nourishes estuaries, which provide abundant food supplies, buffer infrastructure against storms and tidal surges, and dilute and evacuate pollutants.
- Flow alteration imperils freshwater and estuarine ecosystems. These ecosystems have evolved with, and depend upon, naturally variable flows of high-quality fresh water. Greater attention to environmental flow needs must be exercised when attempting to manage floods; supply water to cities, farms, and industries; generate power; and facilitate navigation, recreation, and drainage.
- Environmental flow management provides the water flows needed to sustain freshwater and estuarine ecosystems in coexistence with agriculture, industry, and cities. The goal of environmental flow management is to restore and maintain the socially valued benefits of healthy, resilient freshwater ecosystems through participatory decision making informed by sound science. Ground-water and floodplain management are integral to environmental flow management.
- Climate change intensifies the urgency. Sound environmental flow management hedges against potentially serious and irreversible damage to freshwater ecosystems from climate change impacts by maintaining and enhancing ecosystem resiliency.
- Progress has been made, but much more attention is needed. Several governments have instituted innovative water policies that explicitly recognize environmental flow needs. Environmental flow needs are increasingly being considered in water infrastructure development and are being maintained or restored through releases of water from dams, limitations on ground water and surface-water diversions, and management of land-use practices. Even so, the progress made to date falls far short of the global effort needed to sustain healthy freshwater ecosystems and the economies, livelihoods, and human well-being that depend upon them.
- Environmental flows describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems.

Habitat protection and rehabilitation Options for habitat protection and rehabilitation are essentially limited only by the ideas and capacity of groups and individuals involved, but it is important that some basic principles are followed. Many of our ecosystems have adapted to change, and are now relying on altered conditions (e.g. Murray Hardyhead in salt evaporation basins, River Blackfish and Willows). Essentially this means that the objectives and implications (positive and negative) of any planned restoration should be careful assessed at the outset. The same considerations apply to changes in landuse or management regimes.

Given that much of our knowledge on freshwater ecosystem restoration is in its infancy, it's important that any restoration program include sufficient monitoring to identify if restoration targets have been met. By monitoring sites before, during and after restoration activities have occurred, it enables an adaptive management approach to future design and implementation of restoration programs.

Although often aiming to assist in the recovery of single threatened species, restoration programs should adopt an ecosystem approach, which may includes managing fish communities. Ideally, actions should be aligned within broader plans (e.g. NRM/Catchment Management) and consider the catchment scale approach[273]. There are various guidelines available that may be of use in design and implementation of on-ground works[274,275,276].

Some fish related management programs and works that could relate to species recovery include:

- Environmental water provisions will help to maintain or increase the diversity of physical and biological habitat types.
- Strategic revegetation to increase suitable stream bank vegetation cover and related instream cover (shade, snags, leaf litter etc), provide a buffer from terrestrial impacts (edge effects such as runoff), and to upper catchment areas and swamps to help restore a flow energy balance (reduce incision) and improve water holding capacity for later release as low flow or springs.
- Instream works to improve habitat availability including options to stabilise stream geomorphology (e.g. banks), add cover (e.g. resnagging, rock banks, aquatic plants) and remove artificial structure or invasive species.
- Stock exclusion will help to minimise trampling of sensitive edge habitat and improve water quality. Even reducing stocking rates or limiting stock access during very wet and dry times could improve the condition of important stream edge or wetland habitat.
- Refuge sites should be targeted for habitat protection and restoration measures, with works expanding out from these points to encourage natural recolonisation.
- Siltation impacts should be targeted with revegetation and other physical control such as stormwater treatment especially for new developments (part of ESD guidelines –see later).
- Fish passage at artificial barriers (physical and biological) should be provided across the size spectrum of local species using modern or novel engineering solutions (but need to check and consider the impacts to species isolated upstream especially in reference to introduced predators).

On ground works such as fencing, revegetation and the provision of alternate watering points will not only help protect and expand populations of native fish, but also offer a wide range of other benefits such as:

- Improved water quality - for the environment and stock (less parasites and disease risk).
- Stock management benefits – e.g. easier to move.
- Possible financial gains - through efficient management, reduced erosion and loss of land.
- Biodiversity benefits - through the return of native birds and other wildlife.
- Aesthetics (visual) improvement - as green healthy areas look good!
- Social benefits - provides a sense of achievement and ownership.

Water quality Maintaining and improving water quality is essential for conserving our freshwater fishes. Water quality is heavily linked to environmental water provisions (e.g. for dilution and oxygenation), but the control of point source and diffuse pollution in rural, industrial and urban environments is also required. It is important that preventative measures are taken to ensure low or no levels of deleterious or toxic substances reach aquatic systems. As for habitat protection and restoration, many options for exist for improving water quality across South Australia, with many of the options covered under Environmental Protection Authority (EPA) guidelines or other action plans (e.g. salinity). Examples of water quality improvement methods include:

- Provide effective and monitored stormwater treatment for suspended solids (turbidity), nutrients and toxic substances (e.g. heavy metals, ammonia).
- Greater consideration for developments along side water courses to minimise stream bank disturbance, silt laden runoff and dust settlement (and include contingency for flooding).
- Identify and minimise risks from industrial pollution, especially in sensitive areas.
- Prevent saline discharge into sensitive aquatic habitats (e.g. drainage).
- Improved design in road infrastructure that discourages pigeon roosting (to reduce faecal matter entering the system).
- Riparian (stream edge) buffers to help filter nutrient and silt runoff and to protect against bank erosion.

A restored section of Mosquito Creek, SESA with healthy edge and instream vegetation, improved water quality, stable banks and developing canopy

4.3. **MANAGING ALIEN (INTRODUCED) FISH**

Preventative measures The easiest and cheapest way to control the impacts of alien fish is to prevent their establishment in the first place. Hence, reducing avenues of introduction (Section 3.4) should be the target of review, education and legislation to limit chances of additional species and disease entering our aquatic habitats[277]. This is of particular importance for areas which currently have few or no alien species established such as arid zone Springs, Cooper Creek and other central waterways, the Upper South East and parts of the Southern Fleurieu Peninsula and Mount Lofty Ranges.

Some primary recommendations include:

- Increased education within the community and government to improve awareness of the impacts of alien species (thus increasing the level of preventative control). Promote the fact that native fish occur in many waterways and that they play an important role in the functioning of such ecosystems.
- Review and possibly regulate fingerling sales to the public from local and interstate hatcheries. The aim of this initiative would be to further reduce the potential for inappropriate releases of alien (including non endemic) fish species.
- Develop a freshwater fish translocation and stocking policy (see below).
- Inform the community on the impacts of aquarium escapees and engage with the aquarium trade to spread the message and divert unwanted fish (and plants) to alternate sources.
- Encourage greater community involvement in conservation programs.
- Identify and engage groups likely to release alien for cultural reasons.
- Respond quickly to new incursions to prevent spread and develop the contingency and capacity to respond (including remote locations).

Preventative measures of course do not deal with the significant issue of already established species, although several principles could help minimise their spread and control, with topics on control explored below.

Environmental management By managing the environment, the impacts to native fish posed by introduced species can be reduced in two general ways:

- To promote the environmental requirements of native fishes to increase their population size, health and hence resilience to the impacts of introduced species. For example, increasing habitat complexity (e.g. fencing to protect sensitive riparian vegetation and resnagging) may lessen direct interactions between alien and native species; environmental flows may maintain habitats as a refuge for native species; or combined suitable habitat and flows may allow strong native fish recruitment and subsequent larger populations to help negate the effects of predation and competition. Furthermore, healthy native fish populations, with naturally occurring larger predators such as Murray Cod, may in fact help restore a natural balance through their feeding on introduced fish.
- Provide environmental conditions which discourage or impact introduced species via protection of natural conditions (less disturbed environments) and manipulation or restoration in more disturbed areas. Several studies have found that regulated environments in the Murray-Darling Basin can favour the recruitment and establishment of species such as Goldfish, Carp, Redfin and Gambusia[25,240,278] whilst natural environmental extremes such as flood and drought limit the distribution and success of species like Gambusia, trout and Redfin[13,118,279,280]. Hence, within Environmental Water Requirement studies and provisions, seeking naturally variable flow regimes (e.g. floods, water level fluctuations) and water quality conditions (e.g. temperature and salinity) may contribute to managing introduced species.

Translocation and stocking Current attitudes and practices in regard to fish stocking and translocation in South Australia are in contrast to those of other vertebrate groups. For example, it is not legal to release the introduced Red Fox and in fact, extensive programs of control exist across the country to mitigate their impact on the natural environment. However, it is still permitted to release a comparably significant exotic predator, trout, into waterways and areas that contain threatened fish species, even though it may directly impact on the survival of native species. While active stocking of exotic species might only be a part of the problem that native fish face, it is an area which can be controlled and is currently something which sends a disappointing message about our commitment to the conservation of our unique native fish species.

A formal policy for introduction, translocation and stocking in South Australia, supported with a legislative and administrative framework, is required to identify and minimise risks of incursions to artificial and natural waterways. Ideally, the policy should align with that for other vertebrates in South Australia[272], as well as the National Policy for the Translocation of Live Aquatic Organisms (1999). Such a policy would also raise awareness about the impacts of both exotic and Australian native species outside their natural range, and define the appropriate methodology to minimise or prevent risk to wild fish populations and ecosystems.

Some key elements may include:

- Risk assessments for local environments and species.
- Developing environmental safeguards for the timing and nature of any remaining stocking, especially related to threatened species and during periods of environmental stress.
- Developing understanding of genetic structure in native fish populations to facilitate appropriate management and breeding of genetically appropriate stocks to supplement wild populations.
- Ensure strong protocols and procedures are maintained to minimise the risk of introducing disease and parasites to wild populations.
- Coordination with interstate agencies for shared catchment areas.

For translocations to artificial habitats (e.g. dams), a range of factors should be considered in species selection[251]:

- Wetland position – can species escape? If so it may then be appropriate to limit the release options to those species which occur naturally in the local area to limit the ecological impact and genetic contamination.
- Accurate recent information on local native fish and other important ecological assets and their distribution.
- Biological characteristics of target species to ensure the broader wetland environment is conserved.
- Collection of broodstock from the wild should not threaten the viability of the source population.

Other control options Control of alien species is difficult once firmly established but there are several methods and emerging technologies aimed at suppressing or removing introduced species. Control should be targeted to areas where it is likely to have the greatest benefit and where identified/predicted impacts are high or of significant consequence.

In small systems, simple physical control such as angling or permitted physical removal including netting may help to provide habitat for native fish to colonise[281] or lessen the impacts to restricted native fish populations (e.g. removal and community fish outs of Redfin surrounding Pygmy Perch habitat[22]). Outright control with fish poisons may be possible in small areas, but great care is needed to ensure care of the general environment[281].

Identifying biological weaknesses of alien species (such as key spawning requirements, movement patterns or tolerances) may then provide management options that can be targeted for engineering solutions or environmental manipulation. For example, Carp separation cages are a new technology which targets a specific behaviour to enable selective harvest at places such as fishways[282]. Barriers have also been built to protect small pockets of refuge habitat for native fish and prevent upstream movement of trout in Victoria[283]. Biological control (disease agents) and gene technology are being trialled as potential control methods for Carp and one day may also be available for use in the control of Gambusia.

Minimising disease risk Currently live fish can only be brought into South Australia if they have been certified free of disease. However, as many pathways exist, disease risk should be reviewed concurrently with any introduction as a proactive measure (i.e. incorporated into a translocation and stocking policy). This will help prevent potentially costly and devastating disease outbreaks. Any proposal to release fish to the wild should specifically include a review of quarantine procedures (including the movement of equipment), and other potential disease pathways such as interbasin water transfer (e.g. alternate water supplies/transport methods, water treatment, screens). Reducing the opportunity of new diseases and parasites is the most cost effective way to ensure the protection of freshwater fish in South Australia.

Research to improve our knowledge of current and potential diseases and parasites of wild freshwater fish in South Australia is required. A program to receive enquires, diagnose noticed problems, and routinely monitor for new outbreaks needs to be developed. Importantly, this is beginning to be addressed through initiatives such as the Australian Wildlife Health Network, a network that has been designed to capture information and investigate occurrences of existing and emerging diseases.

4.4. NEW DIRECTIONS IN FISH CONSERVATION

State of the art research and management Developing a better understanding of the role and response of fishes within ecosystems, as well as the response of fishes to various management regimes, will greatly aid in the protection of threatened species and communities in general. Sound research and management strategies are required in fields such as development and planning (in particular Water Allocation Plans and Environmental Water Requirements), habitat restoration, alien species management and tackling climate change. The careful monitoring of our fish populations is likely to play a pivotal part in ensuring adaptive management frameworks are available.

The triple bottom line Increasing awareness of fishes, biodiversity and natural systems will help to increase their value and give them greater consideration within the community, business, planning and development, and the day to day activities of government. Increased understanding and appreciation of the benefits provided by our native animals and habitats is needed to better align their conservation value with economic and social values. This will better enable their true conservation benefit to be fully realised. Ecologically sustainable development (ESD) is seen as way of harnessing natural resources whilst protecting their existence and function, whilst in reality, many changes in landuse and development will have some form of negative environmental impact. It is therefore critical to ensure that when development impacts are identified, the effects are minimised and clear efforts are made to incorporate habitat protection and restoration with any proposal. ESD underpins many pieces of legislation in South Australia, however, greater emphasis on this philosophy is required within planning, policy and development guidelines to accurately reflect the needs of fishes and aquatic habitats.

Monitoring habitat and flow restoration The key to any successful restoration program is the development of detailed plan at the outset, including a detailed monitoring strategy and good documentation. Programs should include S.M.A.R.T. (specific, measurable, achievable, realistic and time-bound) targets to enable progress to be readily assessed and to utilise resources most effectively. This approach allows for adaptive management, enabling past experiences to be incorporated into programs, rather than acting in isolation or repeating previous mistakes.

The restoration of South Australia aquatic habitats has seldom included objectives relating specifically to fish, although there are some significant recent examples in the River Murray system such as the Fishways Program, and an increase in the occurrence of Environmental Water Requirement studies. Hence, while actions such as fencing and exotic plant control in theory provide benefits for fishes, this is often not supported with data showing the response by fish as key environmental indicators. In some areas, restoration efforts aimed to enhance aquatic diversity will be severely hampered by the high abundance of exotic predatory fish and this requires specific recognition within broader catchment management programs.

A key recommendation to underpin both environmental restoration and risk assessment is the undertaking of routine monitoring to identify risks and examine fish community and habitat state before, during and after actions.

Tackling and preparing for climate change The ability of fishes and other biota to cope and ultimately adapt to climate change will depend on the characteristics of particular species and ecosystems, some level of management and probably in many cases, chance. In a sense, we currently have a small window of time to repair damaged systems and ensure populations are as healthy as possible in the lead up to any change. The best prescription for climate change is to sensibly manage and protect systems from external influences (e.g. habitat damage). Emphasis on adequate environmental water allocations will ensure healthy habitats and strong populations exist to face any future change. Research to understand tolerances and requirements of native fish will also help to identify key areas of impact and hence targets for action.

The other aspect of tackling climate change is reducing use of and reliance on carbon. There is an increasing awareness of things that individuals, businesses and governments can do to reduce environmental impacts, such as switching to renewable energy, using less energy for transportation and living, minimising consumption, packaging and waste. Environmentally sensitive plantation (i.e.

not impacting stream flows) and revegetation is a growing consideration, particularly with the rapid increase in carbon credit and carbon offset initiatives.

Fishways Fishways or fish ladders provide a physical conduit for species to scale and pass artificial physical barriers. Recent research and thinking on fishways has resulted in improved design, with structures now engineered to cater for local conditions, the swimming ability of native species, and also their biology and behaviour[151,284,285]. Fishways can range from significant engineering works to small modifications or alternate movement pathways such as artificial creeks. Improving fish passage has been a major focus in the Murray-Darling Basin, with fishways on the Barrages and weirs along the Murray proving effective at allowing passage to a variety of species and sizes of fish during low flows (which now predominate in the system conditions[142]). Fishways have also recently been installed at the mouth of the River Torrens, and also as part of a restoration program to restore water levels in the Piccaninnie Ponds area.

Recommendations relating to continued progress in restoring fish passage include:

- An inventory of barriers on waterways in South Australia ranging from major obstacles to critical local obstacles such as road culverts[286].
- Monitoring to assess impacts of barriers to help prioritise actions. This includes assessing fish populations that may be conversely protected by barriers (e.g. limiting introduced fish access).
- Remove or construct appropriate fishways on priority barriers that inhibit migration.
- Potential new barriers (e.g. flood mitigation dams and gauging weirs) must include fishways.
- Monitor the effectiveness of fishways including fish movement and upstream community change. The modification of structures may be required in some instances.

A new fish ladder (circled above) at the mouth of the River Torrens allowing movement of fish from the sea into freshwater over the Breakout Creek weir

Fisheries Within fisheries legislation and management there is a move toward ecosystem based fisheries. This includes the recognition of the need for healthy habitats and ecosystems that can then provide for ecologically sustainable development (harvest) of wild fishes. Under this premise, harvest and management of fishes needs to reflect the highly variable nature of aquatic environments in South Australia and heavy alteration of flow regimes and habitats. For example, for some species that are highly threatened, harvest in the short-term is not sustainable and management regulations may need to have sliding scales to protect important breeding stock during times of natural or induced drought (e.g. Lake Eyre Basin Golden Perch and Murray Cod). A benefit of proper ecosystem based fisheries is that the recreational, commercial and cultural values of fisheries will provide awareness and promote better environmental management and health to support human values and needs. Conversely the approach invokes the responsibility of stakeholders to ensure that their activities are both sustainable to the species and ecosystems they target. This obviously requires good communication, awareness and involvement of the various stakeholders across conservation, natural resource development, recreation and heritage.

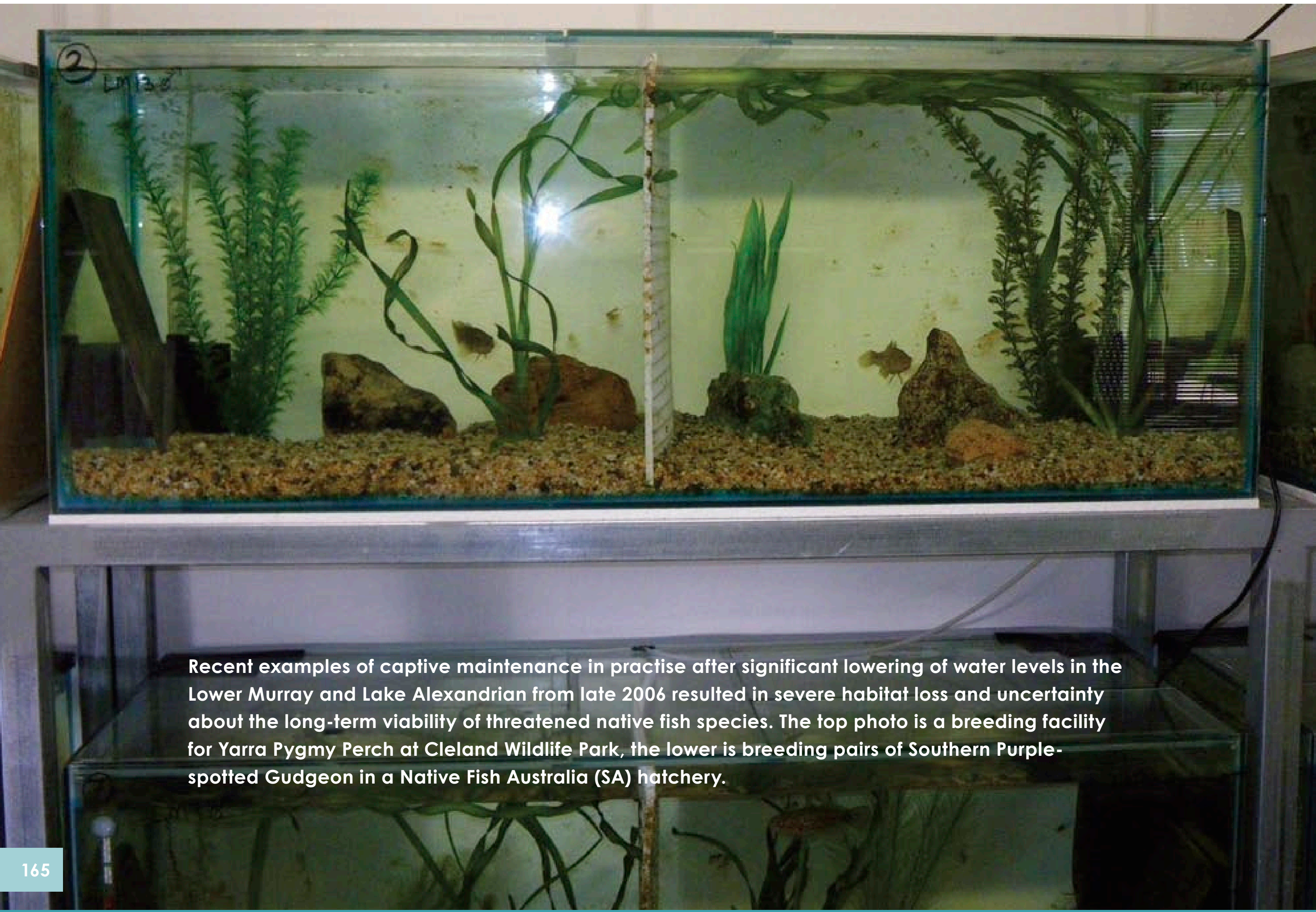
Positive new directions in fisheries also include a growing 'catch and release' ethic which, if supported with careful handling and treatment of fish, promotes sustainable recreation. Some fishing groups are realising the importance of healthy aquatic habitat and flows in protecting fish stocks and are getting involved with local habitat improvement initiatives or providing input and support to environmental water provisions.

Captive management Maintaining threatened species in captivity for short or long time periods should be seen only as a last resort effort to protect against catastrophe such as potential local extinction. A capacity for maintaining fish in captivity should not be cause for reducing efforts to conserve species in the wild. There are also high level of risks associated with captive maintenance, such as potential fish losses, maintaining genetic variation and fitness, and disease contamination[287]. Maintaining fish in captivity is costly (i.e. time consuming work for a long period) and places greater responsibility on individuals and management for species survival.

The method can however provide an important backup under extreme scenarios and has value in education on the plight of species. There may be different goals for captive fish including:

- Temporary captive maintenance – fish are held temporarily until suitable conditions occur and are then returned to the point of capture.
- Establishment of an ex-situ population – fish are maintained, spawned and reared in captivity as a backup in case of catastrophe and as a resource for conserving the wild population.
- Population supplementation or re-introduction program – major local declines or extinctions can drive captive breeding initiatives to supplement or re-establish a population with fish bred in captivity (usually from original broodstock).

Each of the above goals, and indeed species, can require a different approach to captive maintenance (e.g. temporary care of adults versus providing space and conditions for spawning and rearing juveniles) and therefore programs must be mindful of different variables such as the potential short life span of some smaller species. Re-stocking and sustaining captive populations requires consideration of genetic issues to avoid negative impacts from reduced genetic diversity. Re-stocking initiatives must be done in conjunction with the maintenance and/or restoration of habitat, utilising avenues such as environmental water provisions, habitat restoration and engineering solutions to do this. Timing of a decision to undertake captive maintenance is also important as it may be too late once a species is already on the edge of extinction[119]. Recent examples of captive maintenance include Yarra Pygmy Perch from Lake Alexandrina and Southern Purple-spotted Gudgeon[113,119,129].



Recent examples of captive maintenance in practise after significant lowering of water levels in the Lower Murray and Lake Alexandrian from late 2006 resulted in severe habitat loss and uncertainty about the long-term viability of threatened native fish species. The top photo is a breeding facility for Yarra Pygmy Perch at Cleland Wildlife Park, the lower is breeding pairs of Southern Purple-spotted Gudgeon in a Native Fish Australia (SA) hatchery.

4.5. IMPROVING PROTECTION

Legislation There is currently a cross-match of legislation available to protect fish species and habitats in South Australia, with the best opportunities to improve its effective use being through a greater focus on developing or strengthening specific policy and coordination between government agencies. As with most legislation, increased community awareness (and hence community support) is needed to recognise and respond to what may constitute a potentially significant impact (e.g. page 167). Some aspects of government policy, such as permitted release of exotic species, conflicts with other legislation including "No Species Loss" and habitat restoration initiatives (e.g. Naturelinks), and a review to identify and address such perverse incentives would be a major advance in fish conservation in this state.

A very brief synopsis of the objectives and application of the relevant legislation is provided below, but for more information consult the Acts in detail (www.austlii.edu.au) or contact relevant government departments:

- ***EPBC Act 1999:*** provision for protecting nationally listed species (8 of which occur in South Australia) and ecological communities (Desert Mound Springs and Southern Fleurieu Swamps): 'avoiding, remedying or mitigating any adverse effects of activities on the environment and to prevent, reduce, minimise and, where practicable, eliminate harm to the environment'. The list of federally threatened species and ecological communities now warrants a review, primarily to incorporate new information available on South Australian fishes and freshwater ecosystems. It is likely the several additional South Australian freshwater ecological communities are eligible for listing under the *EPBC Act* (e.g. Lower South East rising spring habitat).
- ***Natural Resources Management Act 2004:*** the most holistic legislation relating to protection of ecosystems, ecological drivers (flow and habitat) and species with an overall aim to assist in the achievement of ecologically sustainable development. Objectives are wide ranging and cover many important aspects such as: recognising and protecting the intrinsic values of natural resources; biodiversity conservation; protecting, restoring and managing ecological systems or catchments, prevention or control of impacts caused by pest species; and education and capacity building. Incorporates the Water Resources Act 1997.
- ***National Parks and Wildlife Act 1972:*** provision for the official listing of conservation status of threatened species and the protection and management of species within reserves. Fish have been considered for future specific inclusion[38,286], but this must be formalised to provide an official conservation list.
- ***Fisheries Management Act 2007:*** ensuring, through proper conservation, preservation and fisheries management measures, that the living resources of South Australian waters are not endangered or overexploited. Main application has been: 'Protection' of species from exploitation, regulation of take (e.g. commercial and recreational fisheries), and controls on exotic species.
- ***River Murray Act 2000:*** aims for a healthy River Murray with specific river health, environmental flow and water quality objectives including that the key habitat features in the River Murray system are to be maintained; wetlands of national and international importance are to be protected and restored to enhance ecological processes; barriers to the migration of native species of animal are to be avoided or overcome; the extinction of native species of animal and vegetation associated is to be prevented.
- ***Environmental Protection Act 1993:*** designed to safeguard the life-supporting capacity of air, water, land and ecosystems within an ESD framework and has a mandate for avoiding, remedying or mitigating any adverse effects or harm of activities on the environment.
- ***Development Act 1993:*** regards all matters of resource management with aims that include to facilitate sustainable development and the protection of the environment and to encourage the management of the natural and constructed environment in an ecologically sustainable manner.

TOP Angas River major instream earthworks near Strathalbyn
BOTTOM LEFT Bremer River dammed and filled with silt as part of road works at Harrogate
BOTTOM RIGHT Finniss River dammed, flooding small pool habitat and blocking fish passage

Examples of recent (after 2002) habitat destruction in threatened species habitats in the Eastern Mount Lofty Ranges undertaken by a developer, local council and landholder respectively. Greater legislative protection and enforcement is required to provide sufficient deterrent to prevent such destructive actions, combined with a greater awareness of the presence and requirements of fish within regional planning, government bodies and the wider community.

Links to other plans There is a plethora of existing plans and programs which have the potential to consider and incorporate fish information or actions to help towards species recovery and improved awareness. Some plans have specific targets that directly benefit threatened native fish (e.g. MDBA Native Fish Strategy[236]) and compliment the objectives of this Action Plan. However, other broadly related plans often have a tailored framework that focuses on their relevant topic, with significant gaps in objectives and information relating to native fish. For these and developing plans, especially regional NRM plans, the presence of a specific freshwater fish Action Plan provides an information source and avenue for holistic treatment and identifying relevant threats and actions. Table 6 provides an initial list of relevant plans that can assist in delivering positive outcomes for South Australian native fish.

Table 6. Synopsis of plans relevant to the conservation of freshwater fishes in South Australia.

Plan	Application
National	
Native Fish Strategy for the Murray-Darling Basin 2003-2013	A comprehensive document aimed at rehabilitating native fish communities back to 60 per cent of their estimated pre-European settlement after 50 years of implementation. A series of overarching objectives relating to healthy native fish communities and habitats, threatened species conservation and alien fishes. Drives coordinated cross jurisdictional action and provides an excellent framework for the SAMDB, that could be adapted to other regions.
Living Murray initiative (current phase 2004-2009)	A program established in response to declining health of the River Murray system, being a partnership of the Australian and State/Territory governments. A first step focuses on recovering 500 gigalitres of water for the River Murray by 2009, specifically for the benefit of plants, animals and humans it supports, and improving at six icon sites (SA has Chowilla, the Murray channel and Lower Lakes).
Action Plan for Australian Freshwater Fishes (1993)	The seminal document providing baseline coverage for threatened fish issues and potential actions for Australia, although now is in need of review. Contains Recovery Outlines for several species occurring in South Australia.
Ramsar Convention on Wetlands (signed 1971)	The Ramsar Convention is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. Australia is one of 156 contracting parties, with six Ramsar listed wetlands in South Australia. The South Australian Government is preparing management plans for Ramsar Wetlands based on the wise use and the protection of waterbirds and their habitats...(need to be holistic).
National Plan for Water Security (2007), also a new Basin Plan in development	Relevant objectives include to: address over-allocation in the Murray Darling Basin, develop new governance arrangements for the MDB, set and administer a new cap in the MDB, continue the restoration of the Great Artesian Basin.
National Action Plan for Salinity and Water Quality (2002-2008)	A commitment by the Australian, State and territory governments to jointly fund actions tackling two major natural resource management issues facing Australia's rural industries, regional communities and our unique environment.

Table 6 continued...

Plan	Application
Australia's Biodiversity Conservation Strategy 2010–2020,	Developed through a Review Task Group that reports to the National Resource Management Ministerial Council (NRMMC). The Draft Strategy includes six priorities for change: building ecosystem resilience; mainstreaming biodiversity; knowledge for all; getting results; involving Indigenous peoples; and measuring success.
National Threatened Species Recovery Plans	Recovery plans are developed for *EPBC Act 1999* listed fish species, several of which occur in South Australia. Incorporation of South Australian information and objectives into reviews and new plans is required.
National Recovery Plans for threatened ecological communities	Recovery Plan initiated for Swamps of the Southern Fleurieu by the Conservation Council of SA with a Recovery Team established. Could further incorporate the requirements and thinking on fish such as Southern Pygmy Perch
Regional Recovery Pilot Project – Adelaide and Mount Lofty Ranges	The Commonwealth Government is investigating multi-taxa regional recovery planning options for threatened species and communities. The Regional Recovery Project will pilot the development of a Regional Recovery and Threat Abatement Plan in the Adelaide and Mount Lofty Ranges Region.
Australian Pest Animal Strategy (2007)	A vision that 'Australia's biodiversity, agricultural assets and social values are secure from the impacts of vertebrate pest animals' - to address the undesirable impacts caused by pest exotic vertebrate animals mammals, birds, reptiles, amphibians, and prevent the establishment of new pests. Links to alien fish management. A Strategic Approach to the Management of Ornamental Fish in Australia Aims to provide a framework for identify and regulating noxious species in the Aquarium trade which could cause environmental harm in the natural environment.
South Australia	
No Species Loss - a Biodiversity Strategy for South Australia 2006-2016	Provides a framework to act to halt species decline – 'all threatened species and ecological communities must be improved and where possible restored, requiring long lasting, strategic and creative partnerships of community, industry and government'. Freshwater fishes must be brought into the thinking and implementation of this strategy.
State NRM Plan (2006)	Seeks to integrate NRM across all public and private lands, in partnership with government, industry and community. Objectives associated with water allocation and planning, habitat protection and restoration (e.g. wetlands), biodiversity conservation and invasive species provide key links to freshwater fish conservation. Regional Recovery Plan for Threatened Species and Ecological Communities of Adelaide and the Mount Lofty Ranges A national trial for multi-species recovery, includes including the 203 species profiles: follow the links at: http://www.environment.sa.gov.au/biodiversity/threatened-species/regional-recovery-pilot.html
Regional NRM Plans and Investment strategies	Identifies resource condition targets, threats, environmental objectives and priority actions. These Plans are in development, so it is an ideal time to incorporate fish information and priorities in different regions. Updates and incorporate Catchment Plans. A range of plans are being developed for the Lower Murray Region in reponse to critical drought conditions (e.g. Murray Futures).
Regional biodiversity plans	Plans developed for various regions of the State, generally limited information and priority on fish issues (should be improved).

Table 6 continued...

Plan	Application
Parks Management Plans (State Reserve system)	Provide an information base and management direction within various lands in the State Reserve system. Fish are infrequently mentioned and considered and most plans require updates to this end.
State Water Plan (2000)	Sets out principles for the management of water dependent ecosystems, guides various strategy and policy.
Wetlands Strategy (2003)	Seeks more dedicated and integrated approaches to the management of wetlands in South Australia with a goal to see 'Wetlands recognised and managed as ecological community assets for the benefit of present and future generations'.
Wetland management plans	Management plans for individual wetlands normally devised to guide areas with control structures. Baseline surveying to identify ecological assets and strategies to prevent harm to native fish (e.g. drying of populations) should be important components.
Marine species at risk	Review and recommendations concerning conservation of South Australia's marine bony and cartilaginous fish. Significant overlap with the freshwater fish Action Plan for diadromous and euryhaline taxa.
Management strategy for the sustainable development of recreational fishing (2001)	Review of recreational fishing with a mission to optimise the long term value of, and opportunities for, a sustainable recreational fishery in South Australia, based upon sound management and a healthy environment. Links to recreational catch and effort and utilisation of threatened species.
Biosecurity Strategy for South Australia (2005)	Addresses biosecurity to protect primary industries, the environment and the community, complements the National Biosecurity System, establishing high-level directions for State policy and biosecurity activities. There is a potential link to a translocation and stocking strategy and fish quarantine procedures.
State of the Environment reporting (SA)	The next State of the Environment Report is due out in 2008. The Report will provide analysis of an extensive amount of environmental data across a wide variety of environmental topics and investigate broader issues that need to be considered in creating a sustainable South Australia. Of great interest will be the impact of the current drought on South Australia's environment.
Planning strategy (medium term - 10-15 years).	The Planning Strategy provides direction from the State Government on landuse and development. The Strategy contains various maps, policies and specific strategies, covering a full range of social, economic and environmental issues. These provide direction and a resource for Councils undertaking strategic planning processes, including strategic management plans, Development Plan reviews and Development Plan Amendments.
Greenhouse Strategy 2007-2020	South Australia's long-term response to climate change with a series of strategies and an Action Plan for the State to effectively address climate change. The action plan is a framework to guide the activities of government agencies in implementing the strategy for South Australia to meet its commitment to achieve the Kyoto emissions reduction target within the first commitment period of 2008-2012.
Naturelinks Strategy 2002	A program that aims to conserve South Australia's species and habitats in partnership with the community by establishing ecological links across land and sea.

Aquatic protected areas Reserves are one way of protecting areas of habitat, but there are several challenges in defining reserves or protected areas for aquatic species. The connectivity of freshwater systems means that broader issues (such as flow regulation and water loss, fish introductions and exploitation) can often override any site protection program. Therefore, a holistic approach to fish conservation is needed in order to truly be effective. Whilst the State Reserve system in South Australia (e.g. National Parks, Conservation Parks etc) has never been specifically designed for fish, however several parks are notable for fish they contain and can thus offer the opportunity for local habitat and species protection. Dalhousie Springs, Balcanoona Creek, Ewens Ponds, Bool Lagoon, eastern Hindmarsh Island, and Chowilla are notable examples of reserve areas with high fish diversity or key threatened fish populations. South Australia also has Ramsar wetlands which include international obligations for national action for the conservation and wise use of wetlands and their resources namely:

- Coongie Lakes
- Riverland (Chowilla region)
- Banrock Station wetland
- The Coorong, Lake Alexandrina and Lake Albert
- Bool and Hacks Lagoons

To ensure that the State Reserve system effectively caters for both freshwater and terrestrial biodiversity, it would be advantageous to undertake a thorough inventory of fishes and threats within State Reserves. Such information would be valuable to feed into Park Management Plans and for the development of education and awareness programs for community utilising reserves. Increased awareness of aquatic biodiversity within reserves may also ensure that reserves themselves are considered within broader natural resource management issues such as environmental water requirements and assessments of upstream development. A review of Reserve coverage (in regard to fish species and habitat types) may also be useful for reserve planning purposes. Links between terrestrial and marine parks may also help to protect intervening estuarine areas that are significant sites for numerous species.

4.6. WAYS FOR INVOLVEMENT

Who is responsible (major stakeholders) Conservation of fish, especially smaller species, and protection of their habitat has essentially fallen through the gap of traditional threatened species management (terrestrial focus) and fisheries management (focus of larger commercial species). HIstorically, this has led to a degree of inactivity in regard to freshwater fish conservation, an issue not helped by a relative lack of awareness of this taxonomic group. However, various initiatives by individuals, groups and government has meant that a solid base of information is now available to make significant advances in fish conservation. It is important that a well coordinated State-wide approach be taken to make the most rapid and effective progress. Greater coordination will help engage all stakeholders and provide clearer direction in regard to policy, planning and project initiation. Having an interagency and cross jurisdictional framework to undertake recommendations and actions from this Plan will provide the greatest opportunity for success. Indeed, this will also help harness a new wave of interest in native fish as part of holistic natural resource management.

A second and critical process is the engagement of all stakeholders in implementation of required actions. As mentioned at the outset, this range of stakeholders is diverse, covering decision makers, funders and or doers, and ways for involvement for these groups should become clear from the content and recommendations contained herein. The major stakeholders and their reasonability or potential ways for involvement are outlined in Table 7.

Changes in attitude and awareness Historically, life hidden below the water's surface has been a

Table 7. Outline of major stakeholders that should be involved with implementing the Action Plan.

Who	Example body or group	Role or responsibility
Federal government	DEWHA, MDBA	Nationally listed species/communities and cross jurisdictional coordination of action and funding.
State government	DEH	No species loss, recovery planning, reserve protection (species and habitat).
	DWLBC	Sustainable use of water resources, biodiversity conservation.
	NRM Boards	No species loss, sustainable use of natural resources, habitat protection, threatened species.
	PIRSA	Management and protection of aquatic resources, sustainable use, protected species.
	EPA	Environmental protection/pollution control. Objectives and policy also outline environmental harm including losses of fish.
	Other (e.g. SEWCDB, USE Scheme, Transport SA, ForestrySA)	Ensure the identification, protection and enhancement of existing ecological assets.
	Councils and planners	Key role in ensuring new and existing development and practices alongside aquatic habitats does not jeopardise threatened species, and that their requirements are considered in plans and assessments.
Non-government conservation organisations	TSN, CCSA, Nature Foundation (SA), NFA(SA), Waterfind Environment Fund	Implement onground actions, harness community interest and knowledge. United lobby to influence government decision making and planning.
Community groups	LAPs, Indigenous Communities, Landcare & Catchment groups, Friends of Parks, angling clubs	Consider fish conservation in existing or planned activities, generate awareness and action for species in their area of interest.
Research organisations	Universities, SARDI, SA Museum, CSIRO	Focus on and drive research and monitoring of threatened species and ecosystems.

bit like 'out of sight, out of mind', which in some instances has equated to a lack of care or focus relating to the management of fish populations and their threats. From a social and perhaps political point of view, the value of water resources for human use seemingly far outweighs the intrinsic value of water dependent fauna and flora and, combined with an overall low level of awareness on the existence and plight of freshwater fishes, acts as a major barrier to conservation.

Fortunately, a change in attitude toward the conservation of native fishes and the holistic protection of habitats (e.g. water catchments) is starting to occur. This primarily relates to an improvement in awareness reflected in three key attitudes:

- Identify fishes as an important fauna group that deserve recognition at the same level as other vertebrates in South Australia.
- Recognise the biodiversity value and ecosystem services provided by native fish, in addition to the resource or fisheries value.
- Value native fish higher than exotic species.

In many cases, improved awareness through access to accurate information about species and appropriate planning could avoid many of the impacts on native fish caused by human activities. This document now provides an opportunity for planners to better address the needs of freshwater fishes. Methods to increase community awareness are needed to expose native fish species to the general public, especially in areas where people can be involved in species conservation. Example avenues include:

- Interpretive materials (website content, brochures[106,121,201,288], posters, signage).
- Primary school and high school resources (kits, games, colouring stencils, hands on exercises, promote ownership of a species or local patch of aquatic habitat).
- Media and public presentations, public aquaria and displays (e.g. Zoo, schools).
- Promotional events and market image (e.g. Chocolate pygmy perch).

A promotional event with a local chocolate company resulted in a release of a especially labelled chocolate fish to help promote awareness for the recovery of Southern Pygmy Perch. The successful release was accompanied by brochures, posters, colouring competitions and give-aways at schools and community events in the EMLR, within the range of the real pygmy perch. This event was successful in its goal to raise community awareness about this threatened species. Haigh's currently market a chocolate Murray Cod with part proceeds going to native fish conservation.

Role for the community The community play a pivotal role in the conservation of freshwater fishes, both broadly and locally. By adopting best environmental practices in their day to day activities, being a voice for encouraging conservation and sustainable development and by assisting in conservation/research activities, the community can greatly improve the conservation prospects for many of our species. Some more detailed points include:

• **Attitudes and awareness:** one of the main avenues in helping to change attitudes and increase awareness is through word of mouth, involvement in education.

• **Reporting information:** the Government has a Fishwatch free call number (1800 065 522) to report any suspicious or illegal activity. Ideally, other information such as sightings of threatened fish, oral history or habitat threats should also be reported in a similar manner (however a contact point and website would need to be established).

• **Recreational angling:** harness the interest and knowledge of recreational anglers to ensure sustainable harvests (e.g. catch and release ethic) and to protect habitat and smaller species.

• **Waterwatch:** a program involving the community and school children with environmental monitoring (including invertebrates and water quality). This is also an ideal pathway for teaching about local native fish and their requirements.

• **Fish handling:** in research, community monitoring or angling, there is a need for improved understand of how to handle fish safely, to prevent personal injury (e.g. from Freshwater Catfish spines) but also to minimise damage to fish. For example, fish should obviously be out of water for the minimum period possible, kept in the shade, and not be handled directly (as this can damage scales and sensitive mucus coating (use a soft net instead, or at least have wet hands). Larger fish should be cradled in the water rather than lifted to prevent internal and spinal damage.

Research priorities

- Research to underpin effective implementation of onground works and programs (e.g. WAP) is imperative, with research priorities including:
- Systematics and Genetics: Such information is needed to improve our understanding of the number of species, their distribution, conservation units and status.
- Biology and Ecology : This will provide the necessary biological data to inform management (e.g. water requirements, spawning conditions, key habitat, species tolerance information)[289].
- Habitat Management/Manipulation: Monitoring the response of fish and habitats to changing conditions and threat abetment activities is needed to feed adaptively into species recovery management plans.
- Climate Change Modelling: Tracking and predicting responses to climate change will assist with the development of appropriate preventative planning and restoration.
- Social Research: To better identify social attitudes to determine S.M.A.R.T. targets for awareness and education.

An important aspect of research must include strong collaborative links, publication and peer review and information sharing to provide a combined front to achieve collective goals. Effective communication and knowledge exchange within management and the community is also vital to generate interest, awareness and further engagement in fish conservation activities. Skill, consistency and verification in fish identification could be improved in South Australia, and procedures for the ethical and safe treatment, handling, and survey design should be incorporated into organisational activities (e.g. minimal impact to threatened species, sterilisation of gear, non-target organism).

Capacity for action A new wave of interest and involvement in native fish conservation will require specific expertise and capacity within government and community groups and research organisations. Some requirements for building capacity include:

- Higher education and training avenues to produce individuals with the appropriate background in conservation biology, ecology and resource management.
- Contact points for educational and technical information.
- Recognition of funding sources.
- Strong taxonomic base for routine verification and clarification species (e.g. increased capacity, use and accessibility of the SA Museum specimens).
- Body to drive and develop conservation initiatives and dedicated staff to specialise and implement species recovery actions.
- Action leads to action – develop initial projects that build understanding and provide experience, enabling the development and refinement of new projects.

Underwater view of Ewens Ponds– education is required to help remove the barrier between the water's surface and the life occurring below

4.7. MAJOR RECOMMENDATIONS

Securing and restoring habitat and populations:

- **Water:** develop water allocation plans that protect and restore water requirements for sensitive aquatic ecosystems and fish across all regions of South Australia. This will require a strong commitment by stakeholders to ensure freshwater fishes and their habitats remain for future generations.
- **Habitat:** improve riparian and instream condition, vegetation buffers, water quality, and fish passage (past artificial barriers) through well planned and monitored habitat protection and rehabilitation.
- **Protected areas:** improve our understanding of protected areas to provide greater capacity to cater for the conservation requirements of freshwater fishes, including inventory and planning within the existing State Reserve system and investigation of gaps in species or community coverage for future reserve planning.
- **Urgent conservation measures:** undertake actions for high priority species and populations, to protect against existing and potential threats. Implement species recovery plans and regional action plans, encouraging their incorporation into regional Natural Resource Management frameworks.
- **Water quality:** encourage councils, landholders and industry to improve point source and diffuse pollution problems within aquatic habitats (including stormwater).
- **Alien species:** undertake targeted control of alien species to facilitate recovery and improve resilience of impacted native fish populations.
- **Climate change:** plan for the impacts of climate change, especially potential reductions in available surface water during dry periods.

Improving knowledge and awareness:

- **Biodiversity:** develop a sound systematic framework for all freshwater fish species in South Australia, even for 'common' species that may actually have more complex genetic patterns. This work also needs to be supported by taxonomic studies.
- **Accessible data:** build a detailed database of freshwater fish distribution which incorporates existing data and identifies data gaps or areas without recent inventories.
- **Meaningful research:** incorporate research priorities into NRM and funding programs to underpin effective implementation of on ground works, flow restoration programs and conservation biology.
- **Let people know:** develop a broader education and communication strategy to improve stakeholder and community awareness; undertake targeted awareness raising programs to improve the profile of key threatened species and the level of awareness of key threatening processes.
- **Review:** the Action Plan information should be reviewed every five years, and status assessment and Recvoery outlines updated every two years.

Policy and management:

- **Collaboration:** initiate engagement of stakeholders through a coordinated body or working group to drive policy, awareness raising and to connect people, agencies and states. Develop recovery teams for threatened fishes.
- **Protection:** work to enhance the legislative framework for protecting species, ecological communities and habitats in South Australia through review, development and strengthening of existing Acts and policy. This process should explicitly consider the conservation requirements of fishes and remove perverse incentives.

- **Status:** review federally listed species and ecological communities to incorporate new information.
- **On the front foot:** Develop a coordinated strategy for proactive protection of flows and habitats with high natural value or minimal disturbance, especially in the Lake Eyre Basin.
- **Biosecurity:** Formulate a 'fish introduction, translocation and stocking strategy' to provide proactive measures to address the problem of existing and potential alien fish and disease.
- **Use:** further promote ecosystem based fisheries which recognise the intrinsic value of all native species, sustainable practice and the protection of wild habitats.
- **The triple bottom line:** initiate significant improvement in the recognition and incorporation of fishes into ecologically sustainable development (e.g. planning).
- **Capacity:** address the need for increased capacity to undertake action in South Australia.

Section 5 supporting information

5.1 REFERENCES

1. Hammer MP and Walker KF (2004) A catalogue of South Australian freshwater fishes including new records, range extensions and translocations. Transactions of the Royal Society of South Australia **128,** 85-97.

2. Berra TM (2001) 'Freshwater fish distribution.' (Academic Press: Sydney)

3. Avise JC (2004) 'Molecular Markers, Natural History and Evolution.' 2nd Edn. (Sinauer Associates: Sunderland)

4. Ricciardi A and Rasmussen JB (1999) Extinction rates of North American freshwater fauna. Conservation Biology **13,** 1220-1222.

5. Bruton MN (1995) Have fishes had their chips? The dilemma of threatened fishes. Environmental Biology of Fishes **43,** 1-27.

6. IUCN (2006) 'IUCN Red List of Threatened Species.' (International Union for Conservation of Nature and Natural Resources: www.iucnredlist.org accessed on 13/6/06)

7. Moyle PB (1995) Conservation of native freshwater fishes in the Mediterranean-type climate of California, USA: a review. Biological Conservation **72,** 271-279.

8. Barlow CG, Hogan AE and Rodgers LJ (1987) Implications of translocated fishes in the apparent extinction in the wild of the Lake Eacham Rainbowfish, *Melanotaenia eachamensis*. Australian Journal of Marine and Freshwater Research **38,** 897-902.

9. Jackson J (1999) Threatened Fish Profile: Pedder Galaxias *Galaxias pedderensis*. Australian Society for Fish Biology Newsletter **29,** 31-32.

10. Crook DA and Sanger AC (1997) Recovery Plan for the Pedder, Swan, Clarence, swamp and saddled galaxias. Inland Fisheries Commission, Hobart.

11. Brown A, Nicol S and Koehn J (1998) Recovery plan for the trout cod *Maccullochella macquariensis*. Aquatic Ecosse Pty Ltd and Department of Natural Resources and Environment, Melbourne. p. 31.

12. Wager R and Jackson P (1993) 'The Action Plan for Australian Freshwater Fishes.' (Australian Nature Conservation Agency: Canberra)

13. Hammer M (2001) Molecular systematics and conservation biology of the southern pygmy perch *Nannoperca australis* (Günther, 1861) (Teleostei: Percichthyidae) in south-eastern Australia. B. Sc.(Honours) thesis, Adelaide University.

14. Bertozzi T, Adams M and Walker KF (2000) Species boundaries in carp gudgeons (Eleotrididae: *Hypseleotris*) from the River Murray, South Australia: evidence for multiple species and extensive hybridization. Marine and Freshwater Research **51,** 805-815.

15. Raadik T (2001) When is a mountain galaxias not a mountain galaxias? Fishes of Sahul **15,** 785-789.

16. Hammer MP, Adams M, Unmack PJ and Walker KF (2007) A rethink on *Retropinna*: conservation implications of new taxa and significant genetic substructure in Australian smelts (Pisces: Retropinnidae). Marine and Freshwater Research **58,** 327-341.

17. Blewett CF (1929) Habits of some Australian freshwater fishes. South Australian Naturalist **10,** 21-29.

18. Nettlebeck N (1926) Fishes of the Finniss River. South Australian Naturalist **7,** 64-65.

19. Smith BB and Walker KF (2004) Reproduction of common carp in South Australia, shown by young-of-the-year samples, gonadosomatic index and the histological staging of ovaries. Transactions of the Royal Society of South Australia **128,** 249-257.

20. Smith BB and Walker KF (2004) Spawning dynamics of common carp in the River Murray, South Australia, shown by macroscopic and histological staging of gonads. Journal of Fish Biology **64,** 336-354.

21. Hammer M (2004) Recovery progress for the southern pygmy perch in the Mount Lofty Ranges: 2001-2003. Report to the River Murray Catchment Water Management Board. Native Fish Australia (SA) Inc., Adelaide. p. 23.

22. Hammer M (2002) Recovery outline for the southern pygmy perch in the Mount Lofty Ranges, South Australia. Department of Environmental Biology, University of Adelaide and Native Fish Australia (SA) Inc., Adelaide. p. 32.

23. Hammer M (2002) The South East fish inventory: distribution and conservation of freshwater fishes of south east South Australia. Native Fish Australia (SA) Inc., Adelaide. p. 53.

24. Wedderburn S and Hammer M (2003) The Lower Lakes Fish Inventory: distribution and conservation of freshwater fishes of the Ramsar Convention wetland at the terminus of the Murray-Darling Basin, South Australia. Native Fish Australia (SA) Inc., Adelaide. p. 38.

25. Hammer M (2004) Eastern Mount Lofty Fish Inventory: distribution and conservation of freshwater fishes of tributaries to the Lower River Murray, South Australia. Native Fish Australia (SA) Inc & River Murray Catchment Water Management Board, Adelaide. p. 104.

26. NFA(SA) (in prep.) Kangaroo Island Fish Inventory. Native Fish Australia (SA) Inc., Adelaide.

27. Hammer M (2006) Report on stage one of the Southern Fleurieu fish inventory. Report to Department of Water Land and Biodiversity Conservation. Native Fish Australia Inc. and Aquasave, Adelaide. p. 44.

28. Hammer M (2005) Adelaide Hills Fish Inventory: distribution and conservation of freshwater fishes in the Torrens and Patawalonga catchments, South Australia. Report to Torrens and Patawalonga Catchment Water Management boards. Native Fish Australia (SA) Inc., Adelaide. p. 68.

29. Glover CJM (1990) Fishes. In 'Natural History of the North East Deserts'. (Eds MJ Tyler, CR Twidale, M Davies and CB Wells.) pp. 189-197. (Royal Society of South Australia Inc.: Adelaide)

30. Glover CJM (1989) Fishes. In 'Natural History of Dalhousie Springs'. (Eds W Zeidler and WF Ponder.) pp. 94-96. (South Australian Museum: Adelaide)

31. Wager R and Unmack PJ (2000) 'Fishes of the Lake Eyre Catchment of Central Australia.' (The State of Queensland, Department of Primary Industries and Queensland Fisheries Service: Brisbane)

32. Pierce BE, Young M and Sim T (2001) Flinders Ranges Fishes. In 'A Biological Survey of the Flinders Ranges, South Australia 1997-1999'. (Ed. R Brandle.) pp. 25-33. (Department for Environment and Heritage, South Australia: Adelaide)

33. Ehmann H and Tynan R (1997) 'Wildlife management manual: the Gawler Ranges and Kingoonya soil conservation districts.' (Department of Environment and Heritage: Adelaide)

34. Glover CJM (1987) Threatened fish species in South Australia. In 'Proceedings of the Conference on Australian Threatened Fishes'. Sydney. (Ed. JH Harris) pp. 55-58. (Division of Fisheries, Department of Agriculture New South Wales.)

35. Lloyd LN and Walker KF (1986) Distribution and conservation status of small freshwater fish in the River Murray, South Australia. Transactions of the Royal Society of South Australia 100, 49-57.

36. Pierce B (1997) "Fair go" for endangered eight. Southern Fisheries 5, 12-13.

37. Baker JL (in press) Status of marine species at risk in South Australia: Technical Report - bony and cartilaginous fish. Electronic book, web pages and CD prepared for the South Australian Working Group for Marine Species of Conservation Concern. South Australian Department for Environment and Heritage, Marine and Coastal Community Network of SA, and Threatened Species Network, Adelaide.

38. Department for Environment and Heritage (2003) 2003 review of the status of threatened species in South Australia. Proposed Schedules under the South Australian National Parks and Wildlife Act 1972: Discussion paper. National Parks and Wildlife Council in partnership with the Department for Environment and Heritage, Adelaide. p. 61.

39. Lloyd LN (1987) Ecology and distribution of the small native fish of the lower River Murray, South Australia and their interactions with the exotic mosquitofish, Gambusia affinis holbrooki. M. Sc. thesis, University of Adelaide.

40. Atkins BP, Lloyd LN and Grey JD (1988) Fish. In 'Wetlands of the Bakers Range and Marcollat watercourses'. (Ed. B Atkins.) pp. 89-95. (Department of Environment and Planning: Adelaide)

41. Rutherford BA (1991) 'The South Australian Aquarium Society. 1918-1932, The First Fifteen years. An Official History.' (Brian A. Rutherford: Modbury Heights, South Australia)

42. Hale HM (1928) Aquarists in camp. South Australian Naturalist **9,** 25-26.

43. Glover CJM and Olsen AM (1985) Fish and major fisheries. In 'Natural History of Eyre Peninsula'. (Eds MJ Tyler, CR Twidale and M Davies.) pp. 169-181. (Royal Society of South Australia (SA) Inc.: Adelaide)

44. Scott TD, Glover CJM and Southcott RV (1974) 'The Marine and Freshwater Fishes of South Australia.' 2nd Edn. (Government Printer: Adelaide)

45. Glover CJM (1979) Fishes. In 'Natural History of Kangaroo Island'. (Eds CR Twidale and JK Ling.) pp. 139-153. (Royal Society of South Australia: Adelaide)

46. Glover CJM (1980) Fishes. In 'A Field Guide to the Flinders Ranges'. (Ed. DWP Corbett.) pp. 217 223. (Rigby: Adelaide)

47. Glover CJM (1983) Freshwater and Marine Fishes. In 'Natural History of the South East'. (Eds M Tyler, CR Twidale, JK Ling and JW Holmes.) pp. 157-167. (Royal Society of South Australia: Adelaide)

48. Kuiter RH (1983) Fish in focus: Mount Gambier fishes. Scuber Diver **1983,** 36-41.

49. Kodric-Brown A and Brown JH (1993) Highly structured fish communities in Australian desert springs. Ecology **74,** 1847-1855.

50. Hammer M, Wedderburn S and Westergaard S (2002) Freshwater fishes. In 'A Biological Survey of the Murray Mouth Reserves, South Australia'. (Ed. R Brandle.) pp. 54-61. (Department for Environment and Heritage: Adelaide)

51. Hammer M (2005) Recovery monitoring for the southern pygmy perch in the Mount Lofty Ranges South Australia, 2001-2005 review. Native Fish Australia (SA) Inc., Adelaide. p. 53.

52. Hammer M, Ristic T and Slater S (2005) Freshwater Fish Survey of Baldina Creek with preliminary observations on other watercourses in the eastern North Mount Lofty Ranges, South Australia. Report to the Friends of Burra Parks Inc. Native Fish Australia (SA) Inc., Adelaide. p. 8.

53. Rowntree J and Hammer M (2004) Freshwater fish survey of the central urban River Torrens, Adelaide South Australia. Report to the Adelaide City Council. Native Fish Australia (SA) Inc., Adelaide. p. 15.

54. Hammer M, Ristic T and Crawford M (2004) Freshwater Fish Survey of the Bungala River Catchment, Fleurieu Peninsula South Australia. Native Fish Australia (SA) Inc., Adelaide. p. 12.

55. Hammer M (unpublished) 2002-2007 misc. research data for South Australia.

56. Hammer M and Wedderburn S (2004) Freshwater fish survey of Morgan's Lagoon, River Murray South Australia. Native Fish Australia (SA) Inc., Adelaide. p. 12.

57. Hammer M, Skinner N and Playford T (2004) Observations on the 'Mechanical Dragging' of Eight Mile Creek, South-east South Australia. Aquasave: Report to the South Eastern Water Conservation and Drainage Board. p. 11.

58. Bice C and Ye Q (2006) Monitoring threatened fish communities on Hindmarsh Island, in the Lower Lakes of the River Murray, South Australia in 2005. SARDI Publication RD06/0004-1. SARDI (Aquatic Sciences), Adelaide. p. 40.

59. Higham J, Ye Q and Smith B (2005) Murray-Darling Basin drought monitoring: monitoring small bodied fish in the lower Murray during and after drought conditions in 2003-2004. SARDI Aquatic Sciences publication No. RD04/0154, Adelaide. p. 40.

60. Hicks D (1997) The impact of acid mine drainage on fish distribution in the southeast Mt Lofty Ranges, South Australia. B.Sc. (Honours) thesis, University of Adelaide.

61. Wedderburn S (2000) Habitat and conservation status of small fish in the Lower River Murray, and a comparison of the western carp gudgeon (*Hypseleotris klunzingeri*) and gambusia (*Gambusia holbrooki*) as larval mosquito predators. B.Sc. (Honours) thesis, University of Adelaide.

62. Wedderburn SD (2008) Population fragmentation in the Murray Hardyhead *Craterocephalus fluviatilis* McCulloch, 1912 (Teleostei: Atherinidae): ecology, genetics and osmoregulation. The University of Adelaide.

63. Wedderburn SD, Walker KF and Zampatti BP (2007) Habitat separation of *Craterocephalus* (Atherinidae) species and populations in off-channel areas of the lower River Murray, Australia. Ecology of Freshwater Fish **16,** 442–449.

64. Costello JF, Hudson P, Pritchard JC, Puckridge JT and Reid JRW (2003) ARIDFLO - environmental flow requirements of arid zone rivers. Final report to Environment Australia, Canberra. Department for Water Land and Biodiversity Conservation, Adelaide. p. 123.

65. Hicks D and Sheldon F (1998) Biotic survey of the Wakefield River, for the Mid North Riverine Management Planning Project. Report to the South Australian Department for Environment, Heritage and Aboriginal Affairs. Department of Zoology, University of Adelaide, South Australia. p. 64.

66. Hicks D and Sheldon F (1999) Biotic survey of the Broughton River, for the Mid North Riverine Management Planning Project. Report to the South Australian Department for Environment, Heritage and Aboriginal Affairs. Department of Zoology, University of Adelaide, South Australia. p. 71.

67. Hicks D and Sheldon F (1999) Biotic survey of the Gawler River. Report to the South Australian Department for Environment, Heritage and Aboriginal Affairs. University of Adelaide, Adelaide. p. 90.

68. Hicks D and Sheldon F (1999) Biotic survey of the Light River, for the Mid North Riverine Management Planning Project. Report to the South Australian Department for Environment, Heritage and Aboriginal Affairs. Department of Zoology, University of Adelaide, South Australia. p. 68.

69. Holt M, Swingler K, O'Donnell E, Shirley M, Lake M, Conallin A, Meredith S, Ho S, Prider J, Poulsen D, Richardson S and Cooling M (2004) River Murray Wetlands Baseline Survey. Volume 1 data report. report to River Murray Catchment Water Management Board. Sinclair Knight Merz, Malvern. p. 1032.

70. Smith BB (2006) Final report on the 'fish' component of the 2005 River Murray Wetlands Baseline Survey. Primary Industries and Resources SA, SARDI Aquatic Sciences., Adelaide. p. 83.

71. McEvoy P, Howell S and Hicks DC (2005) Mt Lofty Ranges water resources assessment program: macroinvertebrate and fish survey and analysis below water supply reservoirs. Report to Department of Water, Land and Biodiversity Conservation. Australian Water Quality Centre, Bolivar.

72. Hicks DC and McEvoy P (2005) Biological and stream condition survey of the eastern urban Torrens from Gorge Weir to Gilberton. Report to the Torrens Catchment Water Management Board. Australian Water Quality Centre, Bolivar.

73. Gray S, Howell S and Maxwell S (2005) Ecological Survey of the Torrens River Wetlands at Breakout Creek and within the Horse Agistment Area: Integrated report to the Torrens Catchment Water Management Board. Australian Water Quality Centre, Bolivar. p. 32.

74. Morris SA, Pollard DA, Gehrke PC and Pogonoski JJ (2001) Threatened and potentially threatened freshwater fishes of coastal New South Wales and the Murray Darling Basin. NSW Fisheries, Sydney. p. 166.

75. McDowall RM and Frankenberg RS (1981) The galaxiid fishes of Australia. Records of the Australian Museum **33,** 443-605.

76. McDowall RM and Fulton W (1996) Family Galaxiidae: galaxiids. In 'Freshwater Fishes of South eastern Australia'. 2nd Edn. (Ed. RM McDowall.) pp. 52-77. (Reed Books: Chatswood NSW)

77. McNeil DG (2004) Ecophysiology and behaviour of Ovens River floodplain fish: hypoxia tolerance and the role of the physicochemical environment in structuring Australian billabong fish communities. PhD thesis, LaTrobe University.

78. Smith BB (2006) Interim report on the 'fish' and 'water quality' components of the 2006 River Murray Wetlands Baseline Survey. Primary Industries and Resources SA, SARDI Aquatic Sciences, Adelaide. p. 25.

79. Tucker P (2004) Your wetland: monitoring manual - data collection. River Murray Catchment Water Management Board and Australian Landscape trust, Berri. p. 196.

80. Berra TM and Weatherley AH (1972) A systematic study of the Australian freshwater Serranid fish genus Maccullochella. Copeia **1,** 53-64.

81. Cadwallader PL and Gooley GJ (1984) Past and present distributions and translocations of Murray cod *Maccullochella peeli* and trout cod *M. macquariensis* (Pisces : Percichthyidae) in Victoria. Proceedings of the Royal Society of Victoria **96,** 33-43.

82. Dunstan WJ (1892) Murray fish and thier habits. In 'The Regsiter'. pp. 6-9. Adelaide

83. Pierce B (1990) Chowilla Fisheries Investigation, Project Completion Report. Murray-Darling Basin Commission, Canberra. p. 154.

84. Cadwallader PL (1977) Fisheries and wildlife paper, Victoria number 13: J. O. Langtry's 1949-50 Murray River investigations. Ministry for Conservation, Fisheries and Wildlife Division, East Melbourne. p. 70.

85. Lintermans M and Osborne W (2002) 'Wet and Wild: A Field Guide to the Freshwater Animals of the Southern Tablelands and High Country of the ACT and NSW.' (Environment ACT: Canberra)

86. Growns I, Wooden I and Schiller C (2004) Use of instream wood habitat by trout cod Maccullochella macquariensis (Cuvier) in the Murrumbidgee River. Pacific Conservation Biology **10,** 261-265.

87. Koehn JD and O'Connor WG (1990) 'Biological Information for the Management of Native Freshwater Fish in Victoria.' (Department of Conservation and Environment: Melbourne)

88. Harris JH and Rowland SJ (1996) Family Percichthyidae: cods and basses. In 'Freshwater Fishes of South-eastern Australia'. (Ed. RM McDowall.) pp. 150-163. (Reed Books: Chatswood NSW)

89. Lintermans M (2007) 'Fishes of the Murray-Darling Basin: an Introductory Guide.' (Murray-Darling Basin Commission: Canberra)

90. Berra TM (1974) The Trout Cod, *Maccullochella macquariensis*, a rare freshwater fish of eastern Australia. Biological Conservation **6,** 53-56.

91. Trout Cod Recovery Team (2008) National Recovery Plan for the Trout Cod *Maccullochella macquariensis*. Department of Sustainability and Environment, Melbourne. p. 17.

92. Cadwallader PL (1981) Past and present distributions and translocations of Macquarie perch, *Macquaria australasica* (Pisces: Percichthyidae) with particular reference to Victoria. Proceedings of the Royal Society of Victoria **93,** 23-30.

93. Lintermans M (2000) The status of fish in the Australian Capital Territory: a review of current knowledge and management requirements. Environment ACT, Canberra. p. 108.

94. Hammer M (2009) Status assessment for nationally listed freshwater fishes of south east South Australia during extreme drought, spring 2008. Report to Department for Environment and Heritage, South Australian Government. Aquasave Consultants, Adelaide. p. 39.

95. Fulton W (1986) The Tasmanian mudfish *Galaxias cleaveri* Scott. Fishes of Sahul 4, 150-151.

96. Koehn JD and O'Connor WG (1990) Distribution of freshwater fish in the Otway region South western Victoria Australia. Proceedings of the Royal Society of Victoria 102, 29-40.

97. Koehn JD and Raadik TA (1991) The Tasmanian mudfish, *Galaxias cleaveri* Scott, 1934, in Victoria. Proceedings of the Royal Society of Victoria **103,** 77-86.

98. McDowall RM (1990) 'New Zealand Freshwater Fishes: A Natural History and Guide.' Revised Edn. (Heinemann Reid: Auckland)

99. Andrews AP (1991) Observations on the Tasmanian mudfish, *Galaxias cleaveri* (Pisces: Galaxiidae). Papers and Proceedings of the Royal Society of Tasmania 125, 55-59.

100. Crowley LELM and Ivantsoff W (1990) A review of species previously identified as *Craterocephalus eyresii* (Pisces: Atherinidae). Proceedings of the Linnean Society of New South Wales **112,** 87-103.

101. SAMA (Accessed 2002-2009) Specimen records and holdings of the South Australian Museum. South Australian Museum, Adelaide.

102. Wedderburn S and Barnes T (2009) Condition monitoring of threatened fish species at Lake Alexandrina and Lake Albert (2008-2009). Report to the Murray-Darling Basin Authority and the South Australian Murray-Darling Basin Natural Resources Management Board. The University of Adelaide, Adelaide. p. 42.

103. Wedderburn SD, Walker KF and Zampatti BP (2008) Salinity may cause fragmentation of hardyhead (Teleostei: Atherinidae) populations in the River Murray, Australia. Marine and Freshwater Research **59,** 254–258.

104. Ellis I (2005) Ecology and breeding seasonality of the Murray hardyhead *Craterocephalus fluviatilis* (McCulloch), family Atherinidae, in two lakes near Mildura, Victoria. Report prepared for the Mallee Catchment Management Authority. Murray-Darling Freshwater Research Centre Lower Basin Laboratory, Mildura. p. 59.

105. Lyon J, Ryan T, Papas P, Tonkinson D, O'Brien T and Lennie R (2002) Aquatic fauna of the Woorinen Lakes: survey and recommendations for management. Department of Natural Resources and Environment, Victoria. p. 64.

106. Hammer M and Butler G (2001) Data sheet: freshwater fishes of the Mount Lofty Ranges, part B, Murray Drainages. Upper River Torrens Landcare Group Inc, Mount Pleasant, South Australia. p. 10.

107. Glover CJM and Inglis WG (1971) Freshwater Fish of South Australia. In 'Extract from South Australian Year Book, 1971'. pp. 27-34. (SA Government: Adelaide)

108. Doyle S (2005) Personal Communication on sampling on the Lower River Murray between Mannum and Tailem Bend during the 1960's and 1970's.

109. Moffat D and Voller J (2002) 'Fish and Fish Habitat of the Queensland Murray-Darling Basin.' (Department of Primary Industries, Queensland)

110. McNeil D, Wilson P, Hartwell D and Pellizzari M (2008) Olive perchlett (*Ambassis agassizii)* in the Lachlan River: population status and sustainability in the Lake Brewster region. Report to the Lachlan Catchment Management Authority. SARDI Publication F2008/00846-1. SARDI Aquatic Sciences, West Beach, Adelaide. p. 69.

111. Llewellyn LC (2008) Observations on the breeding biology of *Ambassis agassizii* Steindachner, 1867 (Teleostei:Ambassidae) from the Murray Darling Basin in New South Wales. Australian Zoologist **34,** 476-498.

112. Hammer M (2005) Conservation biology of a small and restricted population of Yarra pygmy perch at Henry Creek, South Australia: causes of a rapid decline. Native Fish Australia (SA) Inc., Adelaide. p. 22.

113. Hammer M (2007) Distribution, status and urgent conservation measures for Yarra Pygmy Perch in the Murray-Darling Basin. Report to Department for Environment and Heritage, South Australian Government. Aquasave Consultants, Adelaide. p. 29.

114. Hammer M (2008) Status review of wild and captive Yarra pygmy perch in the Murray Darling Basin. Report to Department for Environment and Heritage, South Australian Government. Aquasave Consultants, Adelaide. p. 27.

115. Bice CM, Wilson P and Ye Q (2008) Threatened fish populations in the Lower Lakes of the River Murray in spring 2007 and summer 2008. Report to the South Australian Murray-Darling Basin Natural Resources Management Board. SARDI Aquatic Sciences, West Beach. p. 31.

116. Sanger AC (1978) Aspects of the ecology and evolution of the pigmy perches (Teleostei: Kuhlidae). B. Sc. (Honours) thesis, University of Melbourne.

117. Woodward GMA and Malone BS (2002) Patterns of abundance and habitat use by *Nannoperca obscura* (Yarra pygmy perch) and *Nannoperca australis* (southern pygmy perch). Proceedings of the Royal Society of Victoria **114,** 61-72.

118. Hammer M (2007) Survey of nationally threatened fish species in the Mosquito Creek Catchment, South Eastern Australia. Report to Department for Environment and Heritage, South Australian Government. Aquasave Consultants, Adelaide. p. 61.

119. Hammer M (2007) Henry Creek fish research 2006-2007 with a focus on the status of Yarra pygmy perch. Report to Department for Environment and Heritage, South East Region (SA). Aquasave Consultants, Adelaide. p. 10.

120. Slater S and Hammer M (2009) Drought Response Plan for nationally listed freshwater fishes of south east South Australia: regional action, contingency and long term recovery. Department for Environment and Heritage, South East region, Mount Gambier. p. 58.

121. Hammer M (2001) Data sheet: Freshwater Fishes of South Eastern South Australia. Native Fish Australia (SA) Inc, Adelaide. p. 8.

122. Kuiter RH and Allen GR (1986) A synopsis of the Australian pygmy perches (Percichthyidae) with the description of a new species. Revue Francaise Aquariologie **12,** 109-116.

123. Kuiter RH, Humphries P and Arthington AH (1996) Pygmy perches: Family Nannopercidae. In 'Freshwater Fishes of South-Eastern Australia'. 2nd Edn. (Ed. RM McDowall.) pp. 168-175. (Reed Books: Chatswood NSW)

124. Hammer M, Doube J and Roberts M (2000) Conservation of the variegated pygmy perch: freshwater fish survey of lower south eastern South Australia. Report to National Parks and Wildlife SA and the South Eastern Water Conservation and Drainage Board.

125. Hammer M (2007) Conservation of the variegated pygmy perch: 2006 freshwater fish research in lower south eastern South Australia. Report to Department for Environment and Heritage, South Australian Government. Aquasave Consultants, Adelaide. p. 27.

126. Stadter F and Yan W (2000) Assessment of the potential use of groundwater resources in the area south of Mount Gambier. Department for Water Resources, Mount Gambier. p. 191.

127. Carmody G (2006) Save Ewens Ponds! ANGFA Victoria Inc., Melbourne. p. 8.

128. Brown K, Harrington G and Lawson J (2006) Review of groundwater resource condition and management principles for the Tertiary Limestone Aquifer in the South East of South Australia. Department of Water, Land and Biodiversity Conservation, Mount Gambier. p. 92.

129. Hammer M (2007) Report on urgent conservation measures and monitoring of southern purple-spotted gudgeon on the River Murray, South Australia. Report to the South Australian Murray-Darling Basin Natural Resources Management Board. Aquasave Consultants, Adelaide. p. 15.

130. Hammer M (2008) A molecular genetic appraisal of biodiversity and conservation units in freshwater fishes from southern Australia. PhD thesis, University of Adelaide.

131. Hammer M (2008) Aquatic survey of the Murray Bridge Army Range wetlands, South Australia. Aquasave Consultants, Adelaide. p. 12.

132. Larson HK and Hoese DF (1996) Family Gobiidae, subfamilies Eleotridinae and Butinae: gudgeons. In 'Freshwater Fishes of South-eastern Australia'. 2nd Edn. (Ed. RM McDowall.) pp. 200-219. (Reed Books: Chatswood NSW)

133. Llewellyn L (2006) Breeding and development of the endangered Purple-spotted Gudgeon *Mogurnda adspersa* population from the Murray Darling. Australian Zoologist **33,** 480-510.

134. Schiller CB and Harris JH (2001) Native and alien fish. In 'Rivers as Ecological Systems: the Murray-Darling Basin'. pp. 229-258. (Murray Darling Basin Commission: Canberra)

135. DWLBC (2009) Surface water archive. http://e-nrims.dwlbc.sa.gov.au/swa, accessed June, 2009. Department of Water Land and Biodiversity Conservation, Adelaide.

136. Allen GR and Jenkins AP (1999) A review of the Australian freshwater gudgeon, genus *Mogurnda* (Eleotridae) with descriptions of three new species. Aqua **3,** 141-156.

137. McKay KM (1985) An assessment of an inland population of purple spotted gudgeons: *Mogurnda* "balcanoonensis" (previously recorded as *M. mogurnda*) at Balcanoona Creek/ Gammon Ranges National Park, Northern Flinders Ranges of South Australia. Wildlife Conservation Fund Research Grant Project Report. South Australian Department of Environment and Planning, Adelaide.

138. Pierce B (1996) Ozone layer hole causing fish cancer. In 'Southern Fisheries'. pp. 16.

139. Bywater JF, Banaczkowski R and Bailey M (1991) Sensitivity to Uranium of six species of tropical freshwater fishes and four species of Cladocerans from northern Australia. Environmental Toxicology and Chemistry **10,** 1449-1458.

140. Pierce BE (1992) Why chase fish in the desert? South Australia's inland water stock assessment program. In 'SAFISH'. pp. 4-9.

141. Hammer M (2006) Range extensions for four estuarine gobies (Pisces: Gobiidae) in southern Australia: historically overlooked native taxa or recent arrivals? Transactions of the Royal Society of South Australia **130,** 187-196.

142. Bice CM, Jennings PR and Zampatti BP (2007) Fish movement and recruitment in the Coorong and Lower Lakes 2006-07 Progress report. SARDI publication No. F2007/000555-1. SARDI Aquatic Sciences, West Beach SA. p. 48.

143. Potter IC, Hillard RW and Neira FJ (1986) The biology of Australian lampreys. In 'Limnology in Australia'. (Eds P De Deckker and WD Williams.) pp. 207-230. (CSIRO: Melbourne)

144. Potter IC (1996) Family Geotriidae: pouched lampreys. In 'Freshwater Fishes of South-Eastern Australia'. 2nd Edn. (Ed. RM McDowall.). (Reed Books: Chatswood NSW)

145. Morgan DL, Gill HS and Potter IC (1998) Distribution, identification and biology of freshwater fishes in south-western Australia. Records of the Western Australian Museum **Supplement 56,** 1-97.

146. Hicks DC and Hammer M (2004) Investigation of the impact of barriers on indigenous fish in the River Torrens Catchment: Literature Review. Report to the Torrens Catchment Water Management Board. Australian Water Quality Centre, Adelaide.

147. Roughly TC (1961) 'Fish and Fisheries of Australia.' First published 1951. Revised and reprinted 1953, 1955, 1957, 1961 Edn. (Angas and Robertson PTY LTD: Sydney)

148. Potter IC (1980) Ecology of larval and metamorphosing lampreys. Canadian Journal of Fisheries and Aquatic Sciences **37,** 1641-1657.

149. Savadamuthu K (2002) Impacts of farm dams on streamflow in the upper Marne Catchment. Department of Water, Land and Biodiversity Conservation, Adelaide. p. 34.

150. Savadamuthu K (2003) Surface Water Assessment of the Upper Finniss Catchment. Department of Water, Land and Biodiversity Conservation, Adelaide. p. 67.

151. Jennings PR, Zampatti BP and Bice CM (2008) Fish movement and recruitment in the Coorong and Lower Lakes: 2008/08 progress report. SARDI publication number F2007/0005552. SARDI Aquatic Sciences, Adelaide. p. 41.

152. Waite ER (1923) 'The Fishes of South Australia.' (Government Printer: Adelaide)

153. Scott TD (1962) 'The Marine and Freshwater Fishes of South Australia.' (Government Printer: Adelaide)

154. Geddes M and Wedderburn SD (2007) Fish monitoring below tidal barrages in Boundary Creek and Mundoo Channel during freshwater inflow to the River Murray estuary in 2005 and 2006. The University of Adelaide, Adelaide. p. 29.

155. SARDI Aquatic Sciences (unpublished data) SA Fisheries Statistics and data from Inland Waters research projects supplied 2006.

156. Musyl MK and Keenan CP (1996) Evidence for cryptic speciation in Australian freshwater eel-tailed catfish, *Tandanus tandanus* (Teleostei: Plotosidae). Copeia **1996,** 526-534.

157. Jerry DR and Woodland DJ (1997) Electrophoretic evidence for the presence of the undescribed 'Bellinger' catfish (*Tandanus* sp.) (Teleostei: Plotosidae) in four New South Wales mid-northern coastal rivers. Marine And Freshwater Research **48,** 235-240.

158. Hammer M (2004) NFA(SA) 2004 Fishing Competition (Catch and release), February 7th-9th @ Blanchetown, River Murray. Native Fish Australia (SA) Inc., Adelaide. p. 2.

159. Rowntree J and Hammer M (2007) Assessment of fishes, aquatic habitat and potential threats at the proposed location of the Wellington Weir, South Australia. Report to Department for Environment and Heritage, South Australian Government. Aquasave Consultants, Adelaide. p. 27.

160. Zampatti B, Leigh S and Nicol J (2008) Chowilla Icon Site fish assemblage condition monitoring 2005-2008. SARDI Aquatic Sciences Publication Number: F2008/000907-01. SARDI Aquatic Sciences, Adelaide. p. 38.

161. Clunie P and Koehn J (2000) Freshwater Catfish: a Recovery Plan. Draft Interim Final Report for Natural Resource Management Strategy Project R7002 to the Murray Darling Basin Commission. Arthur Rylah Institute for Environmental Research, Heidelberg, Victoria. p. 41.

162. Reynolds LF (1983) Migration patterns of five fish species in the Murray-Darling River system. Australian Journal of Marine and Freshwater Research **34,** 857-871.

163. Reynolds LF (1976) Inland fisheries. In 'SAFIC'. pp. 3-6, 15.

164. Clunie P and Koehn J (2001) Freshwater Catfish: a Recovery Plan. Final report for Natural Resource Management Strategy Project R7002 to the Murray-Darling Basin Commission. Arthur Rylah Institute for Environmental Research, Heidelberg, Victoria. p. 41.

165. Rohan G (1988) River fishery (South Australia) -review of management arrangements. In 'Workshop on Native Fish Management'. Canberra. (Murray Darling Basin Commision.)

166. Hallam ND and Thurgate ME (1992) The Biology of Ewens and Piccaninnie Ponds and Woolwash, Blacks and Gouldens Holes, South Australia. Monash University, Clayton, Victoria. p. 79.

167. McDowall RM (1996) Family Prototroctidae: southern graylings. In 'Freshwater Fishes of South-eastern Australia'. 2nd Edn. (Ed. RM McDowall.) pp. 96-98. (Reed Books: Chatswood NSW)

168. Ault TR and White RWG (1994) Effects of habitat structure and the presence of brown trout on the popualtion density of *Galaxias truttaceus* in Tasmania, Australia. Transactions of the American Fisheries Society **123,** 939-949.

169. Hammer M (2008) Pilot fish movement study in Lower South East, South Australia. Report to Department for Environment and Heritage, South Australian Government. Aquasave Consultants, Adelaide. p. 28.

170. Sanger AC (1986) The evolution and ecology of the *Gadopsis marmoratus* complex. PhD thesis, University of Melbourne.

171. Ryan S (2000) A genetic and taxonomic study of the freshwater blackfish (Gadopsis) of mainland south-eastern Australia. B. Sc. (Honours) thesis, Deakin University.

172. Zietz AH (1902) List of the edible fish of the lower Murray. Transactions and Proceedings of the Royal Society of South Australia **26,** 265-267.

173. Hammer M (2007) Status report on South Australian threatened freshwater fish populations during 2007 drought conditions. Report to Department for Environment and Heritage, South Australian Government. Aquasave Consultants, Adelaide. p. 20.

174. Khan MT, Khan TA and Wilson ME (2004) Habitat use and movement of river blackfish (*Gadopsis marmoratus* R.) in a highly modified Victorian stream, Australia. Ecology of Freshwater Fish **13,** 285-293.

175. Jackson PD (1978) Spawning and early development of the river blackfish, *Gadopsis marmoratus* Richardson (Gadopsiformes: Gadopsidae), in the McKenzie River, Victoria. Australian Journal of Marine and Freshwater Research **29,** 293-298.

176. Sim T, Potts L, Hammer M and Doube J (2000) Fishes. In 'Natural History of Strathalbyn and Goolwa Districts'. pp. 97-108. (Douglas Press: Woodville North, South Australia.)

177. Marne River Environmental Flows Technical Panel (2003) Environmental Water Requirements of the Ephemeral Marne River System, South Australia. River Murray Catchment Water Management Board, Berri. p. 114.

178. Hall A, Higham J, Hammer M, Bice C, and Zampatti B (2009). DRAFT - Drought Action Plan for South Australian Murray-Darling Basin threatened freshwater fish populations. South Australian Department for Environment and Heritage, Adelaide.

179. Hammer M (2006 in review) Review of monitoring data for river blackfish in the Eastern Mount Lofty Ranges, South Australia: 2002-2006. Confidential technical report to the South Australian Murray-Darling Basin Natural Resources Management Board. Aquasave Consultants, Adelaide. p. 31.

180. Pierce B (1990) Murray cod invade South Australia's Cooper Creek. In 'SaFish'. pp. 11.

181. Smith B, Vilizzi L and Conallin A (2007) Analysis of the combined 'fish' dataset from the 2004-2007 South Australian River Murray baseline surveys. SARDI Publication no. F2007/000526-1. SARDI Aquatic Sciences, Adelaide. p. 47.

182. Ye Q, Jones KG and Pierce BE (2000) Murray Cod (*Maccullochella peelii peelii*): Fisheries Assessment Report to PIRSA for the Inland Waters Fishery Management Committee. South Australian Research and Development Institute, 2000/17, Adelaide.

183. Anderson JR, Morison AK and Ray DJ (1992) Age and growth of Murray cod, *Maccullochella peelii* (Perciformes: Percichthyidae), in the lower Murray-Darling Bain, Australia, from thin-sectioned otoliths. Australian Journal of Marine and Freshwater Research **43,** 983-1013.

184. Pierce BE (1994) Of mega-cod and moratoriums. In 'Southern Fisheries'. pp. 31.

185. Walker KF and Thoms MC (1993) Environmental effects of flow regulation on the River Murray, South Australia. Regulated Rivers: Research and Management **8,** 103-119.

186. Maheshwari BL, Walker KF and McMahon (1995) Effect of regulation on the flow regime of the River Murray, Australia. Regulated Rivers: Research and Management **10,** 15-38.

187. Ye Q and Zampatti B (2007) Murray cod stock status: the Lower River Murray, South Australia. Stock Status Report to PIRSA Fisheries. SARDI Publication Number F2007-000211-1. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. p. 32.

188. Gillanders BM and Kingsford MJ (2002) Impact of changes in flow of freshwater on estuarine and open coastal habitats and the associated organisms. Oceanography and Marine Biology. An Annual Review **40,** 233-309.

189. Knight MA, Tosolo A and Doonan AM (2004) South Australian Fisheries and Aquaculture

Information Statistics Report. SARDI Research Report Series, No. 60. SARID Aquatic Sciences, Adelaide.

190. Eckert J and Robinson RD (1990) The fishes of the Coorong. South Australian Naturalist **65,** 4-31.

191. McCarraher DB and McKenzie JA (1986) Observations on the distribution, growth, spawning and diet of Estuary Perch (*Macquaria colonorum*) in Victorian waters. Technical Report No. 42. Arthur Rylah Institute for Environmental Research, Heidelberg, Victoria.

192. Llewellyn LC (1974) Spawning, development and distribution of the southern pigmy perch *Nannoperca australis australis* Günther from inland waters in eastern Australia. Australian Journal of Marine and Freshwater Research **25,** 121-149.

193. Morgan DL, Gill HS, Maddern MG and Beatty SJ (2004) Distribution and impacts of introduced freshwater fishes in Western Australia. New Zealand Journal of Marine and Freshwater Research **38,** 511-523.

194. Arthington AH (1996) Recovery plan for the oxleyan pygmy perch *Nannoperca oxleyana*. Centre for Catchment and In-Stream Research, Griffith University, Queensland.

195. Hammer M (2002) Freshwater Fish Snapshot: Inman River Catchment Stock Exclusion Demonstration Site. Report to the Environmental Protection Authority, Adelaide. p. 5.

196. Merrick JR (1996) Freshwater grunters or perches. In 'Freshwater fishes of south-eastern Australia'. (Ed. RM McDowall.) pp. 164-167. (Reed Books: Chatswood, NSW)

197. Mallen-Cooper M (1994) How high can a fish jump?: Fish need help swimming upstream. New Scientist **142,** 32-38.

198. Gehrke PC and Harris JH (2000) Large-scale patterns in species richness and composition of temperate riverine fish communities, south-eastern Australia. Marine and Freshwater Research **51,** 165-182.

199. Clunie P and Koehn J (2001) Silver Perch: a Recovery Plan. Final report for project R8002 to Murray-Darling Basin Commission: Canberra. Department of Natural Resources and Environment, Heidelberg. p. 41.

200. Hammer M (2006) Review and 2005 performance of fish indicators for Environmental Water Requirements of the Marne River Catchment, South Australia. Report to SAMDB NRM Board. Aquasave Consultants, Adelaide. p. 30.

201. Hammer M and Butler G (2000) Data sheet: freshwater fishes of the Mount Lofty Ranges, part A, South Australian Gulf Division. Upper River Torrens Landcare Group Inc, Mount Pleasant, South Australia. p. 8.

202. Beck RG (1985) Field observations upon the dwarf galaxiid *Galaxiella pusilla* (Mack) (Pisces: Galaxiidae) in the south-east of South Australia, Australia. South Australian Naturalist **60,** 12-22.

203. Nevill J (2001) 'Freshwater Biodiversity: Protecting Freshwater Ecosystems in the Face of Infrastructure Development.' (Water Research Foundation of Australia)

204. Department for Environment and Heritage and Department for Water Land and Biodiversity Conservation (2003) Wetland strategy for South Australia. Department for Environment and Heritage, Adelaide. p. 97.

205. Bachmann M (2002) Silky Tea-tree and Cutting Grass Wetland Rehabilitation Project Summary 1999-2002. Nature Conservation Society of South Australia, Adelaide. p. 176.

206. Unmack P (2005) Historical biogeography and a priori hypotheses based on freshwater fishes. PhD thesis, Arizona State University.

207. Glover CJM and Sim TC (1978) Studies on central Australian fish: a progress report. South Australian Naturalist **52,** 35-44.

208. Glover CJM (1988) Central Australian Fish. South Australian Museum Information Centre, Adelaide. p. 4.

209. Pusey B, Kennard M and Arthington A (2004) 'Freshwater Fishes of North-Eastern Queensland.' (CSIRO Publishing: Collingwood, Vic.)

210. Hammer M (2006) Review of fishes of the Onkaparinga Estuary, South Australia. Aquasave, Adelaide. p. 9.

211. Ye Q, Fleer D and Jones KG (2000) Lake George Fishery Assessment Report. SARDI Aquatic Sciences, Adelaide. p. 23.

212. Honan JA and Mitchell BD (1995) Growth of the large freshwater crayfish *Euastacus bispinosus* Clark (Decapoda: Parastacidae). Freshwater Crayfish **10,** 118-131.

213. Waite ER (1924) Illustrations of and notes on some Australian fishes. Records of the South Australian Museum **11,** 479-487.

214. Piddington RW (1964) A preliminary investigation of the biology of the fish, congolli, *Pseudaphyritis bursinus.* B.Sc. (Honours) thesis, University of Adelaide.

215. Cheshire K (2005) Using otolith chemistry to track the movements of a diadromous fish: the congolli *Pseudaphritis urvilli* (Teleostei: Pseudaphritidae). University of Adelaide.

216. Allen GR and Feinberg MN (1998) Descriptions of a new genus and four new species of freshwater catfishes (Plotosidae) from Australia. Aqua **3,** 9-18.

217. Allen GR, Midgley SH and Allen M (2002) 'Field Guide to the Freshwater Fishes of Australia.' (Western Australian Museum: Perth)

218. Larson HK (1995) A review of the Australian endemic gobiid fish genus *Chlamydogobius*, with description of five new species. The Beagle, Records of the Museum and Arts Gallery of the Northern Territory **12,** 19-15.

219. Ivantsoff W and Glover CJM (1974) *Craterocephalus dalhousiensis* n.sp., a sexually dimorphic teleost (Atherinidae) from South Australia. Australian Zoologist **18,** 88-98.

220. Crowley LELM (1990) A second hardyhead, *Craterocephalus gloveri* (Pisces: Atherinidae), from Dalhousie Springs, central Australia. Ichthyological Exploration of Freshwaters **1,** 113-122.

221. Kodric-Brown A and Brown JH (1993) Incomplete data sets in community ecology and biogeography: a cautionary tale. Ecological Applications **4,** 736-742.

222. Kodric-Brown A, Wilcox C, Bragg JG and Brown JH (2007) Dynamics of fish in Australian desert springs: role of large-mammal disturbance. Diversity and Distributions **13,** 789–798.

223. Beumer JP (1996) Freshwater Eels. In 'Freshwater Fishes of South-Eastern Australia'. (Ed. RM McDowall.). (Reed Books: Chatswood NSW)

224. Gooley GJ, McKinnon LJ, Ingram BA, Larkin B, Collins RO and deSilva SS (1999) Assessment of juvenile eel resources in south eastern Australia and associated development of intensive eel farming for local production. FRDC Project No 94/067. MAFRI, Victoria.

225. Bye JAT (1983) Physical oceanography. In 'Natural History of the South East'. (Eds M Tyler, CR Twidale, JK Ling and JW Holmes.) pp. 75-84. (Royal Society of South Australia Inc.: Adelaide)

226. Kelly DJ and Jellyman DJ (2007) Changes in trophic linkages to shortfin eels (*Anguilla australis)* since the collapse of submerged macrophytes in Lake Ellesmere, New Zealand. Hydrobiologia **579,** 161–173.

227. Ye Q, Higham J and Johnson J (2002) Murray Barrage Fishway Assessment program. Annual report for the Murray Darling Basin Commission. SARDI Aquatic Sciences., Adelaide. p. 57.

228. Langdon SA and Collins AL (2000) Quantification of the maximal swimming performance of Australiasian glass eels, *Anguilla australis* and *Anguilla reinhardtii*, using a hydraulic flume swimming chamber. New Zealand Journal of Marine and Freshwater Research **34,** 629-636.

229. Lake JS (1971) 'Freshwater Fishes and Rivers of Australia.' (Thomas Nelson: Melbourne)

230. McNeil D, Reid D, Schmarr D and Westergaard S (2008) Preliminary fish survey for the Lake Eyre Basin Rivers Assessment: testing the fish trajectory model in South Australia. SARDI Aquatic Sciences Publication Number: F2008/00844-1. SARDI Aquatic Sciences, Adelaide. p. 90.

231. Crowley LELM (1990) Biogeography of the endemic freshwater fish *Craterocephalus* (family Atherinidae). Memoirs of the Queensland Museum **28,** 89-98.

232. Unmack P (1996) The unique Cooper Creek catfish from central Australia. Fishes of Sahul **10,** 460-464.

233. SKM (2002) Determination of environmental water requirements of the Onkaparinga River Catchment, technical report V: fish survey. Sinclair Knight Merz PTY Limited, Armadale, Victoria. p. 17.

234. O'Conner WG and Koehn JD (1998) Spawning of the broad-finned galaxias, *Galaxias brevipinnis* Gunther (Pisces: Galaxiidae) in coastal streams of southeastern Australia. Ecology of Freshwater Fish 7, 95-100.

235. Ye Q (2004) Golden perch (*Macquaria ambigua*). Fishery assessment report to PIRSA Fisheries. SARDI Aquatic Sciences Publication No. RD04/0167. SARDI Aquatic Sciences, Adelaide. p. 75.

236. MDBA (2003) Native Fish Strategy for the Murray-Darling Basin 2003-2013. MDBA Publication No. 25/04. Murray Darling Basin Commission, Canberra. p. 50.

237. Drew MM (2008) A gudie to the managment of native fish: Victorial coastal rivers and wetlands. Department of Sustainability and Environment, Melbourne. p. 224.

238. Poff NE, Allan JD, Bain MB, Karr JR, Prestegaard KL, Richter BD, Sparks RE and Stromberg JC (1997) The natural flow regime: a paradigm for river conservation and restoration. BioScience **47,**769-784.

239. Bunn SE and Arthington AH (2002) Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental Management **30,** 492-507.

240. Gehrke PC, Brown P, Schiller CB, Moffatt DB and Bruce A (1995) River regulation and fish communities in the Murray-Darling River System, Australia. Regulated Rivers: Research and Management **11,** 363-375.

241. MDBA (2006) The shared water resources of the Murray-Darling Basin. MDBA Publication 21/06. Murray Darling Basin Commission, Canberra.

242. Harding CL (2005) Wetland Inventory for the Fleurieu Peninsula, South Australia. Department of Environment and Heritage, SA, Adelaide. p. 112.

243. Robertson AI and Rowling RW (2000) Effects of livestock on riparian zone vegetation in an Australian dryland river. Regulated Rivers: Research and Management **16,** 527-541.

244. McDowall RM (1988) 'Diadromy in Fishes: Migrations Between Freshwater and Marine Environments.' (Croom Helm: London)

245. Napier GM, Fairweather PG and Scott AC (1998) Records of fish kills in inland waters of NSW and Queensland in relation to cotton pesticides. Wetlands (Australia) **17,** 60-71.

246. Jeffree RA, Twining JR and Thomson J (2001) Recovery of fish communities in the Finniss River, northern Australia, following remediation of the Rum Jungle uranium/copper mine site. Environmental Science and Technology **35,** 2932-2941.

247. Hammer M (2000) Barossa outrage!! Putrid water and rotting fish. In 'ANGFA News'. pp. 1,6.

248. Ross ST (1991) Mechanisms structuring stream fish assemblages: are there lessons from introduced species? Environmental Biology of Fishes **30,** 359-368.

249. Lintermans M (2004) Human-assisted dispersal of alien freshwater fish in Australia. New Zealand Journal of Marine and Freshwater Research **38,** 481-501.

250. Reid JRW and Puckridge JT (1990) Coongie Lakes. In 'Natural History of the North-East Deserts'. (Eds MJ Tyler, CR Twidale, M Davies and CB Wells.) pp. 119-131. (Royal Society of South Australia: Adelaide)

251. Walker-Symonds T and Hammer M (2005) The introduction of a local native fish, the flathead gudgeon, into Laratinga Wetland Mt Barker, South Australia. Report to the Mt Barker District Council. Native Fish Australia (SA) Inc., Adelaide. p. 10.

252. McNeil D and Wilson P (2008) The speckled livebearer (*Phalloceros caudimaculatus*). Report to PIRSA Fisheries. SARDI Aquatic Sciences Publication No. F2008/00939-1. SARDI Aquatic Sciences, Adelaide. p. 29.

253. Chong R and Whittington R (2005) A Review of Australian Ornamental Fish Import Risk Management for the Period 1999 - 2004. A Report to the National Aquatic Animal Health Technical Working Group (NAAH-TWG). Department of Primary Industries and Fisheries, Yeerongpilly and University of Sydney, Sydney. p. 106.

254. Whittington RJ and Chong RP (2007) Global trade in ornamental fish from an Australian perspective: the case for revised import risk analysis and management strategies. Preventive Veterinary Medicine **81,** 92-116.

255. Langdon JS and Humphrey JD (1987) Epizootic haematopoietic necrosis, a new viral disease in redfin perch, *Perca fluviatilis* L., in Australia. Journal of Fisheries Disease **10,** 289-297.

256. Humphrey JD and Ashburner LD (1993) Spread of the bacterial fish pathogen A. salmonicida after importation of infected goldfish, into Australia. Australian Veterinary Journal, **70,** 453-454.

257. Hughes JM, Goudkamp, K., Hurwood, D.A., Hancock, M. & Bunn, S.E. (2003) Translocation causes extinction of a local population of the glass shrimp, *Paratya australiensis*. Conservation Biology **17,** 1007-1012.

258. Gillanders BM, Elsdon TS and Munro AR (2006) Impacts of native fish stocking on fish within the Murray-Darling Basin. University of Adelaide, Adelaide. p. 94.

259. McDowall RM (2006) Crying wolf, crying foul, or crying shame: alien salmonids and a biodiversity crisis in the southern cool-temperate galaxioid fishes? Reviews in Fish Biology and Fisheries **16,** 233–422.

260. Smith B and Hammer M (2005) Mapping the current distribution of native and exotic freshwater fishes within the South Australian Murray-Darling Basin: Final Report to PIRSA Rural Solutions (RDO4/0064 + SARDI series number 119). South Australian Research and Development Institute (Aquatic Sciences), Adelaide. p. 60.

261. McDowall RM (Ed.) (1996) 'Freshwater Fishes of South-eastern Australia (2nd Edn.).' (Reed Books: Chatswood NSW)

262. Crowl TA, Townsend CR and McIntosh AR (1992) The impact of introduced brown and rainbow trout on native fish: the case of Australasia. Reviews in Fish Biology and Fisheries **2,** 217-241.

263. Koster WM, Raadik TA and Clunie P (2002) Scoping study of the potential spread and impact of the exotic fish oriental weather loach in the Murray-Darling Basin, Australia: a resource document. Arthur Rylah Institute for Environmental Research, Melbourne. p. 79.

264. Fulton W (2004) Review of trout stocking in South Australia: South Australian Fisheries Management Series No. 41. Primary Industries and Resources SA, Adelaide. p. 67.

265. Morrissy NM (1967) The ecology of trout in South Australia. PhD thesis, University of Adelaide.

266. Morgan DL, Hambleton SJ, Gill HS and Beatty S (2002) Distribution, biology and likely impacts of the introduced redfin perch (Perca fluviatilis) (Percidae) in Western Australia. Marine and Freshwater Research **53,** 1211-1221.

267. Hammer M (2006) Review of monitoring data for river blackfish in the Eastern Mount Lofty Ranges, South Australia: 2002-2006. Report to the South Australian Murray-Darling Basin Natural Resources Management Board. Aquasave Consultants, Adelaide. p. 32.

268. McInnes KL, Suppiah R, Whetton PH, Hennessy KJ and Jones RN (2003) Climate change in South Australia. Report on: assessment of climate change, impacts and possible adaptation strategies relevant to South Australia. Undertaken for the South Australian Government by the Climate Impact Group, CSIRO Atmospheric Research, Aspendale, Victoria. p. 61.

269. Musyl MK and Keenan CP (1992) Population genetics and zoogeography of Australian freshwater golden perch, *Macquaria ambigua* (Richardson 1845) (Teleostei: Percichthyidae), and electrophoretic identification of a new species from the Lake Eyre Basin. Australian Journal of Marine and Freshwater Research **43,** 1585-1601.

270. Bertozzi T (1990) Morphological and biochemical variation in the western carp gudgeon *Hypseleotris klunzingeri* Ogilby from the Lower River Murray, South Australia. Honours thesis, The University of Adelaide.

271. Moritz C (1994) Defining 'evolutionary significant units' for conservation. Trends in Ecology and Evolution **9,** 373-375.

272. Department for Environment and Heritage (2007) Translocation of fauna in South Australia. Draft. NPWSA standard operating procedures. Department for Environment and Heritage, Adelaide. p. 6.

273. Wissmar RC and Bescheta RL (1998) Restoration and management of riparian ecosystems: a catchment perspective. Freshwater Biology **40,** 571-585.

274. Upper River Torrens Landcare Group Inc (2003) Watercourse management: a field guide for the Mount Lofty Ranges (Third Edition). Upper River Torrens Landcare Group, Mount Pleasant SA.

275. Sinclair Knight Merz (2003) Guidelines and protocols for the management of native fish habitat. Sinclair Knight Merz, Armadale Vic. p. 118.

276. Lovett S and Price P (2007) Principles for riparian lands management. Land & Water Australia, Canberra.

277. Department of Fisheries (2009) A five-year managment strategy for the recrational trout fishery. Fisheries Managment Paper No. 234. Department of Fisheries, Perth. p. 38.

278. Gehrke PC and Harris JH (2001) Regional-scale effects of flow regulation on lowland riverine fish communities in New South Wales, Australia. Regulated Rivers: Research and Management **17,** 369-391.

279. Closs GP and Lake PS (1996) Drought, differential mortality and the coexistence of a native and an introduced fish species in a south east Australian intermittent stream. Environmental Biology of Fishes **47,** 17-26.

280. Lake JS (1957) Trout populations and habitats in New South Wales. Australian Journal of Marine and Freshwater Research 8, 414-450.

281. Lintermans M (2000) Recolonization by the mountain galaxias *Galaxias olidus* of a montane stream after the eradication of rainbow trout Oncorhynchus mykiss. Marine and Freshwater Research **51,** 799-804.

282. Stuart I, Williams A, McKenzie J and Holt T (2006) The Williams' cage: a key tool for carp management in Murray-Darling Basin fishways. Final report to the Murray-Darling Basin Commission. Arthur Rylah Institute for Environmental Research, Victoria. p. 31.

283. Saddlier S and Raadik T (1995) Barred Galaxias Recovery Plan: protection of the barred galaxias *Galaxias fuscus* from trout by building weirs downstream of remaining populations, annual report. Department of Conservation and Natural Resources, Heidelberg.

284. Mallen-Cooper M (1999) Developing fishways for non-salmonid fishes; a case study from the Murray River in Australia. In 'Innovations in Fish Passage Technology'. (Ed. M Odeh.) pp. 173-195. (American Fisheries Society: Bethseda)

285. Stuart IG, Zampatti BP and Baumgartner LJ (2008) Can a low-gradient vertical slot fishway provide passage for a lowland river fish community. Marine and Freshwater Research **59,** 332-346.

286. Leigh S and Zampatti B (2005) A preliminary priorization of barriers to fish barriers within anabranch and off-channel habitats along the River Murray SA. Report to DWLBC. SARDI Aquatic Sciences Publication RD04/0234-2. SARDI Aquatic Sciences, Adelaide. p. 49.

287. Philippart JC (1995) Is captive breeding an effective solution for the preservation of endemic species? *Biological Conservation* **72,** 281-295.

288. Hammer M and Butler G (2001) Data sheet: freshwater fishes of the Mount Lofty Ranges, part C, exotic fish. Upper River Torrens Landcare Group Inc, Mount Pleasant, South Australia. p. 4.

289. McNeil DG and Hammer M (2007) Biological review of the freshwater fishes of the Mount Lofty Ranges. SARDI publication number: F2006/000335. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. p. 104.

APPENDIX 1

Freshwater fishes recorded from different Drainage Divisions in South Australia.

[x = recorded, ? unconfirmed records, * SA endemic, blue = diadromous, green = euryhaline]

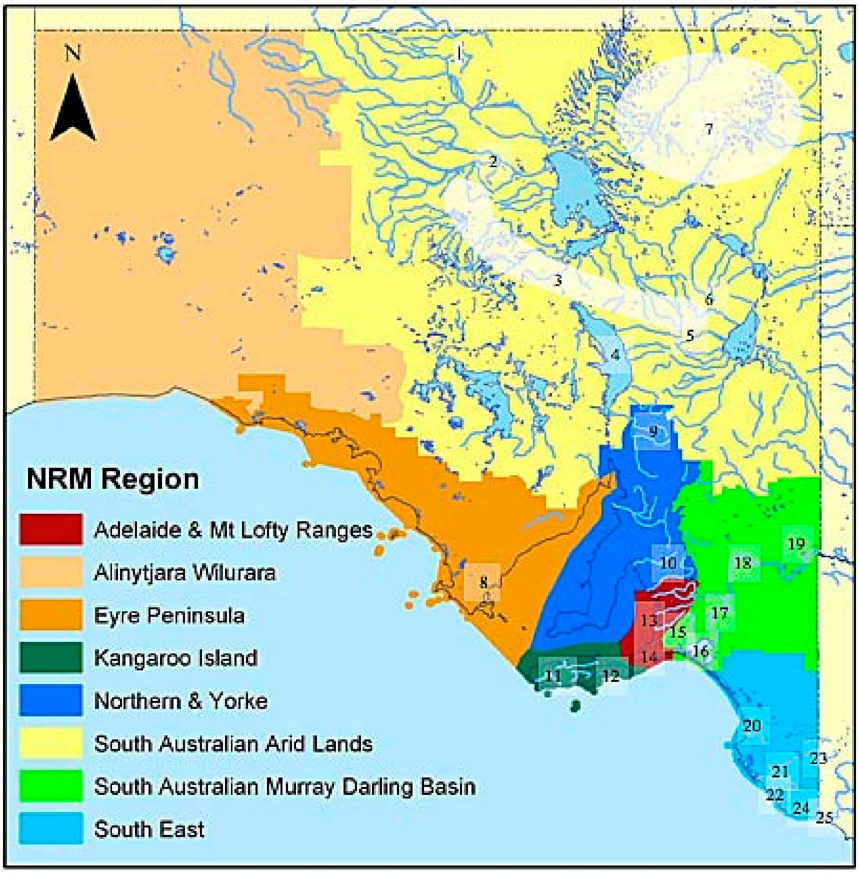
Family	Taxon	Common name	SEC	MD	SAG	LE	WP
Geotriidae	*Geotria australis*	Pouched Lamprey	x	x	x		
Mordaciidae	*Mordacia mordax*	Shortheaded Lamprey	x	x	x		
Anguillidae	*Anguilla australis australis*	Shortfinned Eel	x	x	x		
Plotosidae	*Neosiluroides cooperensis*	Cooper Catfish				x	
	Neosilurus gloveri	Dalhousie Catfish				x	
	Neosilurus hyrtlii	Hyrtl's Catfish				x	
	Porochilus argenteus	Silver Catfish				x	
	Tandanus tandanus	Freshwater Catfish		x			
Clupeidae	*Nematalosa erebi*	Bony Herring		x	?	x	
Retropinnidae	*Prototroctes maraena*	Australian Grayling	x				
	Retropinna semoni	Smelt	x	x		x	
Galaxiidae	*Galaxias brevipinnis*	Climbing Galaxias	x	x	x		
	Galaxias maculatus	Common Galaxias	x	x	x		
	Galaxias olidus	Mountain Galaxias	x	x	x		
	Galaxias rostratus	Flathead Galaxias		x			
	Galaxias truttaceus	Spotted Galaxias	x				
	Galaxiella pusilla	Dwarf Galaxias	x				
	Neochanna cleaveri	Australian Mudfish	x				
Melanotaeniidae	*Melanotaenia fluviatilis*	Murray Rainbowfish	?	x			
	Melanotaenia splendida tatei	Desert Rainbowfish				x	
Atherinidae	*Atherinosoma microstoma*	Smallmouthed Hardyhead	x	x	x		x
	Craterocephalus dalhousiensis	Dalhousie Hardyhead				*	
	Craterocephalus eyresii	Lake Eyre Hardyhead			*	*	?
	Craterocephalus fluviatilis	Murray Hardyhead		x			
	Craterocephalus gloveri	Glover's Hardyhead				*	
	Craterocephalus stercusmuscarum fulvus	Unspecked Hardyhead		x			
	Craterocephalus stercusmuscarum stercusmuscarum	Flyspecked Hardyhead				x	
Ambassidae	*Ambassis agassizii*	Agassiz's Glassfish		x			
	Ambassis sp.	Northwest Glassfish				x	
Percichthyidae	*Gadopsis marmoratus*	River Blackfish	x	x	x		

Appendix 1 continued....

Family	Taxon	Common name	SEC	MD	SAG	LE	WP
	Maccullochella macquariensis	Trout Cod		x			
	Maccullochella peelii peelii	Murray Cod		x			
	Macquaria ambigua ambigua	Murray-Darling Golden Perch		x			
	Macquaria australasica	Macquarie Perch		x			
	Macquaria colonorum	Estuary Perch	x	x			
	Macquaria sp.	Lake Eyre Golden Perch				x	
	Nannoperca australis	Southern Pygmy Perch	x	x	x		
	Nannoperca obscura	Yarra Pygmy Perch	x	x			
	Nannoperca variegata	Variegated Pygmy Perch	x				
Terapontidae	*Amniataba percoides*	Banded Grunter				x	
	Bidyanus bidyanus	Silver Perch		x			
	Bidyanus welchi	Welch's Grunter				x	
	Leiopotherapon unicolor	Spangled Grunter		x	?	x	?
	Scortum barcoo	Barcoo Grunter				x	
Pseudaphritidae	*Pseudaphritis urvillii*	Congolli	x	x	x		x
Eleotridae	*Hypseleotris klunzingeri*	Western Carp Gudgeon		x		x	
Eleotridae	*Hypseleotris klunzingeri*	Western Carp Gudgeon		x		x	
	Hypseleotris sp. 1	Midgley's Carp Gudgeon		x		x	
	Hypseleotris sp. 3	Murray Darling Carp Gudgeon		x	x		
	Hypseleotris spp.	Hybrid forms (e.g. Lake's Carp Gudgeon)	x		x		
	Mogurnda adspersa	Southern Purple-spotted Gudgeon		x	x		
	Mogurnda clivicola	Flinders Ranges Purple-spotted Gudgeon		x			
	Mogurnda thermophila	Dalhousie Purple-spotted Gudgeon			*		
	Philypnodon grandiceps	Flathead Gudgeon	x	x	x		
	Philypnodon macrostomus	Dwarf Flathead Gudgeon		x	x		
Gobiidae	*Chlamydogobius eremius*	Desert Goby				*	
	Chlamydogobius gloveri	Dalhousie Goby				*	
	Pseudogobius olorum	Western Bluespot Goby	x	x	x		x
	Tasmanogobius lasti	Lagoon Goby	x	x	x		
Totals		58	21	35	17	23	3

APPENDIX 2

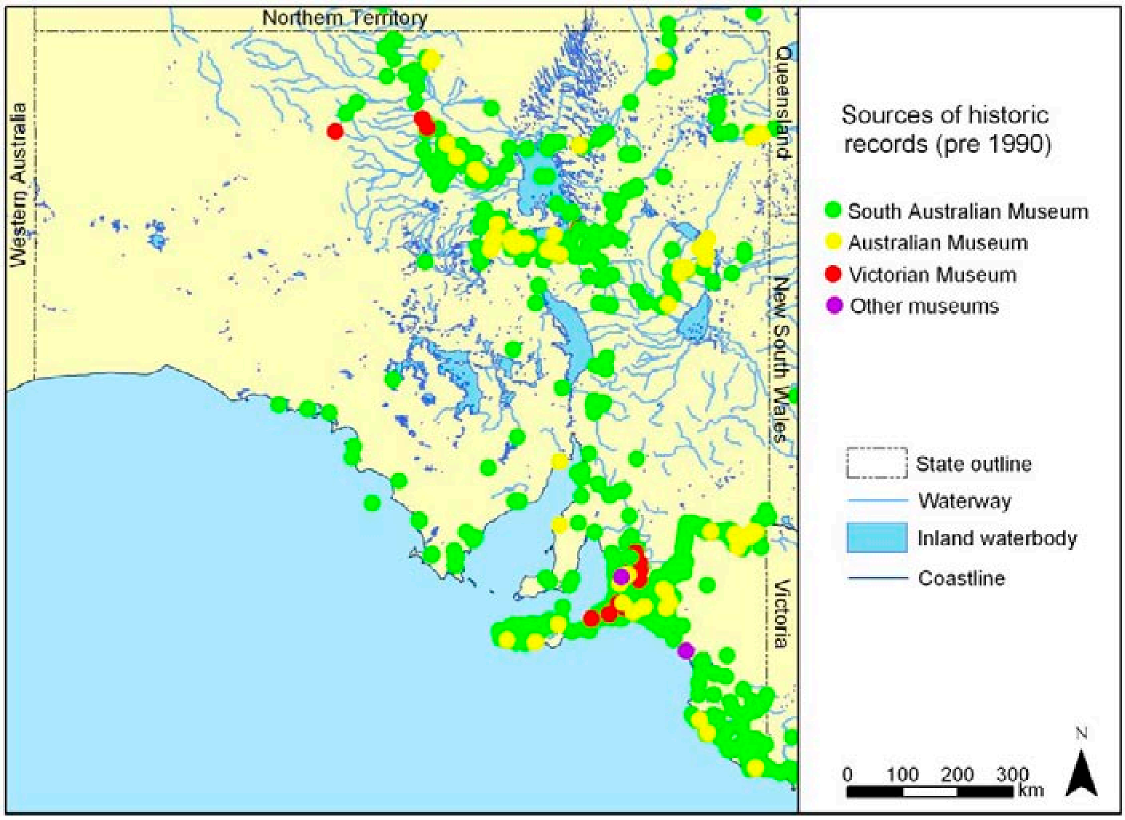
Management jurisdictions and important fish habitats in South Australia



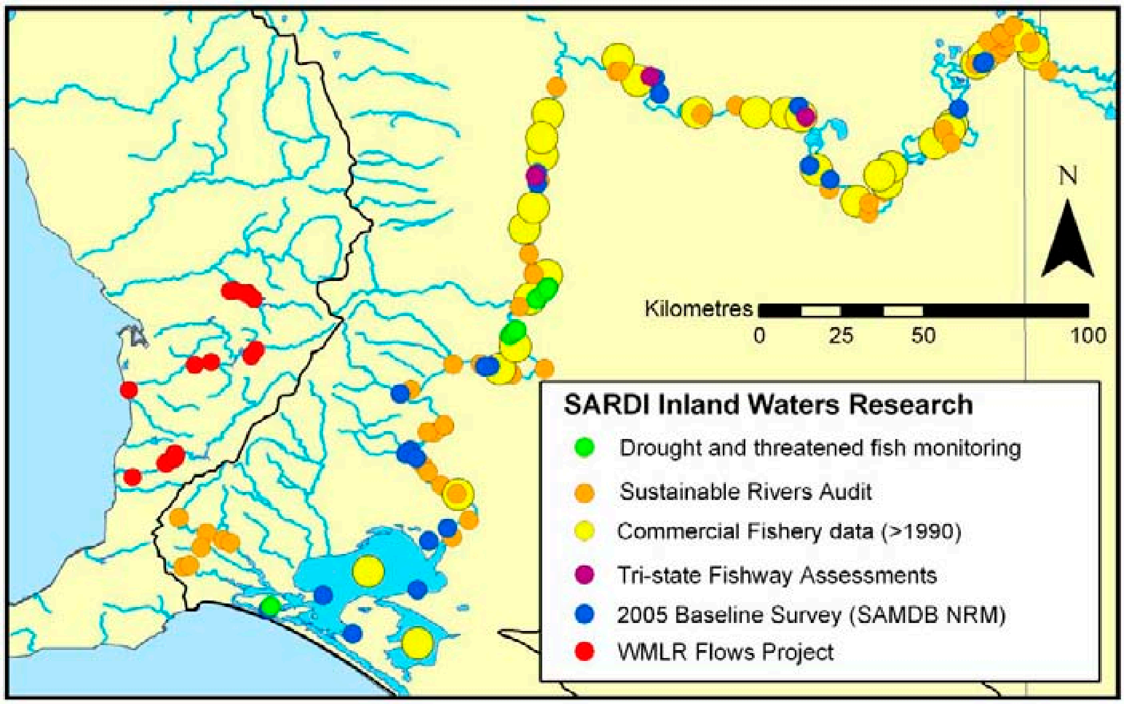
South Australian Arid Lands		Adelaide & Mt Lofty Ranges	
1	Dalhousie Springs	13	Streams (Gawler to Hindmarsh catchments)
2	Neales River	14	Southern Fleurieu Swamps
3	GAB mound springs	**South Australian MDB**	
4	Lake Torrens and fringing springs	15	Eastern Mount Lofty Ranges (Currency, to Marne catchments)
5	Balcanoona Creek	16	Lakes Alexandrina and Albert & the Coorong
6	MacDonnell Creek	17	River Murray wetlands (Blanchetown-Wellington)
7	Coopers Ck, Coongie Lakes and Warburton River	18	River Murray channel
Eyre Peninsula		19	Chowilla region, Berri and Disher Ck wetlands
8	Tod River	**South East**	
Northern and Yorke		20	West Avenue watercourse (Henry Creek)
9	Willochera Creek	21	Mt Burr swamps
10	Broughton River	22	Lake Bonney area & Millicent drains
Kangaroo Island		23	Mosquito Creek and Bool Lagoon
11	Western streams (Middle, Western, Rocky, Stunsail, Harriet)	24	Lower SE rising springs (Ewens, Stratmans, Piccaninnie)
12	Willson River	25	Glenelg River (SA)

APPENDIX 3

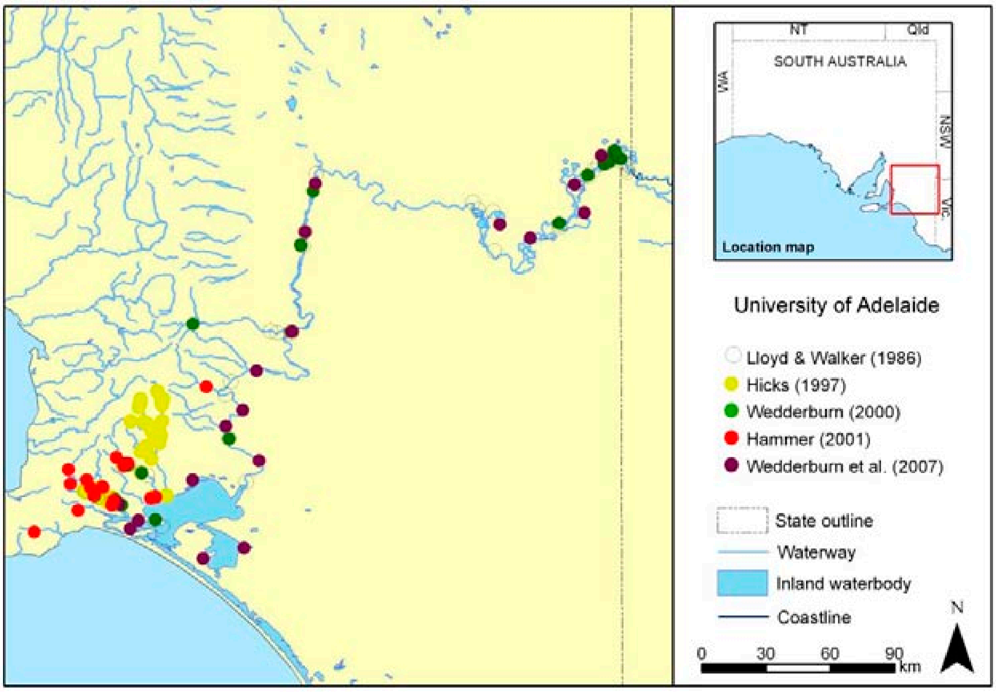
Management jurisdictions and important fish habitats in South Australia



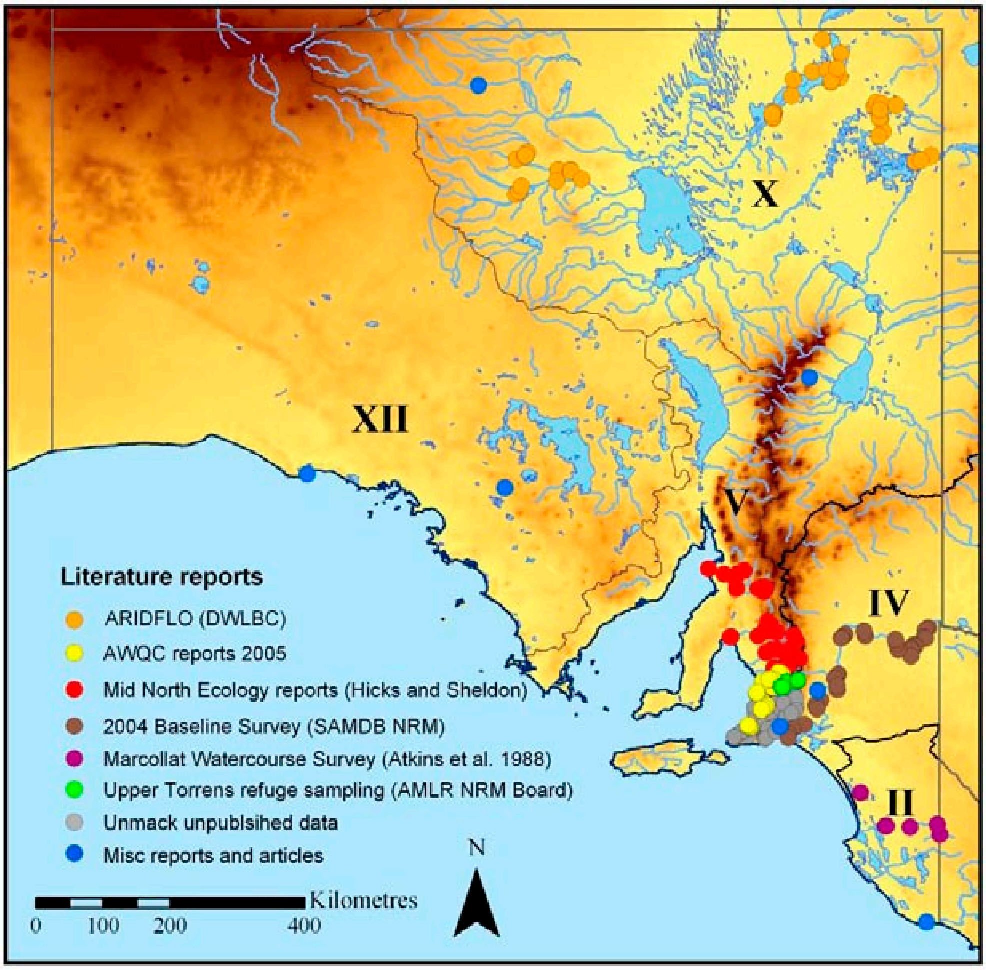
Museum records



Available SARDI Aquatic Sciences Research records 2001-2006



University of Adelaide studies



Miscellaneous research records for South Australia

APPENDIX 4

Conservation criteria used to asses the Status of Taxa in South Australia[38]

IMPORTANT NOTE: It is imperative that, when assessing species schedules for South Australia, the following considerations are made:

When assessing the status of taxa in SA, populations' external to this state must largely be ignored as the focus is on conserving taxa within this state.

Taxa may be classed as 'Rare' in South Australia if they meet one of the following critera (a. to d.) and do not meet the 'IUCN' criteria for 'Critically Endangered', 'Endangered' or 'Vulnerable'.

The definitions for the majority of terms used in the 'Rare' criteria are consistent with 'IUCN' definitions.

It is intended that the 'Rare' category for South Australia includes taxa that are in decline (but do not meet IUCN criteria) as well taxa that naturally have a limited presence (in terms of range or numbers etc) in this state.

Proposed ratings for taxa should be clearly justified by annotating with the assigned criteria.

It is highly recommended that, before commencing any assessment, all the information accompanying the 'IUCN' criteria be read (refer to website : http://www.redlist.org/info/categories_criteria.html)

Species that are considered 'Extinct' or 'Critically Endangered' using the IUCN criteria are currently listed as 'Endangered' on the SA schedules.

IUCN 2001 Criteria[6] used for Critically Endangered, Endangered and Vulnerable. Rare category developed for South Australia by the 'Threatened Species Schedule Subcommittee' in February 2002. IUCN criteria (2001) also applies for Extinct (EX): no reasonable doubt that the last individual has died, following exhaustive surveys, and Extinct in the Wild (EW): taxon is known to survive in captivity or as naturalised population(s) outside of historic range.

CRITICALLY ENDANGERED (CR)

A taxon is Critically Endangered when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing an extremely high risk of extinction in the wild:

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of ≥90% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
    - (a) direct observation
    - (b) an index of abundance appropriate to the taxon
    - (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
    - (d) actual or potential levels of exploitation
    - (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.
2. An observed, estimated, inferred or suspected population size reduction of ≥80% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.
3. A population size reduction of ≥80%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.
4. An observed, estimated, inferred, projected or suspected population size reduction of ≥80% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years), where the time period includes both the past and the future, and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 100 km^2, and estimates indicating at least two of a-c:
    - a. Severely fragmented or known to exist at only a single location.
    - b. Continuing decline, observed, inferred or projected, in any of the following:
        - (i) extent of occurrence
        - (ii) area of occupancy
        - (iii) area, extent and/or quality of habitat
        - (iv) number of locations or subpopulations
        - (v) number of mature individuals.
    - c. Extreme fluctuations in any of the following:
        - (i) extent of occurrence
        - (ii) area of occupancy
        - (iii) number of locations or subpopulations
        - (iv) number of mature individuals.

2. Area of occupancy estimated to be less than 10 km^2, and estimates indicating at least two of a-c:
   - a. Severely fragmented or known to exist at only a single location.
   - b. Continuing decline, observed, inferred or projected, in any of the following:
     - (i) extent of occurrence
     - (ii) area of occupancy
     - (iii) area, extent and/or quality of habitat
     - (iv) number of locations or subpopulations
     - (v) number of mature individuals.
   - c. Extreme fluctuations in any of the following:
     - (i) extent of occurrence
     - (ii) area of occupancy
     - (iii) number of locations or subpopulations
     - (iv) number of mature individuals.

C. Population size estimated to number fewer than 250 mature individuals and either:

1. An estimated continuing decline of at least 25% within three years or one generation, whichever is longer, (up to a maximum of 100 years in the future) OR
2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a-b):
   - (a) Population structure in the form of one of the following:
     - (i) no subpopulation estimated to contain more than 50 mature individuals, OR
     - (ii) at least 90% of mature individuals in one subpopulation.
   - (b) Extreme fluctuations in number of mature individuals.

D. Population size estimated to number fewer than 50 mature individuals.

E. Quantitative analysis showing the probability of extinction in the wild is at least 50% within 10 years or three generations, whichever is the longer (up to a maximum of 100 years).

ENDANGERED (EN)

A taxon is Endangered when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing a very high risk of extinction in the wild:

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of ≥70% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
   - (a) direct observation
   - (b) an index of abundance appropriate to the taxon
   - (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
   - (d) actual or potential levels of exploitation
   - (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.
2. An observed, estimated, inferred or suspected population size reduction of ≥50% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.
3. A population size reduction of ≥50%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.
4. An observed, estimated, inferred, projected or suspected population size reduction of ≥50% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years), where the time period includes both the past and the future, AND where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 5000 km^2, and estimates indicating at least two of a-c:
   - a. Severely fragmented or known to exist at no more than five locations.
   - b. Continuing decline, observed, inferred or projected, in any of the following:
     - (i) extent of occurrence
     - (ii) area of occupancy
     - (iii) area, extent and/or quality of habitat
     - (iv) number of locations or subpopulations
     - (v) number of mature individuals.
   - c. Extreme fluctuations in any of the following:
     - (i)extent of occurrence
     - (ii) area of occupancy
     - (iii) number of locations or subpopulations
     - (iv) number of mature individuals.

2. Area of occupancy estimated to be less than 500 km^2, and estimates indicating at least two of a-c:

    a. Severely fragmented or known to exist at no more than five locations.

    b. Continuing decline, observed, inferred or projected, in any of the following:

        (i) extent of occurrence

        (ii) area of occupancy

        (iii) area, extent and/or quality of habitat

        (iv) number of locations or subpopulations

        (v) number of mature individuals.

    c. Extreme fluctuations in any of the following:

        (i) extent of occurrence

        (ii) area of occupancy

        (iii) number of locations or subpopulations

        (iv) number of mature individuals.

C. Population size estimated to number fewer than 2500 mature individuals and either:

1. An estimated continuing decline of at least 20% within five years or two generations, whichever is longer, (up to a maximum of 100 years in the future) OR
2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a-b):

    (a) Population structure in the form of one of the following:

        (i) no subpopulation estimated to contain more than 250 mature individuals, OR

        (ii) at least 95% of mature individuals in one subpopulation.

    (b) Extreme fluctuations in number of mature individuals.

D. Population size estimated to number fewer than 250 mature individuals.

E. Quantitative analysis showing the probability of extinction in the wild is at least 20% within 20 years or five generations, whichever is the longer (up to a maximum of 100 years).

VULNERABLE (VU)

A taxon is Vulnerable when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing a high risk of extinction in the wild:

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of ≥50% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are: clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
    - (a) direct observation
    - (b) an index of abundance appropriate to the taxon
    - (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
    - (d) actual or potential levels of exploitation
    - (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.
2. An observed, estimated, inferred or suspected population size reduction of ≥30% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.
3. A population size reduction of ≥30%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.
4. An observed, estimated, inferred, projected or suspected population size reduction of ≥30% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years), where the time period includes both the past and the future, AND where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 20,000 km^2, and estimates indicating at least two of a-c:
    - a. Severely fragmented or known to exist at no more than 10 locations.
    - b. Continuing decline, observed, inferred or projected, in any of the following:
        - (i) extent of occurrence
        - (ii) area of occupancy
        - (iii) area, extent and/or quality of habitat
        - (iv) number of locations or subpopulations
        - (v) number of mature individuals.
    - c. Extreme fluctuations in any of the following:
        - (i) extent of occurrence
        - (ii) area of occupancy
        - (iii) number of locations or subpopulations
        - (iv) number of mature individuals.

2. Area of occupancy estimated to be less than 2000 km^2, and estimates indicating at least two of a-c:

    a. Severely fragmented or known to exist at no more than 10 locations.

    b. Continuing decline, observed, inferred or projected, in any of the following:

        (i) extent of occurrence

        (ii) area of occupancy

        (iii) area, extent and/or quality of habitat

        (iv) number of locations or subpopulations

        (v) number of mature individuals.

    c. Extreme fluctuations in any of the following:

        (i) extent of occurrence

        (ii) area of occupancy

        (iii) number of locations or subpopulations

        (iv) number of mature individuals.

C. Population size estimated to number fewer than 10,000 mature individuals and either:

1. An estimated continuing decline of at least 10% within 10 years or three generations, whichever is longer, (up to a maximum of 100 years in the future) OR

2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a-b):

    (a) Population structure in the form of one of the following:

        (i) no subpopulation estimated to contain more than 1000 mature individuals, OR

        (ii) all mature individuals are in one subpopulation.

    (b) Extreme fluctuations in number of mature individuals.

D. Population very small or restricted in the form of either of the following:

1. Population size estimated to number fewer than 1000 mature individuals.

2. Population with a very restricted area of occupancy (typically less than 20 km^2) or number of locations (typically five or fewer) such that it is prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and is thus capable of becoming Critically Endangered or even Extinct in a very short time period.

E. Quantitative analysis showing the probability of extinction in the wild is at least 10% within 100 years.

RARE (RA)

Criteria:

a. Reduced area of occupancy and/or extent of occurrence: Taxa that have disappeared from >50% of their former area of occupancy and/or extent of occurrence and it is observed, estimated, inferred or suspected that further decline is continuing.

b. Declined in abundance: Taxa that have experienced a significant decline in abundance in >50% of their former area of occupancy and/or extent of occurrence and it is observed, estimated, inferred or suspected that further decline is continuing.

c. Small populations: Taxa where it is observed, estimated, inferred or suspected that the total population size numbers <3000 mature individuals and specifying any of the following.

(i) Resident population

(ii) Regular visitors to the state (eg. migratory taxa)

(iii) Irregular visitors to the state (eg. in response to episodic rainfall events)

(iv) Taxa that are experiencing range extensions into SA, with data for other areas showing that they are increasing in range and abundance.

d. Restricted extent of occurrence or area of occupancy: Taxa with either i) or ii)

(i) extent of occurrence <20,000 km^2

(ii) area of occupancy <2,000 km^2 that is highly fragmented

Native Fish Australia SA Incorporated

ACTION PLAN FOR SOUTH AUSTRALIAN

FRESHWATER FISHES

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