

**National Recovery Plan For The
Murray Hardyhead
*Craterocephalus fluviatilis***

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Australian Government

**Department of
Sustainability and
Environment**



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This Recovery Plan has been developed with the involvement and cooperation of a range of stakeholders, but individual stakeholders have not necessarily committed to undertaking specific actions. The attainment of objectives and the provision of funds may be subject to budgetary and other constraints affecting the parties involved. Proposed actions may be subject to modification over the life of the plan due to changes in knowledge.

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Summary

The Murray Hardyhead *Craterocephalus fluviatilis* is a small, silvery, freshwater fish endemic to the lower Murray-Darling River system in South Australia, Victoria and New South Wales. Once considered widespread and common throughout its range, the species has suffered an extensive decline in range and abundance, and is now one of the most threatened vertebrate species in Australia. It is extinct in New South Wales and survives in only a few isolated locations in Victoria and South Australia, where all populations are threatened by rising salinity and declining water levels. Most of the remaining populations are predicted to become extinct in the near future if current drought conditions continue, with perhaps only two or three populations surviving in the short-medium term. The Murray Hardyhead is listed as Vulnerable under the Australian Government *Environment Protection and Biodiversity Conservation Act* 1999. This national Recovery Plan for the Murray Hardyhead is the first recovery plan prepared for the species. The Plan details the species' distribution, biology and ecology, threats and recovery objectives and actions necessary to ensure the long-term survival of the Murray Hardyhead.

Species Information

Description

The Murray Hardyhead *Craterocephalus fluviatilis* McCulloch, 1913 is a small, translucent, silvery fish growing to about 75 mm total length. There are two separate, small dorsal fins, the first with 4–7 spines, the second with one spine and 5–8 rays. The anal fin is small, opposite the second dorsal fin and has one spine and 6–9 rays. The pectoral fins are inserted high on the sides, near the top of the operculum opening, and have one spine and 11–13 rays. The pelvic fins are small, abdominal and have one spine and 5–6 rays. The Murray Hardyhead has relatively small, thin scales, with a mid-lateral scale count of 31–35, and 10–12 scales in transverse series, including 4–8 above the mid-lateral band (description based on Ivanstoff & Crowley 1996, and ARI data).

Very little is known about the Murray Hardyhead. It is a mobile, schooling species. Spawning apparently occurs in late spring and summer, and the adhesive eggs are laid amongst aquatic vegetation (Ivanstoff & Crowley 1996). In Victoria, adults in spawning condition have been collected in stands of *Ruppia* species in saline lakes (Raadik & Fairbrother 1999) and it is presumed the species spawns amongst this vegetation. Newly hatched larvae as small as 5 mm in length have been collected in mid summer (B. Ebner, unpubl. data). Diet consists primarily of microcrustaceans (Hardie 2000; B. Ebner, unpubl. data).

The Murray Hardyhead has been confused with several other hardyheads (Crowley & Ivanstoff 1990), including the Darling River Hardyhead *Craterocephalus amniculus*, the Lake Eyre Hardyhead *Craterocephalus eyresii* and the Unspecked (or Fly-specked, or Freshwater) Hardyhead *Craterocephalus stercusmuscarum fulvus* (eg. Cadwallader & Backhouse 1983). The Unspecked Hardyhead is widespread in the Murray-Darling River system and overlaps in range with the Murray Hardyhead (Ivanstoff & Crowley 1996). There are some locations where both species occur together, such as the Cardross Lakes (Vic) (T. Raadik DSE-ARI pers. com.), and the lower lakes of the Murray River in South Australia (where both occur along with the marine/estuarine species, the Small-mouthed Hardyhead *Atherinasoma microstoma*) (B. Zampatti SA SARDI pers. comm.). The Murray Hardyhead and the Unspecked Hardyhead can be most readily distinguished by scale size and count: the Murray Hardyhead has 10–12 scales in transverse series, including 4–8 above the mid-lateral band, while the Unspecked Hardyhead has larger scales, with eight or fewer scales in transverse series, including three above the mid-lateral band (Ivanstoff & Crowley 1996). However, there is some doubt as to the accuracy of published keys, and additional genetic and morphometric analyses are required to confidently distinguish between these two species.

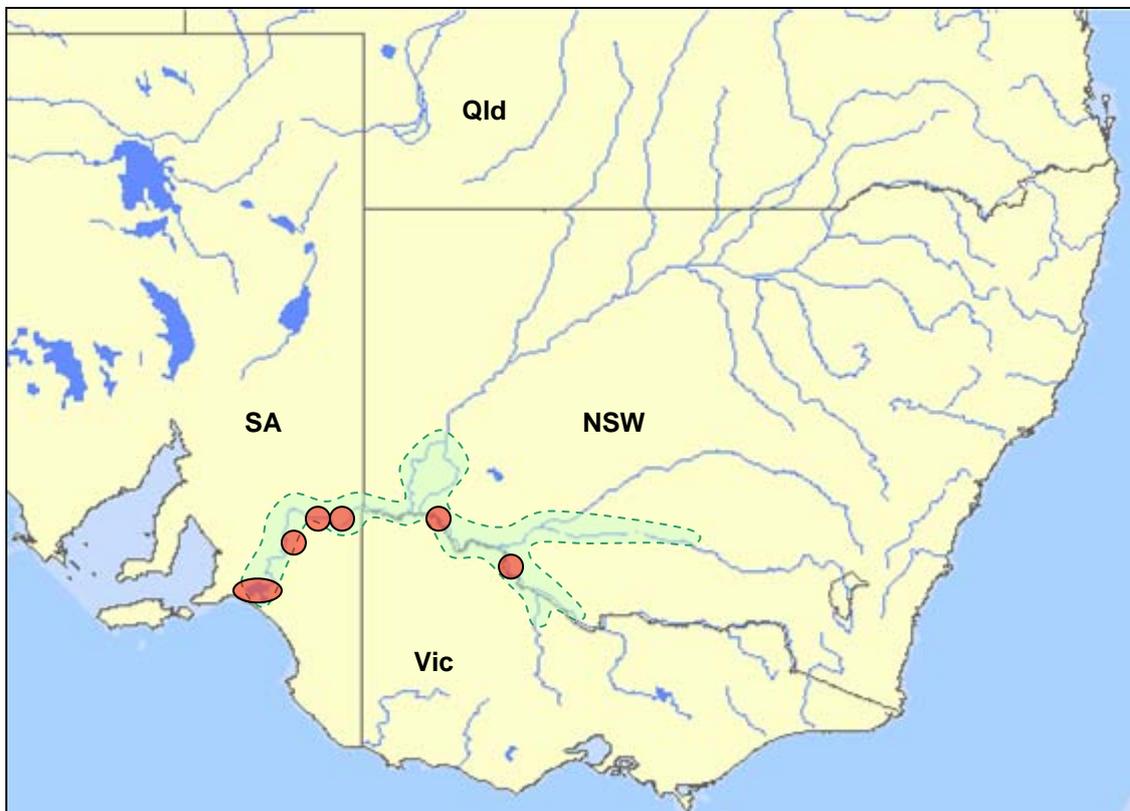
Distribution

The Murray Hardyhead is endemic to the mid and lower Murray-Darling River system in south-eastern Australia (New South Wales, Victoria and South Australia) (Lloyd & Walker 1986; Ivanstoft & Crowley 1996; Ebner *et al.* 2003). The species has been recorded from the Darling River near Wentworth and the Murrumbidgee River at Narrandera (NSW) (DPI 2006), wetlands near Kerang, Swan Hill and Mildura (Victoria) (Chessman & Williams 1974; McGuckin 1999; Raadik & Fairbrother 1999; Hardie 2000; DSE Aquatic Fauna Database), and in the lower Murray River and its tributaries near Renmark, Swan Reach and the lower lakes near the mouth (South Australia) (Lloyd & Walker 1986; Hammer *et al.* 2002; Wedderburn & Hammer 2003). However, the exact distribution of the Murray Hardyhead is unclear due to confusion in identification with other hardyheads, including the Darling River Hardyhead, Lake Eyre Hardyhead and Unspecked Hardyhead (Crowley & Ivanstoft 1990).

In NSW, there has only been one record of Murray Hardyhead in the last 30 years, and the species is considered extinct there (DPI 2006). In Victoria, the species has been recorded from Cardross Lakes and Lake Hawthorn near Mildura (Raadik & Fairbrother 1999) and several lakes in the Swan Hill-Kerang district, including Cullen, Elizabeth, Golf Course, Long, Round, Tuchewop, Wandella, Woorinen North and Yando Lakes (Chessman & Williams 1974; Fleming 1990; McGuckin 1999; Hardie 2000; Lyon *et al.* 2002; DSE Aquatic Fauna Database). Currently the species survives in only four lakes: Cardross Lakes and Lake Hawthorn (Ellis 2007) and Round and Woorinen North Lakes (T. Raddik DSE-ARI unpubl. data).

In South Australia, the species has been recorded from several locations from near Renmark downstream to near the mouth of the Murray River, including the Murray River and tributaries Finnis River, Angas River, Marne River and Dishers Creek (Lloyd & Walker 1986). Current distribution indicates several discrete, apparently isolated populations in or along the Murray River and the lower lakes region, including Scotts Creek, Berri and Dishers Creek evaporation basins, Lake Littra, Lake Albert, Lake Alexandrina and Hindmarsh Island (B. Zampatti SARDI pers. comm).

Figure 1. Distribution of the Murray Hardyhead



likely former distribution indicated by green shading; current distribution indicated by red shading

Detailed distribution information on the Murray Hardyhead is available from: NSW – Department of Primary Industries (www.dpi.nsw.gov.au); Vic – Department of Sustainability and Environment (www.dse.vic.gov.au); SA – Department of Environment and Heritage (www.environment.sa.gov.au).

Population Information

There are perhaps only 13 extant populations of Murray Hardyhead, nine in South Australia and four in Victoria (Table 1), and all of these are considered important to the survival of the species. As many as 15 populations may have become extinct in the last 50 years (Table 2). The lower lakes region of the Murray River in South Australia comprises many more or less isolated populations including Hindmarsh Island, Lake Albert, Dunn's Lagoon, Mud Island, Loveday Bay, Jacobs Bight, Finniss River (Tosolinis and Reedlands), Scotts Creek, Angas River and Lake Alexandrina. This region holds the largest, most genetically diverse of all Murray Hardyhead populations. All other populations are now effectively isolated from one another.

There are no quantitative measures of abundance of the Murray Hardyhead, although there are some qualitative estimates that provide an indication of abundance of some populations. Captures of several hundred fish have been reported during survey and monitoring work at several locations in Victoria and South Australia (eg. Raadik & O'Connor 1996; McGuckin 1999; Hardie 2000; Lyon *et al.* 2002; Wedderburn & Hammer 2003; Ellis 2007), indicating some populations, especially those in saline lakes and in the lower lakes region, were locally common to abundant, probably containing many thousands of fish. The species was considered 'locally common' in Dishers Creek (Lloyd & Walker 1986) and in areas of the Murray River lower Lakes (Wedderburn & Hammer 2003; J. Higham pers comm.). There are apparently seasonal fluctuations in abundance in some populations (Raadik & Fairbrother 1999). At some locations, especially those in the Murray River main channel, records were of few or single fish only, possibly indicating low absolute numbers of fish in these locations.

Table 1. Location of extant populations of the Murray Hardyhead

Location (lat. long. locations using AGD66)	Bioregion*
Victoria	
Round Lake (Swan Hill): 35° 28' 143° 36'	Murray Darling Depression
Woorinen North Lake (Swan Hill): 35° 14' 143° 26'	Murray Darling Depression
Cardross Lakes (Mildura): 34° 19' 142° 06'	Murray Darling Depression
Lake Hawthorn (Mildura): 34° 12' 142° 06'	Murray Darling Depression
South Australia	
<i>Lower Murray Region</i>	
Berri evaporation basin: 34° 18' 140° 34'	Murray Darling Depression
Dishers Creek evaporation basin: 34° 15' 140° 40'	Murray Darling Depression
<i>Lower Lakes Region</i>	
Finniss River (Tosolinis): 35° 26' 139° 02'	Murray Darling Depression
Finniss River (Reedlands): 35° 25' 138° 50'	Murray Darling Depression
Angas River: 35° 54' 138° 59'	Naracoorte Coastal Plain
Scotts Creek: 35° 05' 138° 41'	Murray Darling Depression
Lake Albert: 35° 35' 139° 18'	Murray Darling Depression
Lake Alexandrina: 35° 25' 139° 10'	Murray Darling Depression
Hindmarsh Island: 35° 32' 138° 55'	Murray Darling Depression

* IBRA Bioregions *sensu* DEH (2000)

All sites are public land/water managed for a variety of purposes.

Habitat

The Murray Hardyhead occurs in still and slow-flowing waters including billabongs, lakes and margins and backwaters of lowland rivers (Lloyd & Walker 1986; Crowley & Ivanstoff 1990; Ivanstoff & Crowley 1996), but precise habitat preferences are unclear due to confusion in identification with other hardyhead species. The species may exhibit a preference for inland waters with elevated salinity (McGuckin 1999). Investigation of the exact distribution and habitat utilisation of *C. fluviatilis* (based on reexamination of specimens of *Craterocephalus* from the lower Murray-Darling River system for correct identification) indicates that *C. fluviatilis* inhabits slightly saline waters, while *C. s. fulvus* occurs predominantly in freshwater (B. Ebner, unpubl. data). In Victoria, most records are from saline ephemeral deflation basin lakes (lakes characterised by wind and wave-formed lunettes on their eastern shore; Bowler 1995; Ebner *et al.* 2003), with salinities ranging from 1,200 $\mu\text{S}/\text{cm}$ in Cardross Lakes to about 48,000 $\mu\text{S}/\text{cm}$ in Golf Course Lake (McGuckin 1999) and Lake Elizabeth (Hardie 2000; Lyon *et al.* 2002) (seawater is about 40,000 $\mu\text{S}/\text{cm}$). In South Australia, the species has been recorded from low salinity locations such as the main channel Murray River (salinity between 500 – 900 $\mu\text{S}/\text{cm}$ at Morgan; MDBC monitoring data) to moderately saline sites such as Dishers Creek evaporation basin, with a salinity of 14,300 $\mu\text{S}/\text{cm}$ (Lloyd & Walker 1986). Certainly the species appears to be more common in waters with elevated salinity rather than low salinity sites. However, it is not clear if this indicates habitat preferences, or reflects some other ecological factor such as competition or predation occurring at lower salinity sites which tend to have more fish species present than in saline lakes.

The Murray Hardyhead occurs in open-water and amongst aquatic plants such as fringing emergent rushes *Cumbungi* species and *Juncus* species, and macrophytes including *Ruppia* species and *Potamogeton* species, over silty and sandy substrates, in very shallow to deeper water (Ivanstoff & Crowley 1996; Raadik & Fairbrother 1999; Ebner *et al.* 2003). *Ruppia* especially appears to be a key aquatic species in saline lakes where the Murray Hardyhead occurs (J. McGuckin pers. comm.).

Recovery actions include survey and mapping of habitat that will lead to the identification of habitat critical to the survival of the species.

Decline and Threats

The Murray Hardyhead was once considered widespread and common to abundant throughout the mid and lower reaches of the Murray-Darling River system, but has suffered an extensive decline in range and abundance throughout its distribution (Ebner & Raadik 2001; Ivanstoff & Crowley 1996). Perhaps 15 populations have become extinct in the last 50 years, including at least four populations becoming extinct since 2000 (Table 2). Despite extensive survey effort in New South Wales in areas where the Murray Hardyhead formerly occurred, only a single fish has been recorded since the 1970s, and the species is now considered to be extinct in that State (DPI 2006). Most, if not all, remaining populations in South Australia (the current stronghold of the species) are predicted to become extinct by the end of 2008 (M. Hammer pers. comm.; S. Wedderburn pers. comm.). The lower lakes region currently holds the largest, and probably most genetically diverse of all Murray Hardyhead populations. Even as recently as 2005 the species was considered locally common to abundant in the region (M. Hammer pers. comm.). However, since then record low flows in the Murray River and its local tributaries have resulted in some of these sites drying completely, with the remainder drying out and/or suffering from increasing salinity (M. Hammer pers. comm.). The population in Lake Hawthorn (Vic) is also likely to become extinct by the end of 2008 due to declining lake levels and increasing salinity. The Cardross Lakes (Vic) population is similarly in great peril, but may survive a little longer through an emergency environmental water allocation scheduled for late 2007 (I. Ellis MDFRC pers. comm.). Perhaps only two populations – Round Lake and Woorinen North Lake – may survive in the medium term.

The single biggest current threat facing remaining populations is, simply, lack of water, which is largely caused by many years of extensive dry conditions occurring throughout the Murray-Darling basin. Almost all sites are currently drying up, and some sites will be dry by early-mid

2008, while other sites may still hold water but salinity levels are likely to increase to lethal levels. For instance, Lake Alexandrina was only 0.2 m above sea level in late 2007, and was expected to fall to -1 m below sea level by early 2008. Littoral habitat areas with aquatic vegetation important for Murray Hardyhead became exposed when the lake level dropped below 0.3 m above sea level (M. Hammer pers. comm.). Although water conditions may continue to be suitable for the fish, there is no breeding or feeding habitat, and lack of cover renders the species more exposed to predatory fish and birds. The impact of reducing water levels may also be felt through a combination of high salinity, high water temperatures, low dissolved oxygen and fluctuating pH levels having synergistic or compounding effects.

Table 2. Locations where the Murray Hardyhead is now presumed extinct

Location	Last record	Bioregion*	Comments
New South Wales			
Darling River, Wentworth	1970s	MDD	
Bundidgery Creek, Narrandera	1995	Riverina	single fish recorded despite extensive surveys
Victoria			
Lake Elizabeth	2002	Riverina	formerly common to abundant
Long Lake	1971	Riverina	absent by 1989; lake dry in late 1990s
Lake Tuchewop	1971	Riverina	used as evaporation basin; steadily increasing salinity probably exceeded lethal levels
Golf Course Lake	1999	Riverina	lake dry in 2002
Cullens Lake	1971	Riverina	absent by 1989; lake dry in late 1990s
Lake Wandella	1964	Riverina	
Lake Yando	1963	Riverina	lake dry in late 1990s
South Australia			
Riverglade Wetland Murray Bridge	2006	MDD	wetland now dry
Rocky Gully Wetland Murray Bridge	2006	MDD	wetland now dry; fish may be persisting in nearby small channel?
Murray River Wongulla	early 1980s	MDD	original record a single fish
Murray River Mannum	1968	MDD	
Marne River	early 1980s	MDD	original record a single fish
Lake Littra	2000	MDD	original record a single fish; lake now dry

* IBRA Bioregions *sensu* DEH (2000): MDD = Murray Darling Depression

(information sources: Chessman & Williams 1974; Fleming 1990; McGuckin 1999; Hardie 2000; M. Hammer SA pers. comm.; S. Wedderburn SA pers. comm.; T. Raadik DSE-ARI pers. comm.; DSE aquatic fauna database).

The steady decline in historical distribution and abundance is probably due to a number of factors in addition to the current extended dry conditions. As well as specific threats facing almost all populations, there are other, broader threats facing native freshwater fish in general in the Murray-Darling River system, which are discussed in detail in the *Native Fish Strategy for the Murray-Darling Basin 2003–2013* (MDBC 2003). These factors are summarised below:

Increasing salinity

The Murray Hardyhead can tolerate moderately saline conditions, and all remaining populations occur in slightly to moderately saline waters. Although adults have been recorded in waters with a salinity of up to 48,000 $\mu\text{S}/\text{cm}$, whether they can survive and reproduce at such high salinities is not known. Upper limits for salinity have been proposed at 17,500 $\mu\text{S}/\text{cm}$ (Lugg *et al.* 1989) and 28,000 $\mu\text{S}/\text{cm}$ (McGuckin 1999). While adults may be relatively salt-tolerant, the early life stages, particular eggs and fry, may be more sensitive to high salinity levels. Salinity tolerance also varies between populations (Bill Dixon DSE ARI unpub. data).

Increasing salinity is a major threat, especially to populations in lakes or basins away from the main river channel. In these locations, without intervention (eg. inflows of fresh water), salinity levels could increase to the point where they become lethal to the species. Increasing salinity comes about through decreased runoff into the lakes, increased evaporation and deliberate diversion of saline waters into the lakes. Several populations of Murray Hardyhead occur in terminal drainage lakes that have been used as disposal basins for saline water.

River regulation

River regulation, through reduced and altered flooding and run-off, is seen as a significant threat to Murray Hardyhead, reducing connectivity between floodplain habitat and the main river channel. The amount and quality of inflows to riverine and non riverine wetlands is the main conservation issue that needs to be addressed in order to protect Murray Hardyhead populations. Reduced flooding can lead to a number of potential problems including floodplain lakes drying out and causing local extinction of populations, fragmentation and isolation of populations, decreasing chances of dispersal and recolonisation, and increasing salinity.

Decreasing irrigation run-off

Some non-riverine lakes inhabited by Murray Hardyhead (eg. Cardross Lakes) have been used as disposal basins for excess water run-off from irrigated land, and water levels have been kept higher than would naturally occur. In some cases, there has been a decrease in disposal water due to increased efficiency in water use by irrigators, which may pose a threat to the long-term viability of hardyhead populations in these lakes. Decreasing water levels also have a significant impact on the macrophyte communities within these systems, potentially reducing breeding and feeding habitat for hardyheads. There is also reduced run-off with irrigators receiving only a proportion of their normal entitlement due to extremely dry conditions and low water storage levels in the basin.

High nutrient levels

Lakes enriched with nutrients (primarily nitrogen and phosphorus) from urban and agricultural run-off or biological source such as large numbers of waterbirds, can often be subject to excessive growths of phytoplankton (algal blooms). These algal blooms can effect the ecology of a lake system in many ways, the most serious of which is an excessive diurnal fluctuation in pH and dissolved oxygen, which can stress or eliminate sensitive species. Other problems include oxygen depletion resulting in the death of fish and other aquatic fauna, and reduced light penetration that can lead to macrophyte decline (ANZECC 2000). Round Lake (Vic) supports a population of Murray Hardyhead, and fish have been found in spawning condition there. However, the overall condition of the waterbody for fish was considered moderate to poor, due to the combination of low water level, high turbidity and suspected high nutrient levels (Lyon *et al.* 2002).

Acid sulphate soils

Recent investigations into the formation of sulfidic materials in sediment, such as pyrite (FeS_2) and monosulfides (FeS) have highlighted the potential for their development in inland saline waters, including those in the Murray-Darling Basin. When oxidised, elevated levels of sulfidic materials can cause a number of water quality problems, such as acid formation and low dissolved oxygen levels. This has the potential to cause serious harm to aquatic organisms, as was observed at Bottlebend Lagoon (NSW) in 2002, where there was a large fish kill cause by acid sulfate sediments (Lamontagne *et al.* 2004). Although it is not currently known which hardyhead habitats contain sulfidic materials, preliminary indications are that at least some populations occurring in saline lakes may be at risk from this phenomenon. This is one potential cause of the apparent local extinction of hardyhead populations in recent years in several saline lakes in northern Victoria.

Environmental contamination

Environmental contaminants such as petrochemicals and pesticides are utilised in urban and agricultural areas, and can accumulate in terminal lakes through storm water run-off, spray drift and transport through the irrigation system, and the lakes supporting hardyheads are at risk from contamination. Some contaminants such as organochlorins are known to be very persistent in the environment, toxic in high concentrations and, because of their fat solubility, can accumulate readily in the fat tissue of organisms and therefore result in bioaccumulation

(ANZECC 1992). High rates of spinal deformities have been observed in Murray Hardyheads in Lake Hawthorn and Cardross lakes (Vic) (Ebner & Raadik 2001). The cause is not known, but may be due to an environmental contaminant.

Sedimentation

Wetlands naturally trap sediment although increased sedimentation from increased soil erosion can block natural channels, divert flows, and raise soil levels so that wetlands lose deep habitats or are flooded less often. Sediment may also disrupt reproductive processes by rendering substrate unfit for egg attachment or settling on eggs and blocking development. Major sources of sediment input include desilting dams, run-off from agricultural areas, run-off from roads, clearing of riparian zones and forestry activities. The addition of sediment to rivers and streams due to human disturbances can have major effects on the aquatic biota including causing significant loss of habitats and breeding grounds, thereby reducing the diversity or substantially changing the composition of the aquatic communities. Increased sedimentation has been identified as a major threat to Victorian native freshwater fish and a cause for decline in the range and abundance of native fish species.

Barriers to Migration/Movement

The Murray Hardyhead is not known to be a migratory species, and is able to complete its life cycle in isolated lakes. However, barriers to movement may affect recolonisation after local extinction of populations, such as through drying of floodplain lakes. Dispersal during flooding was probably one way that wetlands are able to be recolonised, and river regulation, construction of levee banks, barriers, weirs etc have almost certainly reduced the ability of Murray Hardyhead (as with other native fish species) to disperse along river systems and across floodplains. Irrigation systems may have also provided opportunities for dispersal, but with the installation of more water efficient systems (such as pipelines) these opportunities may be reduced. The largest, most diverse remaining population in the lower lakes region is effectively isolated from the rest of the Murray River (except in high flows) by Lock 1 (B. Zampatti SARDI pers. comm).

Impact of alien fish

Several alien (introduced) fish species including Common Carp *Cyprinus carpio*, Goldfish *Carrasius auratus*, Redfin *Perca fluviatilis* and Eastern Gambusia *Gambusia holbrooki* occur with Murray Hardyheads. The precise impact of alien fish on Murray Hardyheads is not known, but its small size, pelagic habit and requirement for aquatic vegetation in which to spawn renders it susceptible to predation and habitat degradation. Alien fish can pose a threat to native fish species and their habitats in the Murray-Darling River system, through predation, competition, disease transmission and other effects such as causing habitat degradation, often through the very high densities some alien fish species such as carp can reach (MDBC 2003).

Stocking native fish for recreational angling

Due to its small maximum size and hence susceptibility to predation, the Murray Hardyhead is potentially at risk from stocking of larger native species such as Murray Cod *Maccullochella peelii peeli* and Golden Perch *Macquaria ambigua* for recreational angling.

Populations Under Threat

All remaining populations of Murray Hardyhead (Table 1) are under dire threat, with perhaps only two or three populations surviving by the end of 2008. The current major threat is lack of water, that results in consequences such as sites drying up, salinity increasing to lethal levels, or habitat areas becoming exposed and hence not available to the species for feeding, shelter and breeding. All populations in South Australia are predicted to become extinct by the end of 2008, and at least one, perhaps two of the four remaining populations in Victoria may well be extirpated in the very near future.

Recovery Information

Program Implementation

The Recovery Plan will run for five years from the time of adoption. A national Recovery Team with key State agency and other stakeholder representation will be formed to coordinate recovery actions and exchange information on Murray Hardyhead conservation. Implementation of individual actions will remain the responsibility of the relevant agencies and organisations identified in the Recovery Plan (subject to available resources), who will be responsible for preparing work plans and monitoring progress toward recovery within their own jurisdiction (in liaison with the Recovery Team). Lead agencies in each State should maintain liaison with each other, to exchange information on the species, monitor progress towards recovery, and facilitate the end of program review.

Program Evaluation

Lead agencies will be responsible for informal evaluation of their progress. Towards the end of the Recovery Plan, an external reviewer should be appointed to undertake a formal review and evaluation of the recovery program.

Recovery Objectives

The **overall objective** for recovery of the Murray Hardyhead is to minimise the probability of extinction of the Murray Hardyhead in the wild, and to increase the probability of important populations becoming self-sustaining in the long term.

Within the life span of this Recovery Plan, the **Specific Objectives** for recovery of the Murray Hardyhead are to:

1. Investigate and manage threats to populations and habitats.
2. Determine population persistence and trends.
3. Determine habitat preferences.
4. Investigate important life history attributes.
5. Establish and maintain the Murray Hardyhead in captivity.
6. Establish new populations of Murray Hardyhead in the wild.
7. Increase community awareness of Murray Hardyhead conservation.

Note: A summary of the recovery plan actions is provided here. Detailed implementation information can be found in the supporting document 'Background and Implementation Information for the Murray Hardyhead Craterocephalus fluviatilis National Recovery Plan' available at www.environment.gov.au

Recovery Objectives, Actions and Performance Criteria – Summary

Objective	Performance Criteria	Actions
1. Investigate and manage threats to populations and habitats.	At least two current wild populations are surviving and breeding after five years.	1.1 Identify current/potential threats for all extant populations, including changing water management regimes, salinity levels, presence and impact of acid sulphate soils, and impact of introduced species. 1.2 Supply environmental water to Round and Woorinen North Lakes annually as required to maintain water quality conditions to ensure long-term sustainability of populations. 1.3 Supply environmental water to Cardross Lakes for at least one season to ensure short-term persistence of the population there. 1.4 Develop and implement water quality and habitat monitoring programs at Cardross, Hawthorn, Round and Woorinen North Lakes 1.5 Investigate reasons for the recent extinction of Murray Hardyhead in Lake Elizabeth. 1.6 Undertake a cost-benefit analysis of maintaining or restoring habitat conditions at five locations for Murray Hardyhead in Victoria.
2. Determine population persistence and trends.	All remaining populations monitored at least annually to determine area, extent, size, structure, estimation of population change and habitat quality.	2.1 Undertake a genetic assessment of population structure throughout range to determine presence and limits of Evolutionarily Significant Units. 2.2 Develop and implement population monitoring programs at Cardross, Hawthorn, Round and Woorinen North Lakes to determine population trends and responses against recovery actions, especially environmental water allocations to maintain water quality. 2.3 Survey all current populations in South Australia at least once annually to determine presence and persistence.
3. Determine habitat preferences.	Habitat features and preferences identified and incorporated into relevant management processes.	3.1 Survey known habitat, collect habitat and environmental information and determine habitat preferences for lake and riverine dwelling populations. 3.2 Prepare management plans for Round and Woorinen North Lakes incorporating habitat requirements for Murray Hardyhead.

Objective	Performance Criteria	Actions
4. Investigate important life history attributes.	Key life history attributes are identified and information incorporated into site management for population and habitat protection.	4.1 Evaluate current reproductive status, fecundity, recruitment levels and longevity. 4.2 Determine stimuli for reproduction/spawning. 4.3 Investigate salinity tolerance at critical life history stages.
5. Establish and maintain the Murray Hardyhead in captivity.	A captive population of at least 100 adult fish is established and successfully breeding, and resulting offspring raised through to adults.	5.1 Establish a facility in Victoria to maintain and breed the Murray Hardyhead in captivity. 5.2 Take at least 50 fish from Cardross Lakes and 50 fish from Lake Hawthorn to establish the captive population. 5.3 Maintain fish for first year and attempt to breed in captivity. 5.4 If breeding is successful, attempt to raise young through to adults. 5.5 Investigate the feasibility of establishing a captive population in South Australia.
6. Establish new populations of Murray Hardyhead in the wild.	At least one new population is established at a secure location in the wild.	6.1 Evaluate and select suitable translocation sites that are ecologically and biologically suitable, have security of tenure, are managed appropriately and have stakeholder support. 6.2 Prepare and implement site management plan (if none available) to ensure site is suitable for establishment of new population. 6.3 Prepare and implement translocation plan taking account of national and State policies and guidelines for translocation of aquatic organisms. 6.4 Maintain and monitor translocated populations.
7. Increase community awareness of Murray Hardyhead conservation.	Knowledge of Murray Hardyhead increases with managers and the public, and conservation requirements included in NRM plans and projects.	7.1 Publicise results of Murray Hardyhead investigations and incorporate into catchment management, river health and wetlands programs where appropriate. 7.2 Promote community awareness of and identify opportunities for involvement in the conservation of the Murray Hardyhead.

Cost of the Recovery Plan

The estimated cost of the recovery program is \$2.832 million over five years.

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Totals	1	2	3	4	5	0

Affected Interests

The Murray Hardyhead occurs in areas with a variety of land management tenures and agencies, although virtually all of these are in some form of public authority ownership and management. Consequently, management is the responsibility of a range of agencies and organisations (Table 3).

Table 3: Organisations with an interest in conservation of the Murray Hardyhead

Organisation	Type
<i>National/Regional</i>	
Murray Darling Basin Commission	executive arm of the Murray-Darling Basin Ministerial Council
Murray Darling Freshwater Research Centre	Research Institute
<i>Victoria</i>	
Dept of Sustainability and Environment	State Government
Parks Victoria	State Government
Department of Primary Industries	State Government
Goulburn-Murray Water	Regional Authority
Sunraysia Rural Water Authority	Regional Authority
Mallee Catchment Management Authority	Regional Authority
North Central Catchment Management Authority	Regional Authority
<i>New South Wales</i>	
Department of Primary Industries Fisheries	State Government
<i>South Australia</i>	
River Murray Catchment and Water Management Board	Regional Authority
SARDI Aquatic Sciences	State Government
Department for Environment and Heritage	State Government
University of Adelaide	Tertiary education
Goolwa-Wellington LAP	Regional Authority

This Recovery Plan has the support of State/territory government agencies and regional land/water managers including Catchment Management Authorities.

Role and Interests of Indigenous People

Consultation has occurred with the Ngarrindjeri people of the lower Murray and Coorong, including the Raukkan Community Association, as part of a PhD program on the Murray

Hardyhead undertaken there (by Scotte Wedderburn; B. Zampatti SARDI SA pers. comm.). Elsewhere, indigenous communities on whose traditional lands and waters the Murray Hardyhead occurs will be advised, through the relevant regional Indigenous Facilitator, of the Recovery Plan and invited to provide comments if so desired. Opportunities to involve indigenous communities in the implementation of the Recovery Plan will be explored once it is finalised.

Benefits to Other Species/Ecological Communities

The Recovery Plan includes a number of potential biodiversity benefits for other species and ecological communities. Principally, this will be through the protection and management of habitat and the allocation of environmental water. The adoption of broad-scale management techniques and collection of baseline data will also benefit other aquatic species occurring in association with Murray Hardyhead, particularly those species with similar habitat requirements and life histories. Other regionally threatened species likely to benefit include the Freshwater Catfish *Tandanus tandanus*, Southern Purple-spotted Gudgeon *Mogurnda adspersa*, Olive Perchlet *Ambassis agassizi* and Unspecked Hardyhead.

The Recovery Plan will also provide an important public education role as threatened fish have the potential to act as 'flagship' species for highlighting broader nature conservation issues in aquatic habitats, such as habitat degradation, barriers to migration and invasive species.

Social and Economic Impacts

The conservation program for Murray Hardyhead has received support from community environment groups. However, there has been considerable opposition from local communities in north western Victoria over proposals to supply environmental water for the species, when agricultural industries are facing reduced irrigation water allocations. Meetings with key stakeholder groups have been held to explain the dire national situation of the species and the Government's responsibility to act to prevent loss of species. Communication with key stakeholder groups will continue as the recovery actions are implemented.

The Murray River is the focus of considerable community attention, especially through the Murray-Darling Basin Commission 'Living Murray' program, and plans to restore significant environmental flows to the Murray River. Increases in environmental flows and a shift to a more natural flooding regime will potentially benefit species like the Murray Hardyhead reliant on floodplain habitat. Wetland restoration is also seen in the community as a major benefit to the environment, and rehabilitation of riparian zones is being initiated and undertaken in many regions by management agencies and many local communities. Threatened species recovery, wetland management and control/amelioration of threatening processes are included as goals in many regional planning and management strategies (eg. regional catchment strategies prepared by CMAs in Victoria).

Some recovery actions, such as provision of environmental water allocations to lakes supporting populations of Murray Hardyhead, are already underway and managed within existing program budgets. Provisions for 'top-up' environmental flows are already being made for Round Lake and Cardross Lakes to dilute the increasingly saline water in these lakes, for conservation of the Murray Hardyhead.

However, given the current dire situation, where the Murray Hardyhead is at high risk of extinction, it should be recognised that recovery of the species will require significant direct investment, and may well continue to generate local community hostility, despite broader community support for threatened species conservation.

Management Practices

The Murray Hardyhead is a potential major beneficiary of efforts to restore ecological processes in the Murray River, including increased environmental flows in the Murray River. While a range of management practices planned or underway may be of benefit, it needs to be recognised that there are some management practices that may be detrimental to Murray Hardyhead populations, especially those in isolated lakes, and threaten their survival.

Management practices that will aid recovery

- Monitoring and managing water quality in lakes and other isolated water bodies where hardyheads occur, to ensure quality is kept within acceptable parameters; important parameters include salinity, temperature, dissolved oxygen, nutrients, blue-green algae, heavy metals, pesticides and suspended solids. Water quality could be maintained in some lakes through allocation of environmental flows through savings in piping water supplies, such as at Woorinen North Lake, Round and Cardross Lakes.
- Providing or increasing environmental flows to the Murray River and important wetlands.
- Consideration of translocation to establish new populations in suitable habitat, particularly at sites from where the species has been extirpated.
- Management of wetlands as potential future suitable habitat for Murray Hardyhead.

Management practices that will avoid significant adverse impacts

- Maintaining or improving hydrological regimes of wetlands to avoid increased salinity and decreased water quality or changes in water level that may lead to loss in aquatic vegetation or reduction of other important habitat.
- Avoiding practices such as disposal of saline water, or blocking or reducing freshwater flows that dilute saline waters, leading to an increase in salinity above acceptable levels for sustainable populations.
- Undertaking a risk assessment for any proposed translocations of additional fish species to lakes or other isolated bodies of water where hardyheads occur.
- Controlling and reducing pesticide and fertiliser run-off into wetlands and waterways, to avoid increasing nutrient levels that could lead to problems such as algal blooms, reduction in dissolved oxygen, increasing sedimentation rates etc.

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