National Recovery Plan for the Trout Cod *Maccullochella macquariensis*

Trout Cod Recovery Team

Australian Government

Department of Sustainability and Environment

Victoria The Place To Be

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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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Detailed background information on the Trout Cod and implementation detail of this Recovery Plan can be found in the document 'Background and Implementation Information for the Trout Cod Maccullochella macquariensis *National Recovery Plan' available at www.environment.gov.au.*

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Abbreviations

ARI	Arthur Rylah Institutive for Environmental Research (DSE, Vic)
CMA	Catchment Management Authority
DSE	Department of Sustainability and Environment (Vic)
DPI	Department of Primary Industries (Vic)
PCL	ACT Parks, Conservation and Lands
IUCN	International Union for the Conservation of Nature
MDBC	Murray Darling Basin Commission
PV Parks	Victoria
PIRVic	Primary Industries Research Victoria (DPI, Vic)
TCRT	Trout Cod Recovery Team

Summary

The Trout Cod *Maccullochella macquariensis* is a moderately large freshwater percicthyid fish endemic to the Murray-Darling River system in south-eastern Australia. It has suffered a catastrophic decline in range and abundance, to the point where just one natural population remains in the wild. The Trout Cod is Listed as **Endangered** under the Australian Government *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act). The first national Recovery Plan for the Trout Cod was prepared in 1994 (Douglas *et al.* 1994), and revised in 1998 (Brown *et al.* 1998). This version builds on these earlier plans, and relies heavily on the information and ideas contained in those plans. This plan details the species' distribution and biology, conservation status, threats, and recovery objectives and actions necessary to ensure the long-term survival of the Trout Cod.

Species Information

Distribution

Past distribution

The Trout Cod is endemic to the Murray-Darling River system in south-eastern Australia, with records from the Murray River (SA & NSW), Murrumbidgee River (NSW & ACT), Macquarie River (NSW) and the Goulburn, Broken, Campaspe, Ovens, King, Buffalo and Mitta Mitta Rivers (Vic) (Berra & Weatherley 1972; Cadwallader 1977; Cadwallader & Gooley 1984; Scott *et. al.* 1980) (Fig. 1). The species was also translocated into several waters outside its recorded range, including Cataract Dam on the Nepean River (NSW) prior to 1910 (Rimmer 1988); Seven Creeks, a tributary of the Goulburn River (Vic) in the early 1920s; and Lake Sambell at Beechworth (Vic) in 1928 (Cadwallader & Gooley 1984). Interestingly, there have been no confirmed records of Trout Cod from either the Darling River (NSW, Qld) or the Lachlan River (NSW).

The mid reaches of the Murray River and its tributaries, particularly in Victoria, and the Murrumbidgee River in NSW seem to have been the centre of its distribution. Up until 1950 at least, Trout Cod were present in the Murray River from Mildura to upstream of Yarrawonga (Cadwallader 1977; Lake 1971), although the species was considered rare downstream from Echuca, but more common upstream (J.O. Langtry, in Cadwallader 1977).

Present distribution

At present only two potentially sustainable, breeding populations of Trout Cod are known: a naturally occurring population in the Murray River (NSW) downstream of the Yarrawonga Weir between Yarrawonga and Barmah (Cadwallader & Gooley 1984; Ingram *et al*. 1990; Douglas *et al.* 1994), and the translocated population in Seven Creeks below Polly McQuinns Weir (Vic) (Cadwallader 1979; Morison & Anderson 1987; Richardson & Ingram 1989).

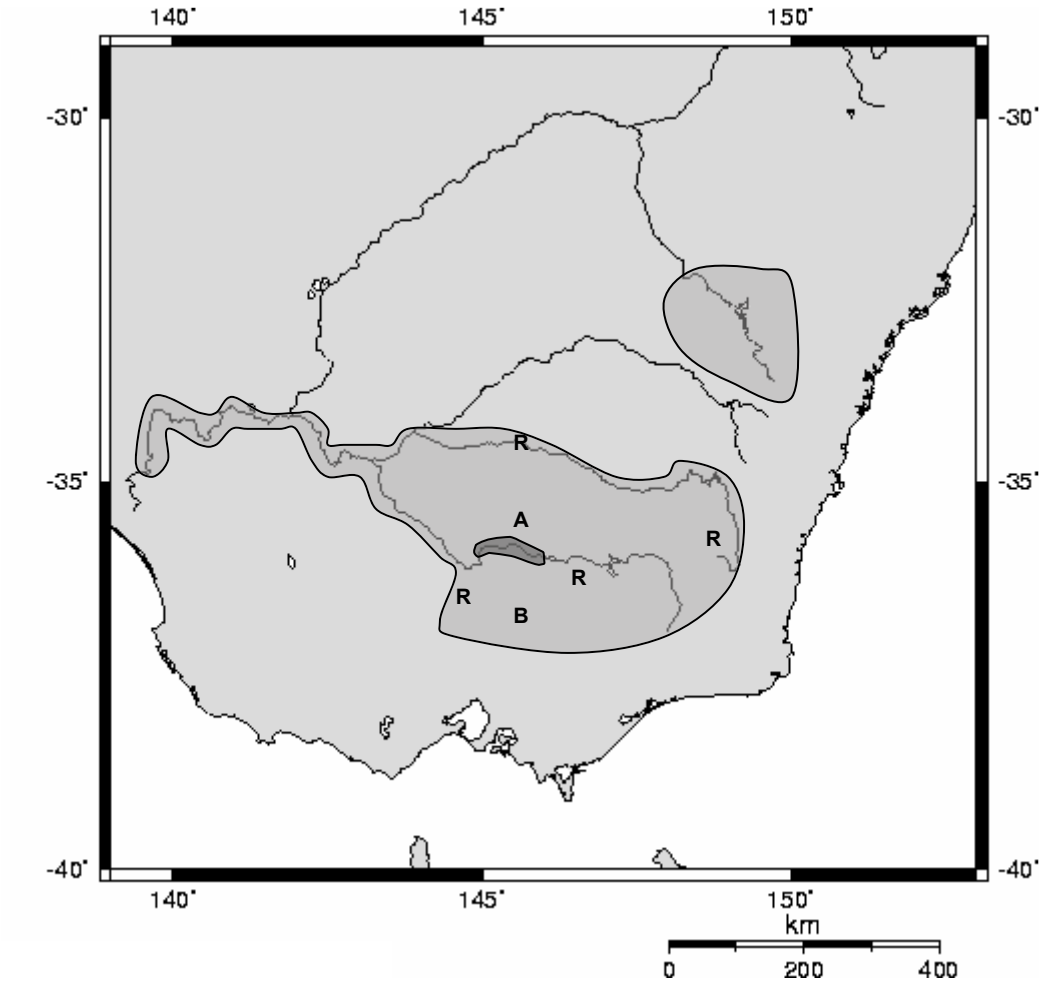
There have been no recent records of wild adult Trout Cod in the Murray River downstream from Echuca (NSW, SA), Macquarie River (NSW), Murrumbidgee River (NSW, ACT), and the Goulburn, Broken, Campaspe, Ovens, King, Buffalo and Mitta Mitta Rivers (Vic). The wild populations formerly occurring in these rivers are now probably extinct. The translocated population in Lake Sambell (Vic) apparently died out in 1970. Trout Cod and Murray Cod translocated into Cataract Dam (Nepean River NSW) have hybridised, and the cod population existing there is composed largely of hybrids (Wajon 1983; Harris & Dixon 1988).

Since the mid 1980s, when techniques to induce spawning in Trout Cod were developed (Rimmer 1987; Ingram & Rimmer 1992), small numbers of juvenile fish have been produced for release into sites within the presumed historical range of the species to establish new populations (Table 2). In several locations, including the Murrumbidgee River (NSW, ACT), the Macquarie River (NSW), the Ovens River and Goulburn Rivers (Vic), stocked fish have survived and are approaching or have reached breeding size. Fish stocked into Ryans Creek (Vic) survived and bred (Douglas & Brown 2000), but the population has since become extinct, possibly due to illegal fishing. In November and December 2003, drifting larvae of Trout Cod and some one year-old juveniles were collected in the Goulburn River downstream from Lake Nagambie (Koster *et al*. 2004), indicating breeding in the stocked population there. However, in January 2004, a fish kill occurred in the Goulburn River for several kilometres downstream of Lake Nagambie, in which many hundreds of native and introduced

fish were killed, including at least 20 Trout Cod. Subsequent surveys failed to detect any Trout Cod, and it is unsure if the population still persist there (Koster *et al.* 2004).

Detailed distribution information on the Trout Cod is available from:
New South Wales: Department of Primary Industries (www.dpi.nsw.gov.au)
Victoria: Department of Sustainability and Environment (www.dse.vic.gov.au)
ACT: ACT Parks, Conservation and Lands (www.environment.act.gov.au)

Figure 1. Distribution of the Trout Cod in south-eastern Australia



former distribution indicated by stippled area

current distribution A = Murray River population B = Seven Creeks population R = extant reintroduced populations

Population Information

Natural and stocked populations of Trout Cod occur in the following locations (Table 1):

Table 1. Location of Current and Recent Populations of Trout Cod

Location	Status	Breeding	Bioregion*	Comments
NSW				
Murray River Yarrawonga to Barmah	Natural	Yes	Riverina	Only known natural population. Self-sustaining
Upper Murray River upstream from Lake Hume	Stocked	Unknown	South Eastern Highlands	No recent records
Murrumbidgee River from Dubbo to Gundagai	Stocked	Unknown	Riverina, NSW South Western Slopes, South Eastern Highlands	Stocked fish persist. Some evidence of recruitment – yet to be confirmed if self-sustaining
Talbingo Dam (Tumut River)	Stocked	Unknown	South Eastern Highlands	Occasional anecdotal reports
Upper Murrumbidgee River (above Burrinjuck Dam to Cooma)	Stocked	Unknown	South Eastern Highlands	Recently commenced – no data to assess
Macquarie River	Stocked	Unknown	NSW South Western Slopes	No recent records
Cataract Dam	Stocked	Yes	Sydney Basin	Population persists. Some hybridisation with Murray Cod
Vic				
Seven Creeks Polly McQuinns weir to Galls Gap Road	Stocked	Yes	Victorian Midlands, South Eastern Highlands	Self-sustaining; narrow genetic base
Ovens River system	Stocked	Unknown	Riverina Victorian Midlands, South Eastern Highlands	Stocked fish moved into King River; fish kills reported in 2003 after ash/sediment runoff following extensive wildfires
Ryans Creek	Stocked		South Eastern Highlands	Extirpated, probably through illegal fishing
Hughes Creek	Stocked	Unknown	South Eastern Highlands	Persistence unknown
Buffalo Creek	Stocked	Unknown	South Eastern Highlands	Persistence unknown
Buffalo River	Stocked	Unknown	South Eastern Highlands	Persistence unknown
Rose River	Stocked	Unknown	South Eastern Highlands	Persistence unknown
Koetong Creek	Stocked	Unknown	South Eastern Highlands	Persistence unknown
Mitta Mitta River	Stocked	Unknown	South Eastern Highlands	Persistence unknown
Coliban River	Stocked	Unknown	Victorian Midlands	Persistence unknown
Goulburn River downstream from Lake Eildon	Stocked	Unknown	South Eastern Highlands	Persistence unknown
Goulburn River downstream from Lake Nagambie	Stocked	Yes (2003)	Riverina	20+ Trout Cod killed in Jan 2004; unknown if pop. still persists
ACT				
Murrumbidgee River	Stocked	Unknown	South Eastern Highlands	
Cotter River	Stocked	Suspected	South Eastern Highlands	Bendora Reservoir

*** IBRA Bioregions *sensu* DEH (2000)**

Habitat

The Trout Cod is a riverine species, inhabiting a variety of flowing waters in the mid to upper reaches of rivers and streams with cover in the form of woody debris or boulders. The Murray River downstream from Yarrawonga Weir is a large (60–100 m wide), flowing and deep (>3 m) river with a

sand, silt and clay substrate, and contains abundant woody debris. Trout Cod have been detected from within, under or adjacent to snags (logs), branch piles and steep clay banks, usually in areas of relatively fast flowing current. Seven Creeks is a relatively narrow stream (5–7 m wide) having a rock, gravel and sand substrate, and pools (generally <2 m deep) interspersed by rapids and cascades up to about 4 m in height. Larger Trout Cod are often found in the deeper pools but smaller fish have also been taken amongst boulders, under logs and other cover in shallower waters (S. Saddlier DSE-ARI pers. comm.). The upper Murrumbidgee River, where Trout Cod were present until the mid 1970s (Lintermans *et al*. 1988) is a medium sized stream (20–50 m wide), with deep holes, rocky gorges and large boulders, although with little woody debris. Stocked Trout Cod have also survived and bred in impoundments such as Cataract Dam and Lake Sambell.

An assessment of habitat critical to survival has been carried out on the Trout Cod population in the Murray River (Koehn & Nicol 1998). Trout Cod used river positions where large woody debris is present in high quantity, close to deeper water and high surface velocity, further from the river bank (Koehn & Nicol 1998). These characteristics are distinct from those of Murray Cod and Golden Perch, and demonstrate that Trout Cod habitat requirements (at least in the Murray River) are specific rather than general. Positions having these characteristics are in limited supply and are patchily distributed in the Murray River system (Nicol *et al.* 2002).

The species has been considered to be more common in the cooler waters of the upper reaches of streams (eg. Lake 1971; J.O. Langtry, in Cadwallader 1977; Cadwallader & Backhouse 1983), although the evidence to support this view is largely anecdotal. The smaller maximum size and more streamlined shape of Trout Cod when compared with Murray Cod were considered to be adaptations to faster-flowing (possibly cooler) waters (J.O. Langtry, in Cadwallader 1977). The distribution of Murray Cod overlaps that of Trout Cod almost completely. Historically, the geographic extent of Trout Cod in the upper Murrumbidgee River exceeded that of Murray Cod (M. Lintermans, MDBC pers. comm.). However, Trout Cod also occurred in the mid and lower reaches of the Murray River system, including in South Australia (Scott *et al.* 1980), although they were certainly considered rare downstream of Echuca (J.O. Langtry, in Cadwallader 1977). Douglas *et al.* (1994) recorded minimum winter water temperatures of 5-10°C and maximum summer water temperatures of 20-25°C at sites of wild populations in the Murray River and Seven Creeks, and in earthen ponds at Snobs Creek Fisheries Research Station in which Trout Cod reached reproductive condition. In captivity, Trout Cod were found to be more prone to bacterial or fungal infections if kept at temperatures of 25°C or above for more than a few days (Merrick & Schmida 1984).

Historical records (museum records and fisheries reports) suggest that Trout Cod inhabited many types of riverine habitat that are now difficult to describe because they have been extensively modified by human-induced changes to the rivers. Habitats of the Murray River downstream from Yarrawonga Weir and Seven Creeks do represent conditions in which the species can survive and reproduce (Douglas *et al*. 1994). 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 Trout Cod has undergone an extensive decline in range and abundance throughout the Murray-Darling River system, apparently in only the last few decades (Cadwallader & Gooley 1984). From being widespread and common, especially in the mid Murray River and its major Victorian tributaries (J.O. Langtry, in Cadwallader 1977), the species has declined to just a single natural breeding population, in the Murray River between Yarrawonga and Barmah. A second breeding population occurs in Seven Creeks near Euroa, arising from an earlier translocation from the Goulburn River (Vic). Other populations (see Table 1), all arising from stockings, have shown little or no evidence of breeding yet. A population of cod in Cataract Dam (NSW) is composed predominantly of hybrids between Trout Cod and Murray Cod.

There appear to be at least some specific threats (eg. fishing, desnagging, poor water quality) affecting Trout Cod. Other well-documented threats operating in the Murray-Darling River system (eg. reduced flooding and flows, low water temperatures, barriers) and affecting many native fish species, may also be impacting on Trout Cod, contributing to the substantial decline in range and abundance. The major current and suspected threats are detailed as follows:

Removal of Large Woody Debris (Desnagging)

Desnagging involves the removal, lopping or realignment of large woody debris (snags), to facilitate navigation, improve water flow, mitigate floods and protect assets such as bridges from flood damage due to debris jams forming. The identification of habitat critical to survival for theTrout Cod (Koehn & Nicol 1998) indicates that, in at least part of its range, desnagging has been a principle cause of decline. Desnagging has preferentially destroyed the prime habitat of adult Trout Cod in its position towards the centre of the river, close to the deep, fast flowing water. In addition to the direct destruction of Trout Cod habitat, desnagging will also have led to fragmentation of remaining available habitat. The strong site fidelity, small local home range and apparent lack of any spawning migration probably limit the capacity of Trout Cod to recolonise new habitat. Consequently, habitat fragmentation resulting from desnagging will have rendered remaining Trout Cod isolated from one another and liable to localised extinction through stochastic processes. While desnagging as a regular activity has now largely ceased (except for specific instances where infrastructure such as bridges may be at risk), and experimental re-snagging programs being used by the Living Murray Program are likely to be benificial to the species, the long-term effects may still be impacting Trout Cod populations. For a species with these life cycle characteristics, it becomes likely that localised extinctions may continue to occur after the primary cause of species decline has ceased to operate.

River Regulation

The impact of river regulation and altered flow regimes, implicated in the decline of other Murray-Darling River system fish species (MDBC 2003a), on Trout Cod is unknown. Flooding downstream from Yarrawonga weir is largely suppressed in most years, while summer flows are elevated compared with the pre-regulation condition, with flows providing 'bank full' conditions at the 'Barmah choke' during the irrigation season. However, Trout Cod are able to survive and breed in these conditions (Douglas *et al.* 1994; J. Koehn & S. Nicol DSE-ARI unpubl.). There is little evidence that the breeding behaviour of Trout Cod in the Murray River is disturbed by the regulated flow regime that exists downstream from Yarrawonga weir, with the temperature profile in this section of river (Douglas *et al.* 1994) apparently being suitable for Trout Cod. However, there remains a possibility that Trout Cod movement patterns, including any movement associated with breeding, are suppressed in the regulated section of the Murray below Yarrawonga. Since the habitats occupied by adult Trout Cod are patchily distributed, increased movement associated with breeding may be an important factor in successful pairing. The effect of these flows on young-of-year Trout Cod is unknown. It is possible that elevated flows exert excessive energy demands on the developing year class, leading to diminished survival. Alternatively, elevated flows may force these fish into competition with Murray Cod inhabiting lower velocity habitats. Substantial amounts of water are abstracted directly from the Ovens River system and Seven Creeks, for agricultural and domestic use. Again, the impact on Trout Cod populations, especially the impact of reduced summer flows, is not known.

Barriers to Movements

Barriers to movement limit the ability of migratory fish species to complete their life cycle, and, even for non-migratory species, can limit the ability to colonise or recolonise suitable habitat, and can reduce gene flow by fragmenting populations. Barriers to fish movements include dams, weirs, culverts, levee banks and areas of unsuitable habitat, high flow or turbulence. Barriers have been recognised as a major threatening process operating throughout the Murray-Darling River system (MDBC 2003a), and in many coastal waterways in eastern and southern Australia. The strong site fidelity, small local home range and apparent lack of any spawning migration by Trout Cod may mean that barriers do not have as great an impact, but information on the movement requirements of the species is still rudimentary. Adult Trout Cod have moved through the fishway on Yarrawonga weir (Thorncraft & Harris 1997), indicating some movement occurs, although adult hatchery-reared Trout Cod released in the Murrumbidgee River (NSW & ACT) and the Cotter River (ACT) mostly remained at or near release sites or had some downstream dispersal, and had poor survivorship (Ebner *et al*. 2005; Ebner *et al*. 2007). A major program is underway in the Murray-Darling River system facilitating fish passage past barriers, which should be of substantial benefit to the native fish of the Basin.

Loss to Irrigation

A substantial amount of water is abstracted from the Murray River system annually (10,800 GL/year; MDBC 2003b), through collection in impoundments, diversion through irrigation channels and direct pumping from rivers. The potential for loss of native fish through these sources is unknown, but could potentially be relatively high (Koehn *et al.* 2004), a view supported by a preliminary investigation of the movements of tagged fish in Lake Nagambie (Goulburn River, Vic) (T. Ryan, DSE-ARI, pers. comm.).

Poor Water Quality

Poor water quality can be caused by reduced flows through diversion, impoundment or sustained dry periods reducing run-off. Consequences include raised water temperatures, reduced dissolved oxygen levels, concentration of nutrients and environmental contaminants. Nutrient run-off from urban and agricultural areas can cause increased growth of phytoplankton, initiating plankton blooms and reducing oxygen levels. Fish kills can result from these conditions, and in just such an event in the Goulburn River in and downstream from Lake Nagambie (Vic) in January 2004, about 20 Trout Cod (most likely from stocked fish) were among thousands of native and introduced fish killed, apparently due to extremely low dissolved oxygen levels linked to poor water quality. This stocked population had bred in the wild in 2003 and possibly 2002 (Koster *et al.* 2004), the first solid evidence of reproduction in a recently stocked population. Subsequent surveys failed to detect any Trout Cod in the area affected by the fish kill (Koster *et al.* 2004) and it is uncertain if the population still persists there.

Siltation

Increased siltation through runoff after events such as wildfires can have a major effect on isolated or stocked populations. Extensive wildfires in south-eastern Australia in the summer of 2003 burnt through several areas in the ACT and Victoria where stocked populations of Trout Cod, and large amounts of sediment are now flowing into streams. An extensive fish kill occurred in the Buckland and Ovens Rivers (Vic) in March 2003 (J. Lyon DSE-ARI pers. comm.) after heavy rains fell over the fire area and washed enormous amounts of sediment and ash into the system, although it is not known if any Trout Cod were killed.

Altered Water Temperatures (*Thermal Pollution*)

The impact of cold-water flows from large dams has been significant on species such as Golden Perch *Macquaria ambigua* and Murray Cod (MDBC 2003a; Ryan *et al.* 2003). Trout Cod may have been similarly impacted, particularly in areas such as the Mitta Mitta River and Murray River downstream of the Hume dam (Koehn *et al.* 1995). Reduced temperature may impair reproduction, growth and survival of young fish, and favour potential competitors as Redfin Perch *Perca fluviatilis* and Brown Trout *Salmo trutta* (Ryan *et al.* 2003).

Predation and Competition

Several introduced fish species, including Common Carp *Cyprinus carpio*, Redfin Perch and Brown Trout, co-occur with the remaining wild populations of Trout Cod, although their impact on Trout Cod is not clear. There is a clear risk of predation of stocked juvenile Trout Cod from larger predatory species such as Redfin Perch and trout, and perhaps even competition for food and space from trout in populations such as Seven Creeks and upper Ovens/King Rivers. The risks of predation and competition may well be exacerbated by stocking both native and introduced species for recreational angling. As early as 1960, J.O. Langtry speculated that the demise of native fish including Trout Cod from some upland rivers might be due in part to stocking with trout (J.O. Langtry, in Cadwallader 1977). As a precaution, trout stocking does not occur in Seven Creeks, the Ovens River and King River below Lake William Hovell. It would be prudent to maintain this at least until there is evidence that the stocked Trout Cod populations are breeding and wild-bred fish are attaining adult size, and the nature of interactions between trout and cod are known. In addition to predation and competition for habitat and food resources, introduced fish species can also impact on native species and freshwater ecosystems through habitat degradation and spread of diseases and parasites. One objective is to investigate the interaction between Trout Cod and introduced freshwater fish (see Action 4.2).

Recreational Fishing

There is little evidence of the historical impact of commercial and recreational fishing on Trout Cod. Commercial fishing throughout the historical range of the species no longer occurs, but the area, particularly the Murray River, is extremely popular with recreational anglers and has heavy recreational fishing pressure. Trout cod are known to be very susceptible to angling, and in the ACT where Trout Cod and Murray Cod were present, it was usually Trout Cod that were caught first (Lintermans *et al*. 1988). Thus, despite their patchy distribution, once an angler targets a Trout Cod site, there is a high probability of capture. The last natural wild Trout Cod population in the ACT occurred in an area that was heavily fished, and became extinct in the 1970s (M. Lintermans MDBC pers. comm.). Although a total prohibition on the taking of Trout Cod exists throughout the species' range, fisheries compliance inspections and anecdotal evidence indicates that Trout Cod are frequently caught in the Murray River downstream of Yarrawonga, and at the sites of reintroductions in

Victoria, NSW and the ACT (S. McMonigle DPI Fisheries Vic., D. Gilligan NSW Fisheries, M. Lintermans MDBC; pers. comm.). Captured Trout Cod must be returned to the water unharmed immediately, but the survival rate of released fish is not known.

Mis-identification of Trout Cod as Murray Cod still occurs, and can lead to significant losses from small populations. Studies on other recreational freshwater fish species indicate post-capture mortality rates between 1% and 70% of released fish (Muoneke & Childress 1994). A stocked population of Trout Cod in Ryans Creek (Loombah Weir, Vic) is considered to have been eliminated through illegal fishing, despite the species being protected and the waterbody being closed to all fishing. There is still some illegal take from the Murray River, as evidenced by successful prosecutions by NSW Fisheries inspectors, despite the species being protected, a closed season in place, information in recreational angling guides, and information signs at all major access points to the river (A. Sanger NSW Fisheries pers. comm.). Douglas *et al* (1994) considered there was a low level of compliance with regulations prohibiting the taking of Trout Cod in the Murray River. More recently, there is evidence of increasing non-compliance on the Ovens River and Goulburn River populations in Victoria (D. Trickey and S McMonigle, DPI-Fisheries Vic., pers. comm.)

Hybridisation

Trout Cod and Murray Cod stocked into Cataract Dam (Nepean River NSW) have hybridised (Wajon 1983; Harris & Dixon 1988). Both species also hybridise under hatchery conditions (Douglas *et al.* 1994), but hybrids appear to be extremely rare in natural wild populations (Douglas *et al*. 1995), possibly because of behavioural and/or habitat preference differences between the parent species. While there appears to be little threat from hybridisation in rivers, it would be prudent that, where Trout Cod are stocked, especially in confined impoundments, caution should be exercised in stocking Murray Cod in the same waters.

Disease

A variety of parasites are reported to infect Trout Cod, including protozoans *Chilodonella* species, *Ichthyophthirius* species, *Myxosoma* species and *Trichodina* species (Ashburner & Ehl 1973; Ashburner 1978; Rowland & Ingram 1991). *Chilodonella* infestation has killed adult Trout Cod kept at a hatchery (Ingram & Rimmer 1992). The introduced Redfin Perch carries the virus Epizootic Haematopoietic Necrosis Virus (EHVN) that is known to infect other native freshwater fish including the related Macquarie Perch (Langdon 1989; MDBC 2003a). The impact of disease on wild Trout Cod populations is not known, although Douglas *et al*. (1994) considered that *Chilodonella* species may be a threat in the wild. There is the potential to introduce disease to wild populations through the release of hatchery-bred fish. Hatcheries breeding Trout Cod in Victoria and New South Wales comply with National Policy for the Translocation of Live Aquatic Organisms guidelines (MCFFA 1999), requiring disease screening prior to release.

Low Genetic Diversity

The Trout Cod population in Seven Creeks has very low genetic diversity when compared with the Murray River population (Bearlin & Tikel 2003), which may affect its long-term viability. The possibility of supplementation needs to be investigated in the context of the contribution of this population to the long-term conservation of Trout Cod.

Human Activities with the potential to have detrimental impact on Trout Cod

- Removal of snags, woody debris, rocks from potential habitat. Where this is unavoidable (eg. for protection of assets such as bridges), alternative suitable habitat should be created as a compensation or offset.
- Reduction in/alteration of flows, such as abstraction of more water from the system.
- Building barriers to migration/movement such as dams, weirs, causeways and levees.
- Removal of riparian vegetation/habitat.
- Events leading to increased siltation or sedimentation, such as works on riverbank and floodplain.
- Release of potential predators/competitors in areas where natural or stocked populations occur.
- Pesticide and fertiliser run-off changing nutrient regimes leading to algae blooms, reduction in dissolved oxygen, increasing sedimentation rates etc.

- Recreational fishing (eg. incidental capture) that causes mortality.

Populations Under Threat

All populations of Trout Cod occur in public waters, and are considered under threat. In some cases, the actual threat may have occurred long ago (eg. desnagging), but its consequences are still being felt. In other cases, such as river regulation, the threat is sustained and on-going, but a major program is underway (*Living Murray*) to attempt to address this. Other threats are erratic and episodic, such as fires and deteriorating water quality causing fish kills. The cumulative impact of many small or low risk threats (eg. fish kills, angling mortality, low water temperatures or lack of flooding reducing breeding success) can combine to further reduce population numbers and increase extinction risk. Due to the early stages of reintroductions and very little evidence of successful reproduction, these stocked populations in particular are not yet self-sustaining and especially vulnerable to a range of threats and stochastic events. Locations of important populations are provided in Table 3 (p. 14).

Table 2. Populations and Threats

Threat	Location/Population	Threat Ranking	
		Current/Potential	High Medium Low
Desnagging	All except upper Murrumbidgee River	Current (historical)	Medium/Low
River regulation	All (except Ovens River and upper Mitta Mitta River)	Current	Medium/High
Barriers	All	Current	Medium/Low
Loss to Irrigation	Murray River, Ovens River	Current	Medium/Low
Poor water quality	Goulburn River All	Current Potential	High Low
Siltation	Ovens River, Cotter River	Current	High
Thermal pollution	Murray River Goulburn River Murrumbidgee River Cotter River	Current Current Current Current	Low Low Low High
Predation, competition	All	Potential	Low
Fishing	All	Current	Medium/High
Hybridisation	Cataract Dam All other populations	Current Potential	High Low
Disease	Captive populations Wild populations	Current Potential?	High Low
Low genetic diversity	Seven Creeks other stocked populations	Current Potential	High Low/Medium

Recovery Information

Strategy for Recovery

The strategy for recovery of Trout Cod will be to continue to focus on protection and management of locations with natural and reintroduced populations of Trout Cod, continuing stockings, and monitoring stocked populations for establishment and reproduction. Investigation of key biological and ecological attributes, such as spawning cues, movement of stocked fish and distribution of habitat critical to survival is also required to facilitate recovery. Another important issue to address is education and awareness to build community support for conservation efforts. The Trout Cod could benefit from integrated catchment management initiatives, including maintaining or restoring environmental flows,

and protection and revegetation of riparian zones to increase streamside cover and reduce erosion and sediment input into waterways. Many such programs are already occurring in catchments where Trout Cod occur. The species is a potential major beneficiary of the 'Living Murray' program. Restoration of fish passage past barriers will also be of benefit to the species. Monitoring the ecological response of Trout Cod to these measures will be a key factor in managing the recovery of this species.

Program Implementation

The Recovery Plan will run for five years from the time of adoption. The Trout Cod Recovery Team, a group comprising representatives from DSE, DPI, G-B CMA (Vic), NSW Fisheries, ACT Parks Conservation and Lands and MDBC will continue to coordinate implementation of the recovery plan. Any technical, scientific, habitat management or education issue requiring skills not available within the Recovery Team will be referred to specialist organisations and individuals as appropriate. 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.

Program Evaluation

The Recovery Team will be responsible for informal evaluation annually. Within five years from adoption, an external reviewer will be appointed to undertake a formal review and evaluation of the recovery program.

Recovery Objectives

The **Long-term Objective** of recovery is to minimise the probability of extinction of the Trout Cod 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** of recovery are to:

1. Investigate key aspects of biology and ecology.
2. Determine the growth rates and viability of populations.
3. Identify and map habitat critical to survival.
4. Investigate and control threatening processes.
5. Manage Murray River population to ensure its continued sustainability natural and reintroduced populations to achieve self-sustainability.
6. Manage Seven Creeks (Vic) population to ensure its continued sustainability.
7. Manage Ovens River population to ensure its continued sustainability.
8. Manage the Murrumbidgee River and Cotter River populations (ACT) to ensure their continued sustainability.
9. Breed Trout Cod for reintroduction.
10. Undertake reintroductions to establish new populations.
11. Encourage community awareness and support.
12. Trial a stocked recreational fishery for Trout Cod in Victoria.
13. Manage Recovery Plan implementation.

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 Trout Cod Maccullochella macquariensis *National Recovery Plan' available at www.dse.vic.gov.au*

Recovery Objectives, Performance Criteria and Actions - Summary

Objective	Performance Critera	Actions
1. Investigate key aspects of biology and ecology, especially as they relate to conservation management and identification of threatening processes.	Successfully obtaining biological information for preparation of management strategies to maintain, enhance or restore processes fundamental to survival, reproduction and viability of populations.	1.1 Evaluate current reproductive status, fecundity, recruitment levels and longevity of natural and stocked populations. 1.2 Investigate movement and dispersal patterns of Trout Cod. 1.3 Determine stimuli for reproduction. 1.4 Measure population trends and responses against recovery actions by collecting demographic information including recruitment and mortality, timing of life history stages and morphological data.
2. Identify and map habitat critical to survival.	Predictive model for potential habitat developed and tested.	2.1 Survey and map potential habitat, using ecological and bioclimatic information that may indicate habitat preference.
3. Investigate and control threatening processes.	Improved understanding and control of the main threatening processes affecting Trout Cod.	3.1 Investigate the precise impacts of known and potential threats to Trout Cod. 3.2 Investigate the interaction between Trout Cod and introduced freshwater fish. 3.3 Investigate the impact of incidental angling capture on Trout Cod. 3.4 Identify and remove barriers to movement of Trout Cod populations, through the existing fishways programs in Victoria and NSW.
4. Manage Murray River (NSW) population to ensure its continued sustainability.	Population parameters such as area of occupancy, presence of a range of size and age classes, spawning and recruitment indicate a stable or increasing population.	4.1 Monitor the range and status of the Trout Cod population in the Murray River, particularly (a) identification of the area and extent of the population; (b) estimates of the size and structure and (c) inference or estimation of population change. 4.2 Monitor movement of Trout Cod through the fishway on the Yarrawonga weir. 4.3 Determine the frequency and impact of population fragmentation along the Murray River, using genetic marker analysis and/or other means. 4.4 Assess the available habitat in the Murray River as a potential limiting factor for population growth. 4.5 Maintain fisheries compliance activity along the Murray River Trout Cod zone.
5. Manage Seven Creeks (Vic) population to ensure its continued sustainability.	Population parameters such as area of occupancy, presence of a range of size and age classes, spawning and recruitment indicate a stable or increasing population.	5.1 Introduce new stock from the Murray River to Seven Creeks to improve the genetic variability of the Seven Creeks stock, and monitor survival of the introduced fish. 5.2 Continue in-stream habitat enhancement in lowland section, and monitor performance and change in stream morphology.

		5.3 Continue fencing and riparian protection and revegetation along Seven Creeks Trout Cod zone. 5.4 Protect the current environmental flows in Seven Creeks. 5.5 Continue to prohibit the stocking of recreational angling species in the Seven Creeks Trout Cod zone. 5.6 Maintain fisheries compliance activity along Seven Creeks Trout Cod zone.
6. Manage Ovens River (Vic) population to ensure its continued sustainability.	Wild reproduction and recruitment detected in the reintroduced populations.	6.1 Continue the reintroduction to the Ovens River system, Victoria. 6.2 Undertake trials to determine the effect of size of fish at release on survival and establishment. 6.3 Monitor the survival, growth and recruitment of the reintroduced population in the Ovens River system, and determine needs for additional stockings. 6.4 Assess the available habitat in the Ovens River as a potential limiting factor for population growth. 6.5 Maintain fisheries compliance activity along Ovens River Trout Cod zone. 6.6 Manage the stocking of recreational fish species in the Ovens River system (downstream from Bright), including the King River downstream from Lake William Hovell.
7. Manage Murrumbidgee River (NSW) population to ensure its continued sustainability	Wild reproduction and recruitment detected in the reintroduced populations.	7.1 Monitor the range and status of the Trout Cod population in the Murrumbidgee River, and determine recruitment rates. 7.2 Assess the available habitat in the Murrumbidgee River as a potential limiting factor for population growth. 7.3 Maintain fisheries compliance activity along the Murrumbidgee River Trout Cod zone.
8. Manage the Murrumbidgee River and Cotter River populations (ACT) to ensure their continued sustainability.	Wild reproduction and recruitment detected in the reintroduced populations.	8.1 Continue the reintroduction to the Murrumbidgee River system, ACT. 8.2 Monitor the survival, growth and recruitment of the reintroduced population in the Murrumbidgee River and Cotter River, ACT. 8.3 Prohibit the stocking of recreational fish species in the Trout Cod zones of the Murrumbidgee River and Cotter River. 8.4 Maintain fisheries compliance activity along Murrumbidgee River and Cotter River Trout Cod zones.
9. Breed Trout Cod for reintroduction to establish new populations.	Adult fish maintained in captivity, managed to maximise genetic diversity, and breeding every year to provide 40,000+ fish for reintroductions.	9.1 Maintain captive adult breeding populations at Snobs Creek Fisheries Research Station and Narrandera Fisheries Research Station, and breed for reintroduction to the wild.

10. Undertake reintroductions to establish new populations in the wild.	Establish new, viable populations to decrease the risk of extinction of the species.	10.1 Monitor the survival, growth and recruitment of the reintroduced population in the Goulburn, Mitta Mitta and Upper Murray River systems, and determine needs for additional stockings. 10.2 Identify and prioritise new sites for stocking Trout Cod to establish new populations, in consultation with stakeholders.
11. Encourage community awareness and support for Trout Cod conservation.	There is support for Trout Cod conservation, participation by community groups in conservation activities, and compliance with fisheries regulations.	11.1 Encourage the reporting of Trout Cod incidental captures by anglers. 11.2 Maintain the Fishcare Volunteers program, with emphasis on Trout Cod issues in the Murray, Murrumbidgee and Macquarie River catchments. 11.3 Maintain/enhance education programs to assist anglers to distinguish between Trout Cod and Murray Cod. 11.4 Develop an education kit on Trout Cod conservation and distribute to schools. 11.5 Encourage the involvement of community groups in the conservation program for Trout Cod. 11.6 Ensure the results of research and management on Trout Cod are publicised through scientific meetings, journal publications and articles for the popular press, including fishing magazines.
12. Trial development of a recreational fishery for stocked Trout Cod in Victoria.	A recreational fishery for Trout Cod in a specific location that does not conflict with conservation objectives is established, and angler understanding of and support for Trout Cod conservation is improved.	12.1 Liaise with the Victorian Recreational Fishing Peak Body, VRFish, to gauge interest in the development of stocked Trout Cod fisheries in impoundments. 12.2 Identify impounded waters where stocked Trout Cod would be accessible to anglers and where there would be no conflict with conservation stockings. 12.3 Determine fishing regulations for stocked Trout Cod fishery. 12.4 Stock for 4 consecutive years and undertake stock assessment in the 5th year. 12.5 Monitor catch rates, angler satisfaction and improved angler awareness of Trout Cod conservation issues. 12.6 Provide information to anglers on Trout Cod conservation.
13. Manage Recovery Plan implementation.	Recovery Team established with representation from key Sate agency stakeholders, to communicate and coordinate recovery actions, facilitate information exchange and prepare funding applications to implement plan.	13.1 Continue with a national Recovery Team to coordinate recovery actions and exchange knowledge with local and interstate agencies to maintain communication, to assist with management and implementation. 13.2 Establish and facilitate regional recovery processes where required. 13.3 Ensure funding submissions are organised through appropriate management agencies each year (or as required). 13.4 Undertake a formal review and evaluation within five years from adoption.

Cost of the Recovery Plan

The estimated cost of the recovery program is $3.543 million over five years.

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Totals	**$739,000**	**$580,000**	**$1,029,000**	**$502,000**	**$753,000**	**$3,543,000**

Role and interests of indigenous people

Indigenous communities on whose traditional lands and waters the Trout Cod occurs will be advised, through the relevant regional Indigenous Facilitator, of the preparation of this Recovery Plan. 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 in the Murray-Darling River system in south-eastern Australia. Principally, this will be through the identification and control of threatening processes, and the protection and management of habitat. The adoption of broad-scale management techniques and collection of baseline data will also benefit other threatened aquatic species and communities occurring in association with Trout Cod, particularly those species with similar habitat requirements and life histories such as the Murray Cod. The endangered Macquarie Perch *Macquaria australasica* occurs with Trout Cod in Seven Creeks (Vic) and measures to protect Trout Cod there will also assist in protecting Macquarie Perch. The 'Lowland Riverine Fish Community of the southern Murray-Darling basin' has been listed as a threatened community under the Victorian *Flora and Fauna Guarantee Act* 1988, and the 'Aquatic ecological community of the lower Murray River' has been listed as Endangered under the NSW *Fisheries Management Act* 1994. Regionally threatened species in these listed communities, including Golden Perch *Macaquaria ambigua*, Silver Perch *Bidyanus bidyanus* and Freshwater Catfish *Tandanus tandanus* may also benefit from implementation of this Recovery Plan.

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 in the Murray-Darling basin, such as habitat degradation, barriers to migration and invasive species.

Social and economic impacts

The implementation of this Recovery Plan is unlikely to cause significant adverse social and economic impacts. 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 more natural flooding regimes will potentially benefit species like the Trout Cod. A program to provide fish passage over barriers such as weirs is in place in the Murray-Darling River system. Rehabilitation of riparian zones is being initiated and undertaken in many regions by management agencies and many local communities. A positive social impact is the participation of the community-based group Native Fish Australia in production of Trout Cod for reintroduction.

The principle social impact of this Recovery Plan relates to the continuation of the protected status of Trout Cod (and subsequent lack of opportunity for anglers to legally take this species), which has been fully protected throughout its range for some years now. Implementation of this Plan will see a continuation of existing protection measures, including current regulations for seasonal and permanent closures of waters to fishing, provision of advice to anglers through signage and recreational fishing guides, and patrols and inspections by fisheries officers to check compliance with regulations. These measures will have no additional social impact above that already occurring in regions where Trout Cod occur.

There is some concern amongst anglers that recreational fishing opportunities may be lost where Trout Cod populations are being established, especially in Victoria. It is recognised that,

in some areas, there may be an impact to anglers targeting other recreational species as a result of the reintroduction of Trout Cod. While the ultimate aim is to recover the species to the point where it is no longer considered threatened, and therefore is able to provide recreational fishing opportunities again, in reality this will take many years to achieve. Trout Cod are now readily bred in hatcheries, so there is a good opportunity to establish a recreational fishery in a discrete water (away from other wild populations), both to provide an opportunity for anglers to legally fish for this species, and also as a valuable community education opportunity to promote broader conservation of Trout Cod. An objective in this Recovery Plan will be to investigate the feasibility of establishing a discrete recreational fishery for this species, where there will definitely be no negative impact on the conservation of the species (see Objective 13). A positive social impact has been the participation of the community-based group Native Fish Australia in production of Trout Cod for reintroduction.

There are costs associated with implementation of this Recovery Plan, specifically acquiring the funding required to implement the actions in this Plan, such as research, habitat management, monitoring, managing reintroductions, compliance and angler and broader community education.

Management Practices

Recovery efforts for Trout Cod have been underway for almost two decades now, and a number of management actions have been implemented to directly benefit Trout Cod conservation. The species is also a potential major beneficiary of efforts to restore ecological processes in the Murray River, including increased environmental flows in the Murray River and facilitating fish passage between the Murray mouth and Lake Hume (Albury). 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 Trout Cod and jeopardise their recovery.

Management practices required for conservation of Trout Cod include:

- Establishment of new populations of Trout Cod at suitable locations, with stakeholder support.
- Improved flow regimes in the Murray-Darling River system.
- Habitat restoration programs, especially resnagging river reaches, and rehabilitation of riparian zones to ensure a continuing supply of snags.
- Provision of both upstream and downstream fish passage in the Murray-Darling River system.
- Actions that enhance the sustainability of current Trout Cod populations.

Acknowledgments

This Recovery Plan has been prepared by the national Trout Cod Recovery Team, comprising:
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References

A consolidated reference list can be found in the document 'Background and Implementation Information for the Trout Cod Maccullochella macquariensis *National Recovery Plan' available at www.dse.vic.gov.au.*