

Trout cod (*Maccullochella macquariensis*) recovery plan

Author: NSW Department of Primary Industries

Author title: Threatened Species Unit

Branch: Fisheries Conservation and Aquaculture

Prepared in accordance with the threatened species provisions of the
NSW *Fisheries Management Act 1994*.



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Trout cod habitat, Murrumbidgee River Photo: NSW DPI (Ian Wooden)

Trout cod habitat, Seven Creeks Photo: Murray Darling Basin Commission

Trout cod habitat Photo: NSW DPI (Ian Wooden)

Trout cod habitat Photo: NSW DPI

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Disclaimer The information contained in this publication is based on knowledge and understanding at the time of writing (April 2006). However, because of advances in knowledge, users are reminded of the need to ensure that information upon which they rely is up to date and to check currency of the information with the appropriate officer of New South Wales Department of Primary Industries or the user's independent advisor.

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Overview

Introduction

The trout cod (*Maccullochella macquariensis*) is a large, predatory, freshwater fish that has been listed as 'endangered' under the NSW *Fisheries Management Act 1994*. It is also listed as 'endangered' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and the *ACT Nature Conservation Act 1980*, and as 'threatened' under the Victorian *Flora and Fauna Guarantee Act 1998*. Trout cod is also listed as endangered by the World Conservation Union (IUCN), by the Australian Society for Fish Biology and the Australian and New Zealand Environment and Conservation Council.

Trout cod were once widespread throughout the southern tributaries of the Murray-Darling system, including tributaries of the Murray River in Victoria, the Murrumbidgee (including upland tributaries in the ACT), and the upper half of the Macquarie River. The natural distribution and abundance of trout cod has declined since European settlement. In fact, trout cod have contracted to just four known breeding populations, namely; a naturally occurring population in the Murray River below Yarrawonga Weir, a translocated population in Seven Creeks (a tributary of the Goulburn River) below Polly McQuinn's Weir in Victoria, a stocked population in the Murrumbidgee River at Narrandera and a translocated population in Cataract Dam in coastal NSW (outside the species range).

The lack of reliable historical records makes the extent, rate and timing of the decline in trout cod populations difficult to ascertain. There is also no definitive research to determine the fundamental cause(s) of decline. It is likely that a range of factors, have contributed to the species decline, and that some of these factors have a greater importance in different locations and/or habitats. The processes thought to be primarily responsible for the species' decline include habitat degradation (removal of snags, alteration of river flows, barriers to fish migration, water extraction), illegal fishing and impacts of introduced species.

This recovery plan has been developed to promote the recovery of trout cod in NSW to an extent where it can be considered secure and self-sustaining in the wild. The recovery plan describes the legislative context for the plan, other implications of threatened species listings (such as environmental impact assessment) and what is currently known about the biology, ecology, threats and management of this species. It then outlines a series of recovery objectives, actions and criteria for evaluating the success of the plan.

Recovery objectives

The overall objective of this recovery plan is to ensure the recovery and natural viability of trout cod populations throughout their former range in NSW. The specific objectives of the plan are to:

- Ensure the security of the existing trout cod population in the Murray River by maintaining and improving, where necessary, the aquatic habitat values in that locality, and through habitat protection mechanisms.
- Establish and protect additional stocked populations of trout cod at selected locations throughout the species former range.
- Reduce fishing related mortality of trout cod by setting appropriate regulatory controls and maximise angler compliance.

- Improve our understanding of the population size, distribution, ecological requirements, and historical and existing genetic status of trout cod.
- Improve our understanding of the threats to the survival of trout cod, and contribute to management actions to ameliorate identified threats.
- Coordinate and initiate new community awareness and education programs relating to trout cod.
- Coordinate and support appropriate actions by the community and government to provide a strategic, regional approach to trout cod survival and effective threat management.
- Increase awareness of the status of and threats to trout cod, and enhance community support for recovery actions.
- Assess the outcomes of past and current recovery actions and the species' conservation status.

Recovery criteria

The plan will be judged a long-term success if it leads to the status of trout cod being revised from 'endangered' to 'vulnerable' and eventually de-listed from schedules of the *NSW Fisheries Management Act 1994* within 15 years.

The evaluation criteria for individual recovery actions in this plan are included underneath each action.

Recovery actions

- The recovery actions in this plan are classified into the following areas:
- Habitat protection and restoration
- Reduce the impact of Illegal fishing and incidental capture
- Minimising risks from inter-specific competition and introduced species
- Establishing new populations through stocking
- Research and monitoring
- Community awareness, involvement and support.

Implementation and costs

The NSW Department of Primary Industries will coordinate and lead the implementation of this recovery plan, with support from relevant NSW government agencies, universities, councils, and the community. The recovery plan will be resourced by a combination of recurrent and external funding. Many of the actions identified within the plan can be implemented as part of the core functions of the Department of Primary Industries and other public authorities. Implementation of the recovery plan does not require or propose the need for additional recurrent funds. However the implementation of some recovery actions will be subject to securing additional funding from grant programs such as the Natural Heritage Trust and Envirofund.

1. Introduction

1.1 Legislative context

In NSW, the *Fisheries Management Act 1994* provides the legislative framework for the protection and recovery of threatened species, populations and communities of fish, aquatic invertebrates and marine plants.

Trout cod are listed / classified as:

- Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
- Endangered under the *Fisheries Management Act 1994* (NSW)
- Endangered under the *Nature Conservation Act 1980* (ACT)
- Threatened taxon under the *Flora and Fauna Guarantee Act 1998* (Victoria)
- Endangered by the Australian Society for Fish Biology (ASFB)
- Endangered by the Natural Resource Management Ministerial Council (Incorporating the Australian and New Zealand Environment and Conservation Council (ANZECC))
- Endangered by the World Conservation Union (IUCN)

1.1.1 Recovery planning

The NSW Department of Primary Industries (NSW DPI) prepares recovery plans for all species, populations and ecological communities listed as endangered or vulnerable on the schedules of the *Fisheries Management Act 1994*. Once a recovery plan has been finalised and approved, it is a statutory document. Ministers and public authorities need to take appropriate actions to implement the measures in the plan for which they are responsible, and must not undertake actions inconsistent with an approved recovery plan without consulting the Minister for Primary Industries.

Under the NSW *Environmental Planning and Assessment Act 1979*, relevant recovery plans must be considered by consent authorities (eg. local councils), determining authorities (eg. State government agencies), and the Director-General of NSW DPI (as a concurrence authority) when they are exercising a decision-making function under Part 3, 4 or 5 of the Act.

National recovery plans must also be prepared for threatened species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth). A National Recovery Plan for trout cod has been in place since 1994, with a revised plan being adopted in March 2001 (see Section 1.4).

1.1.2 Critical habitat

The *Fisheries Management Act 1994* requires, wherever possible, the identification and declaration of ‘critical habitat’ for endangered species, populations and ecological communities. Critical habitat is the whole or any part of the habitat of an endangered species, population or ecological community that is critical to its survival.

The declaration of critical habitat provides increased protection for the habitat of threatened species and the ability to regulate activities within these areas. Once declared, it becomes an offence to damage critical habitat (unless the action is specifically exempt under the legislation) and a species impact statement is mandatory for all developments and activities (including fishing activities) within the declared critical habitat. Critical habitat has not been declared for trout cod.

The habitat requirements of trout cod are discussed in Section 2.5.

1.1.3 Environmental planning and assessment

If a planned development, or other activities that require government approval, are likely to have an impact on threatened species, these impacts must be considered by a consent and/or determining authority. Where such actions are likely to result in a significant impact on a threatened species or its habitat, a detailed species impact statement must be prepared. The consent or determining authority must then seek the concurrence of the Director-General of NSW DPI, or in certain circumstances, consult with the Minister for Primary Industries.

Even if a proposed action does not require approval under the *Environmental Planning and Assessment Act 1979*, it may still require approval under the *Fisheries Management Act 1994*. A specific licence or permit may be required if the action will result in harm to threatened species, populations or ecological communities, or their habitat.

The *Environment Protection and Biodiversity Conservation Act 1999* also requires that where a development or activity is likely to have a significant impact on a nationally listed threatened species, the matter must be referred to the Commonwealth Minister for Environment and Heritage. If the Minister decides that the issue is a matter of national environmental significance, then assessment of the impacts and Commonwealth approval will be required. This is a separate process to the environmental assessment and approval process under NSW legislation.

1.2 Recovery plan preparation

This recovery plan has been developed in accordance with the requirements of the *Fisheries Management Act 1994* (as outlined in section 220ZN; see Appendix 1) and with consideration of the Recovery Plan Guidelines for Nationally Listed Threatened Species and Ecological Communities under the *Environment Protection and Biodiversity Conservation Act 1999*.

The NSW DPI Fisheries Ecosystems Unit, in consultation with relevant stakeholder groups and agencies, has prepared the trout cod plan. While the recovery plan is based on the input of these people, individual components in the plan do not necessarily represent the views nor the official position of all individuals or agencies consulted.

The information in this recovery plan was accurate to the best of the knowledge of NSW DPI at the time of preparation.

1.3 Recovery plan implementation

This recovery plan has been developed to guide actions by government agencies and the community to conserve NSW populations of trout cod and to promote their recovery.

NSW DPI is the lead agency responsible for the implementation of this recovery plan. However, the success of the plan and the long-term recovery of trout cod will require action by many

other organisations and individuals who either have an interest in the conservation of the species or whose actions and decisions have the potential to affect its survival. The Government agencies with responsibility for implementing some of the actions in this plan include NSW DPI, the Department of Planning, the Department of Natural Resources, the NSW Department of Environment and Conservation (DEC) and relevant local councils.

The *Fisheries Management Act 1994* requires that public authorities (other than local councils) that are identified in a recovery plan as responsible for certain measures must report on the actions that have been taken to implement these measures in their annual report to Parliament. Local councils must report on recovery plan actions that have been taken in their annual State of Environment report.

Others identified as having a part to play in implementing some actions include universities, Catchment Management Authorities (CMAs), water management forums, Landcare and Rivercare groups. This plan is also developed in accordance with the principles of the Native Fish Strategy for the Murray Darling Basin that was released in May 2004.

Recovery actions are outlined in Section 6.

1.4 Linkages with other recovery and threat abatement plans

A number of other trout cod management and/or recovery plans have been prepared by other jurisdictions including:

National

Douglas, J. W., Gooley, G. J. & Ingram, B. A., 1994. Trout Cod, *Maccullochella macquariensis* (Cuvier) (Pisces: Percichthyidae), Resource Handbook and Research and Recovery Plan. Department of Conservation and Natural Resources, Victoria.

Brown, A., Nicol, S. & Koehn, J., 1998. Trout cod (*Maccullochella macquariensis*) Recovery Plan. Aquatic Ecosse Pty. Ltd. & Department of Natural Resources and Environment, Victoria.*

*Note: this plan supersedes the 1994 National recovery plan, and sets actions over an eight year period (up to 2006).

Victoria

Department of Natural Resources and Environment, 1993. Action Plan No. 38: Trout cod (*Maccullochella macquariensis*), Victoria.

Australian Capital Territory

ACT Government, 1999. Trout Cod (*Maccullochella macquariensis*): An endangered species. Action Plan No. 12. Environment ACT, Canberra.

1.4.1 Other listings

Trout cod is only one of several Murray Darling fish species that have undergone major declines in distribution and abundance and are listed as threatened under the schedules of the *Fisheries Management Act 1994*. These include:

- Macquarie perch (*Macquaria australasica*);
- Silver perch (*Bidyanus bidyanus*);
- River snail (*Notopala sublineata*);
- Murray hardyhead (*Craterocephalus fluviatilis*);
- Southern pygmy perch (*Nannoperca australis*);
- Western population of purple spotted gudgeon (*Mogurnda adspersa*);
- Western population of olive perchlet (*Ambassis agassizii*);
- Aquatic ecological community in the natural drainage system of the lower Murray River catchment; and
- Aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River.

Draft recovery plans for these species, populations and ecological communities are currently under development. Once recovery plans have been finalised it is likely that recovery activities for these species will be cross-linked in some areas and will be beneficial for the recovery of trout cod.

In addition, several ‘key threatening processes’ (KTPs) of relevance to trout cod have been listed under the *Fisheries Management Act 1994*. These include:

- Removal of large woody debris from NSW rivers and streams;
- Degradation of riparian vegetation along NSW water courses;
- Introduction of fish to fresh waters within a river catchment outside their natural range;
- Installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams.
- Hook and line fishing in areas important for the survival of threatened fish species

Additionally, the ‘Alteration to the natural flow regimes of rivers, streams, floodplains and wetlands’ is listed as a key threatening process under the NSW *Threatened Species Conservation Act 1995*.

The preparation and implementation of threat abatement plans for these KTPs should benefit the recovery of trout cod.

1.5 Biodiversity benefits

Trout cod in the Murray River and its major tributaries are part of a fish community in which several other members are under threat. Hence, recovery activities to protect and restore habitats for trout cod should also make an important contribution to the conservation of other species occupying similar habitat.

As trout cod are a top order predator, recovering them to their former range and population levels will have the additional benefit of maintaining natural selection pressure on prey species within the river ecosystem. Also, efforts to protect and recover trout cod populations will deliver a range of indirect biodiversity benefits. For example, increasing community awareness about the plight of trout cod may assist in raising the profile of threatened species in general and lead to increased opportunities to conserve and protect threatened species and aquatic biodiversity.

2. Biology and ecology

2.1 Names

Common: trout cod

Other names: bluenose cod, blue cod

Scientific: *Maccullochella macquariensis* (Cuvier)

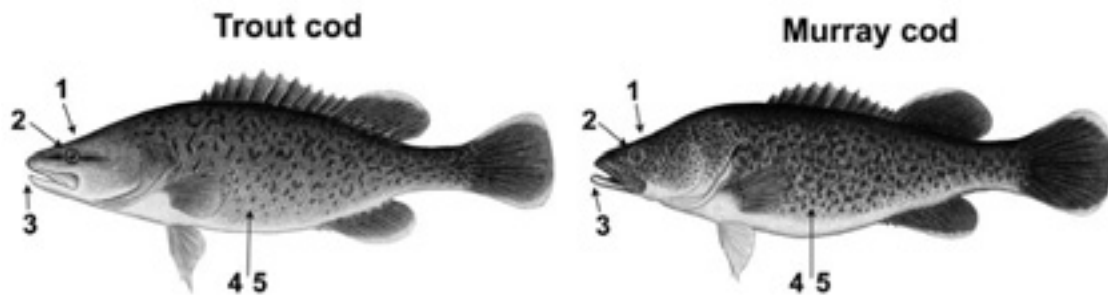
2.2 Systematic position

The trout cod is a member of the family Percichthyidae (southern hemisphere freshwater cods and basses). Its nearest relatives are the Murray cod (*Maccullochella peelii peelii*) from the inland Murray-Darling River system, the eastern cod (*Maccullochella ikei*) from the coastal Clarence and Richmond rivers in northern NSW, and the Mary River cod (*Maccullochella peelii mariensis*) from the coastal Mary River in southern Queensland.

2.3 Description

The trout cod is a large, elongate, deep-bodied fish with relatively large eyes and a long, broad, rounded snout with a straight profile. Trout cod have been recorded to 850 mm and 16 kg, but most fish caught are less than 5 kg (Harris & Rowland 1996). Trout cod of all sizes have an

Figure 1: Differences between trout cod and Murray cod



Feature	Trout cod	Murray cod
1 Head profile	Straight	Concave
Head width	Narrow	Broad
2 Eyes	Larger, usually with eye stripe in all sizes	Smaller, eye stripe usually absent in fish over 4 kg
3 Jaws	Upper overhangs lower	Equal, or bottom jaw protrudes
4 Body colour	Blue-grey to dark brown on back, paler (grey to white) on ventral surface	Pale green to creamy-yellow on back, paler on ventral surface
5 Body markings	Dark spots and irregular dashes, except on forehead or snout	Green mottled or mosaic pattern, extending onto forehead or snout
Max. reported weight	16 kg	114 kg

upper jaw that overhangs the lower. They are bluish grey or sometimes dark to light brown, with small dark, irregular spots or bars extending onto lower sides and onto the base of the dorsal, anal and caudal fins. The under-surface is creamy white to grey. A dark horizontal stripe extends through the eye.

The trout cod is similar in appearance to the Murray cod (Figure 1). Historically, this created some confusion as to whether trout cod was a distinct species or a morphological variant form of Murray cod. Despite being formally described in 1829, it was not until 1972 that trout cod were recognised as a species distinct from the Murray cod.

2.4 Distribution and abundance

2.4.1 Historical distribution and abundance

Trout cod were once widespread throughout the southern tributaries of the Murray-Darling system, including tributaries of the Murray River in Victoria, the Murrumbidgee (including upland tributaries in the ACT), and the upper half of the Macquarie River (Figure 2). However, the small number of records and the early confusion between trout cod and Murray cod has probably distorted our understanding of this distribution. For example, except for the first officially reported trout cod (the Holotype) and one other unconfirmed report, there have been no further documented reports of trout cod occurring naturally in the Macquarie River system. Trout cod have never been recorded in the Lachlan River (Douglas *et al.* 1994), however their historic occurrence is possible in this system as their distribution includes both neighbouring rivers to the north and south.

2.4.2 Present distribution and abundance

The natural distribution and abundance of trout cod has declined since European settlement. Currently, the only known breeding populations of trout cod include a naturally occurring population in the Murray River below Yarrawonga Weir, a translocated population in Seven Creeks (a tributary of the Goulburn River) below Polly McQuinn's Weir in Victoria (Ingram & Richardson, 1989; Ingram *et al.* 1990), a stocked population in Loombah Weir in Victoria (Douglas and Brown 2000) and a translocated population in Cataract Dam in coastal NSW (outside the species range). The population in Cataract Dam is thought to have hybridised with Murray cod (Gehrke & Harris 1996, Douglas *et al.* 1994).

The distribution of trout cod in the Murray River appears to be patchy. This patchiness appears to be related to habitat availability (Brown & Nicol. 1998). Surveys conducted in the Murray River during 1995 and 1996 indicate that the level of recruitment is inadequate to sustain this population. Similarly, research has revealed that the population in Seven Creeks is insecure and will face extinction without management intervention (Brown *et al.* 1998).

2.4.3 Distribution of stocked fish

Since the mid 1980s both NSW Fisheries (now part of NSW DPI) and the Victorian Department of Primary Industries have been operating a breeding and conservation stocking program for trout cod. This program has resulted in trout cod being stocked at numerous sites throughout their former range. Between 1986 and 2005, over one million trout cod (826,000 from Narrandera Fisheries Centre in NSW and the balance from Snob's Creek Hatchery in Victoria),

were released as fingerlings or juveniles into a range of selected sites. The ACT Government also supports the trout cod stocking program and has allowed stocking of trout cod at Angle Crossing and Bendora Reservoir.

In NSW, stocked populations occur in the upper Murray River above the Hume Dam, upper Murrumbidgee River between Adaminaby and Murrells Crossing, near Cooma, middle sections of the Murrumbidgee River from Burrinjuck to Yanco Weir, the Macquarie River near Dubbo and Talbingo Dam in the Kosciusko National Park. The primary stocking sites in NSW include Angle Crossing, Wantabadgery, Collingullie, Narrandera and Yanco in the Murrumbidgee River system and Namina Falls and Devils Elbow in the Macquarie River System.

The trout cod conservation stocking program has been very successful having established populations in several locations within the lower catchment of the Murrumbidgee River (Gilligan, 2005). To date, recruitment of stocked populations has not been confirmed however there is strong evidence to suggest that natural recruitment may have occurred in the Murrumbidgee River downstream of Burrinjuck Dam (particularly around Wagga Wagga and Narrandera) (Gilligan, 2005) and at Bendora Reservoir (M. Lintermans pers comm). Examination of otoliths (screening for hatchery chemical batch marks and accurate ageing) from juvenile fish collected in these regions will help determine if the populations are naturally recruiting (see section 8.4).

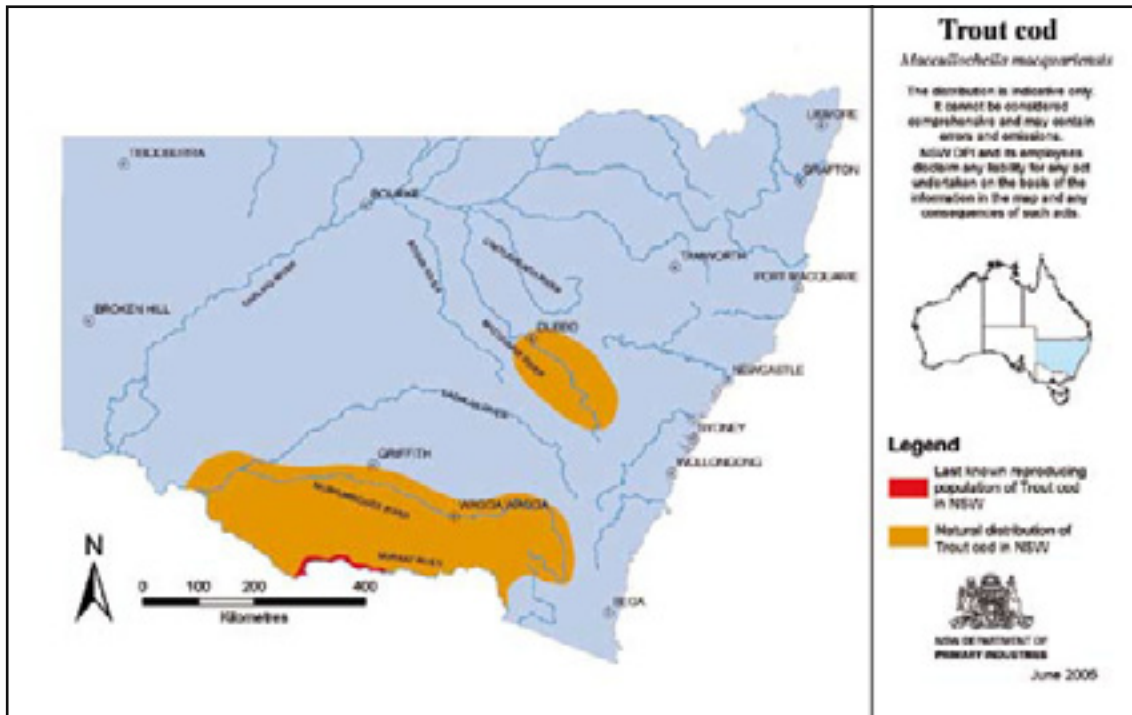


Figure 2: Natural distribution of trout cod in NSW.

2.5 Habitat

Historical records indicate that trout cod used many types of riverine habitat that have now been extensively modified. The habitats of the Murray River below Yarrowongga Weir (where the last remaining natural population of trout cod occur), the Murrumbidgee River and Seven Creeks represent conditions in which trout cod survive and reproduce. Specifically, the Murray River below Yarrowongga Weir and the Murrumbidgee River at Narrandera are large (60 – 100m wide), flowing and deep (>3m) rivers with sand, silt and clay substrates, containing abundant snags. In contrast, Seven Creeks is a relatively narrow stream (5 – 7m wide) having a rock, gravel and



Figure 3: Trout cod habitat, Seven Creeks. (Photo: Murray Darling Basin Commission)

Figure 4: Trout cod habitat, Murrumbidgee River (Photo: NSW DPI)



sand substrate, and pools (generally <2m deep) interspersed with rapids and cascades up to about 4m in height (Brown *et al.* 1998). It is important to note that the habitat at Seven Creeks may not reflect all the natural habitat requirements of the species because the population is the result of a translocation of trout cod to a site outside its natural range (Douglas *et al.* 1994).

A formal investigation into the critical habitat requirements of trout cod was undertaken in 1998 by Brown & Nicol as an action under the National recovery plan. This study identified habitat requirements by studying the movement/migration of trout cod, and by measuring habitat parameters at sites where populations currently exist. The results indicated that trout cod occupied sites with large woody debris, or snags, and that snags located away from the bank may be preferred (Nicol *et al.* 2002). Grouns *et al.* (in press) found that 95% of trout cod caught in habitat surveys were associated with the presence of woody habitat. As a result of the large scale removal of snags from many Australian streams and rivers suitable habitats for trout cod may now be limited and patchy in distribution.

2.6 Life History and ecology

Little is known about the biology and ecology of trout cod in the wild with much of the available information derived from hatchery-reared fish.

2.6.1 Growth

The growth rates of trout cod in the wild has not been documented, but in plankton rich fry-rearing ponds, fry grow rapidly and may exceed a length of 45mm within 5 weeks (Douglas *et al.* 1994).

Trout cod are known to grow to 850mm in length and 16kg in weight, though they more commonly occur to lengths of 500mm and weights up to 1.5kg.

2.6.2 Reproduction

Trout cod are believed to form pairs and spawn annually during late October to early November when water temperatures reach about 16°C (Ingram & Rimmer 1992; ACT Government 1999; Gilligan & Schiller 2003). Spawning occurs under a wide range of flow conditions and is not flow dependant (Gilligan & Schiller 2003). The environmental conditions favouring successful recruitment are unknown.

Males and females form pairs and 1,200 to 11,000 eggs are released at one expulsion. The eggs are large (2.5 – 3.6mm), adhesive and opaque, and are probably deposited on hard surfaces on or near the stream bottom.

Hatching begins 5-10 days after fertilisation at a temperature of 20°C and larvae live off the yolk sac for about 17 days. Larvae begin feeding on zooplankton at 6-9mm and disperse downstream in the flow for a short distance. The peak period for larval dispersal is November (Gilligan & Schiller 2003).

Trout cod reach sexual maturity at approximately 350mm in males and 430mm in females, which corresponds to ages of 3-5 years and weights of 0.75 to 1.5kg. Generally male trout cod mature younger and smaller than females, although this may vary depending on environmental conditions.

2.6.3 Behaviour and movement

The migration and local movement requirements of trout cod are unclear. Early researchers thought that trout cod undertook significant upstream migrations, either to spawn or for other, less obvious reasons (Brown *et al.* 1998). More recently, radio tracking studies of trout cod in the Murray River below Yarrawonga, indicate that trout cod in this area showed no sign of spawning migration and indeed very little local movement beyond a small home range (Brown & Nicol 1998). It should be noted however that during the tracking study this area of the Murray River (which has a regulated flow regime) did not experience any significant flood flows. It may therefore underestimate the movement of trout cod under natural conditions. Research is continuing to clarify the movement patterns and associated trigger mechanisms for trout cod movements.

In aquaria, juvenile trout cod establish well-defined territories (Cadwallader 1979). In contrast however, recreational anglers often report catching several juvenile trout cod at one site over a short period of time suggesting that under certain conditions or for some age groups, trout cod may be gregarious. It may equally indicate a preference for a particular habitat feature (Brown *et al.* 1998).

2.6.4 Diet

Trout cod are opportunistic carnivores, with a broad diet including freshwater crustaceans such as yabbies, crayfish and shrimp, as well as fish and aquatic insects (ACT Government 1999).

3. Conservation status

3.1 Listings

Trout cod are listed / classified as:

- Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
- Endangered under the *Fisheries Management Act 1994* (NSW)
- Endangered under the *Nature Conservation Act 1980* (ACT)
- Threatened taxon under the *Flora and Fauna Guarantee Act 1998* (Victoria)
- Endangered by the Australian Society for Fish Biology (ASFB)
- Endangered by the Australian and New Zealand Environment and Conservation Council (ANZECC)
- Endangered by the World Conservation Union (IUCN)

3.2 Reasons for concern

The natural range and abundance of trout cod has declined over the last 50-60 years. From once being widespread throughout the southern tributaries of the Murray-Darling system, the Murrumbidgee and the upper half of the Macquarie River, trout cod have contracted to just four isolated breeding populations. Such populations are generally less able to cope with or recover from, severe loss of critical habitat, threatening processes and natural catastrophic events, than larger, more widely distributed populations (Douglas *et al.* 1994).

The lack of reliable historical records makes the extent, rate and timing of the decline in trout cod difficult to ascertain. There is also no definitive research to determine the fundamental cause(s) of trout cod decline. It is likely that a range of factors, acting singularly or in conjunction, have contributed to trout cod decline, and that some of these factors assume a greater importance in different locations and/or habitats.

4. Current issues and threats

Significant pressure has been placed on the rivers in the Murray-Darling Basin as a result of numerous factors including river regulation, flood mitigation works, water extraction for irrigation of agricultural land, intensive agricultural practices and the introduction of introduced species.

There is a wide range of threatening processes operating on trout cod, which are discussed in detail in the documents listed in Section 1.4, as well as in other readily available publications. This section discusses only those threatening processes currently considered to be primarily responsible for the decline in trout cod, as well as a number of other important issues.

4.1 Removal of instream woody habitat

The removal of instream woody habitat (woody debris or 'snags') is listed as a key threatening process under the *Fisheries Management Act 1994*. Snags have a critical role to play in the ecological functioning of rivers and consist of whole trees, limbs and root masses that are partly or wholly submerged. Over the years, tens of thousands of snags have been removed from Australian streams and rivers in an effort to stabilise rivers (Erskine 1990; 1992; 2001), to increase river navigability and for flood mitigation (Gippel 1995). Snags are considered to be particularly important in lowland river reaches where other forms of habitat complexity (such as boulders, undercut banks and rock bars) are uncommon.

Research to date shows a close association between trout cod and snags (Brown & Nicol 1998). Wager & Jackson (1993) lists 'desnagging' as one of the main factors contributing to the decline of trout cod. Snag structures provide complex and diverse habitat for trout cod and provide cover from predation, refuge from high velocity flows and feeding sites (Morris *et al.* 2001; Lawrence, 1991). Also, the adhesive nature of trout cod eggs indicates that hard substrates such as snags are preferred egg-laying sites (Cadwallader, 1979; Koehn & O'Connor, 1990a).

In addition to the direct destruction of trout cod habitat, de-snagging may also lead to fragmentation of remaining available habitat and limit their ability to recolonise new habitat. While research is continuing to clarify the movement patterns and trigger mechanisms for trout cod, it is reasonable to assume that habitat fragmentation resulting from the removal of snags could potentially lead to localised extinction of remaining populations (Brown *et al.* 1998).

4.2 River regulation

A regulated river is a river or stream where flow has been controlled or modified from its natural condition. The flow regime of the Murray River has changed markedly over the last century, and especially the last 50 years, as a result of river regulation and water extraction. This has detrimentally affected the natural riverine environment as well as surrounding riparian and floodplain habitats. Rivers are regulated for a number of reasons including irrigation, hydroelectricity generation, urban and rural water supply and diversions to other catchments (Young 2001).

Large fish species such as trout cod are at the top of the aquatic food chain and rely on the full range of ecosystems processes. They are often the type of fish most vulnerable to changes in natural flow variability and habitat condition. While the impacts of river regulation are complex and interrelated, they fall generally into the three main categories of; altered flow regimes, barriers to fish movement and changes to temperature regimes (cold water pollution).

4.2.1 Altered flow regimes

In their natural state, inland rivers such as the Murray were characterised by variable flow patterns. Native species have become adapted to these flow patterns, and periods of low and high flows have important ecological functions. River regulation has resulted in changes in the size of flows; seasonality of flow patterns; frequency and duration of floods; timing, variability and predictability of flows; rates of rise and fall of water levels; and surface and subsurface water levels. In addition, the diversion of millions of litres of water for irrigation, either by gravity into irrigation canals or by pumping into pipelines or channels, has reduced the overall amount of water in the river for environmental and ecological needs. All rivers in which trout cod occur are impacted by altered flow regimes. In the case of the Murray River, it is estimated that approximately 75% of flow is diverted.

The ecological responses to flow regime change are many and complex. While there is little evidence that the breeding behaviour of trout cod in the Murray River is disturbed by the regulated flow regime that exists below Yarrowonga there is a strong possibility (by analogy with Murray cod) that the movement patterns of trout cod, including those associated breeding, are suppressed by the regulated flow regime. Changes to the natural fluctuation in water levels and seasonal flooding are reduced thereby eliminating many of the important environmental 'cues' for activities such as migration and spawning (Koehn & O'Connor 1990). In flood years Murray cod show a high level of recruitment, which is thought to be the result of enrichment of food resources following floodplain inundation. Conversely, under regulated conditions and in years when no flooding has occurred Murray cod display reduced spawning migration and lower levels of recruitment (Brown *et al.* 1998).

The large-scale extraction of water from rivers is also likely to be having serious adverse impacts on trout cod. As the species undergoes a short period of downstream larval drift, water extraction during the breeding season of October to December has the potential to remove large numbers of recruits from the ecosystem. Data on the density of drifting larval trout cod and Murray cod suggests that millions of cod larvae are potentially removed from the remnant Murray River population annually (Gilligan & Schiller 2003).

4.2.2 Barriers to fish movement

Since European settlement numerous barriers to fish movement have been constructed across watercourses, including dams, weirs, levee banks, culverts and road crossings. The unimpeded passage of fish throughout streams is crucial for spawning, migration, recolonisation, general movement and habitat selection (Koehn & O'Connor 1990). Instream barriers can prevent fish reaching spawning and feeding areas as well as interrupting gene flow and causing fish populations to fragment (NSW Fisheries 1999). Barriers are not only 'physical' structures (e.g. dams and weirs), they can also be 'hydraulic' (e.g. areas of high velocity flow or turbulence), or 'behavioural' (e.g. dark tunnels or unnatural substrates created by pipes), or even areas of poor quality habitat where food or shelter is sparse.

A significant number of barriers exist within the range of trout cod. As trout cod show strong site fidelity, have a small local home range and lack any spawning migration, the primary impact of barriers may be on the species' ability to recolonise areas of suitable habitat and fragment populations. Many of the problems associated with barriers can be overcome through proper design of new structures and construction of fishways to allow passage through existing barriers. Improving fish passage in areas inhabited by trout cod would assist in increasing breeding opportunities and access to habitat for both re-stocked and natural populations.

4.2.3 Cold water pollution

Cold water pollution refers to an artificial lowering in temperature of a water body (NSW Fisheries 2001). Water held in large impoundments is stratified, with a warm surface layer and a cold, dense bottom layer. The release of cold water from low-level outlets in large dams can significantly alter temperature regimes in downstream stretches of rivers, the effects of which can often be measured hundreds of kilometres downstream. These lowered water temperatures (by as much as 8-12°C in spring/summer), can reduce annual temperature ranges and delay the timing of summer temperature peaks. Cold water pollution affects a significant proportion of river reaches including the Mitta Mitta river downstream of Dartmouth Dam, the Murray River downstream of Hume Dam, the Tumut River downstream of Blowering Dam and the Murrumbidgee River downstream of Burrinjuck Dam.

For the majority of native fish species successful breeding will only occur once spawning temperature thresholds have been reached. Koehn (2001) reported that the generalised optimal spawning temperature for trout cod is around 18°C. Although little work has been undertaken on the precise impact of cold water pollution on trout cod, a recent study demonstrated that the egg survival of trout cod, as well as a number of other native species including Murray cod, golden perch, silver perch, and eel tail catfish was reduced by temperatures below 15°C (Lyon *et al.* 2002). Lower temperatures may delay spawning, reduce spawning success or even result in spawning failure.

Cold water pollution may also affect trout cod by reducing hatching success and survival, impairing metabolic functioning (including those associated with digestion and swimming speeds), reducing growth rates and increasing the species' susceptibility to diseases. It may also have more indirect impacts by lowering the productivity of the river system thereby reducing available food sources. Lowering river temperatures also tends to favour introduced coldwater species such as trout, redfin and carp. Such species may prey on and compete for resources with native species. As the current distribution of trout cod is within the river reaches affected by cold water pollution it is likely to be adversely impacting on the species. Further research into this issue is required.

4.3 Illegal fishing

Regulations are in place in NSW to prevent the harm or capture of trout cod. Under the provisions of the *Fisheries Management Act 1994*, the catching and keeping of trout cod is an offence and heavy penalties apply (up to \$220,000 and 2 years imprisonment). There is a prohibition on the use of setlines in the special management zone of the Murray River between Yarrowonga Weir and the Tocumwal Road Bridge¹. Despite the protected status of the species and regulations in place for their protection, anecdotal reports indicate that illegal fishing and harvesting are taking place. The extent of this illegal activity is unknown, and the impact of such activities is difficult to assess. However, with close to 1 million recreational fishers in NSW (approximately 200,000 fish in inland waters, NSW Fisheries 2002b and unpublished data), the significance of this potential pressure on trout cod should not be underestimated. A discussion paper 'Review of NSW Recreational Freshwater and Saltwater Fishing rules' released by NSW DPI in July 05 recommends the prohibition of un-attended lines in any inland NSW waters. The ban on the use of un-attended lines would reduce the fishing impact on trout cod.

¹ While set lines are often used to target Murray cod, due to the infrequent checking of these lines, there is a high potential for unacceptable mortality and harm to non-target and protected species, especially trout cod (NSW Fisheries 2002a).

The inability of some anglers to distinguish between trout cod and Murray cod is likely to contribute to illegal capture. Even if trout cod are correctly identified and returned to the water soon after capture, some fish are likely to suffer injury and stress and may not survive. While no studies have looked at hooking mortality for trout cod or closely related cod species, published information for other fish in the same Family (Percichthyidae) show mortalities ranging from 1% to as high as 70% (Muoneke & Childress 1994). Consequently angling regulations should aim to minimise incidental capture of trout cod and restrict those types of fishing activity that pose a high risk of causing mortality or severe injury.

While there have been numerous regional newspaper articles about the perceived recovery of trout cod into parts of the species' former range, this perception is mostly based on the relatively large numbers of juvenile trout cod being caught in areas which have been stocked. With little evidence to suggest that recently stocked populations are successfully breeding, the trout cod caught at these locations cannot be considered to be a sign of the species' recovery. There is potential to improve angler understanding of the actual status of trout cod populations through greater involvement of anglers in recovery activities.

4.4 Inter-specific competition and introduced species

There is increasing evidence to suggest that inter-specific competition is having a detrimental impact on trout cod. Inter-specific competition is the result of a common demand by two or more species upon a limited supply of resources, which can result in local extinction of one or more competing species (Thain & Hickman 2001). When one species is a better competitor, interspecific competition negatively influences the other species by reducing population sizes and/or growth rates, which in turn affects the population dynamics of the competitor.

Predictably, research has shown that Murray cod is trout cod's nearest competitor both for physical habitat and dietary requirements (Brown & Nicol 1998). Surveys undertaken in the Murray River indicate the successful recruitment of Murray cod and an unexplained failure of recruitment in trout cod populations over several years. Brown *et al.* (1998) suggests that a possible explanation for this is that trout cod, through loss of habitat and increased competition, can no longer recruit successfully when Murray cod are relatively abundant and are recruiting on a regular basis.

Trout cod are also likely to be adversely affected by introduced fish species such as trout, carp, redfin and goldfish. Introduced species can impact on native species and freshwater ecosystems through predation (particularly on eggs and larvae), competition for habitat and food resources, habitat degradation, and spread of diseases and parasites.

4.5 Genetically unsuitable trout cod

Stocking programs are playing an increasingly important role in the management of fish species that are declining in the wild. A conservation stocking program for trout cod is in place in NSW. As part of this program trout cod are released as juveniles into the wild at selected sites within the known former range of the species. This program is integral to the management of trout cod, and also provides additional opportunities for research into the breeding biology and early life history of the species.

There are a number of potentially problematic genetic issues associated with poorly planned breeding and stocking programs which can have significant impacts on species such as trout cod which are declining in the wild. Genetic variation is the raw material for evolution, and thus conserving the genetic diversity of threatened species is critical to their long-term viability. It is therefore imperative that stocking programs comply with genetic protocols that

address problems such as reduced genetic diversity, inappropriate genetic composition and hybridisation. The genetic protocols that govern the breeding and stocking of trout cod are outlined in Appendix 2.

Stocking can change the genetic makeup of fish populations and in many cases, fish from hatcheries contain lower levels of genetic variation than naturally occurring wild stocks (Keenan *et al.* 1995). For example, research has shown that the remnant trout cod population in the mid-Murray region between Yarrowonga and Tocumwal contains a higher level of genetic diversity and is significantly different to the Seven Creeks population that was stocked (Bearlin & Tikel, 2003).

Research also suggests that there is a low level of hybridisation between trout cod and Murray cod in the Murray River. The level of mitochondrial DNA divergence of trout cod from Murray cod approaches or exceeds that of the divergence between Murray cod and either eastern or Mary River cod (Jerry *et al.* 2001, Gilligan unpublished data). First generation hybrids between trout cod and Murray cod have been reported (Harris & Dixon 1988, Wajon 1983), however, as cross breeding of eastern cod and Murray cod show poor fertilisation rates, poor survival and high frequencies of deformities (Rowland 1985), the potential for introgression of Murray cod genes into trout cod populations appears low. Despite these natural constraints, correlations between human-induced habitat changes and fish hybridisation (Camption 1987 cited in Douglas *et al.* 1994) indicate that further modification of riverine habitat may increase hybridisation levels.

There are a number of steps that can be taken to maximise genetic variation and maintain natural population structure in fish used for restocking purposes including for example, using sufficient numbers of broodfish and replacing broodfish on a regular basis.

4.6 Community awareness and support

Currently, there appears to be a lack of public understanding of issues affecting the recovery and long-term conservation of trout cod. This, combined with the inability of some anglers to distinguish between Murray cod and trout cod, is having a detrimental impact on the species survival. There is a need to widely disseminate information relating the species' status, primary threats and recovery activities among a range of stakeholders including anglers, community groups, relevant councils, planners and government organisations. This can assist in raising the profile of the species and in minimising adverse impacts resulting from human activities (such as reducing the incidence of illegal fishing and the impacts of incidental capture).

While some broad education activities have been carried out, a key part of this recovery plan is to maintain and enhance these initiatives to ensure community support and involvement in the recovery and long-term conservation of trout cod. The Native Fish Australia organisation has been active in trout cod conservation through assistance with stocking and research and are a possible stakeholder who could assist with increasing community awareness and support for the trout cod program.

5. Recovery objectives and performance criteria

5.1 Recovery plan objectives

The overall objective of this recovery plan is to prevent the extinction and ensure the recovery and ongoing viability in nature of trout cod populations in NSW.

The plan aims to achieve recovery of the species to such an extent that it can eventually be delisted from Schedule 4 of the NSW *Fisheries Management Act 1994*.

The specific objectives of the recovery plan are to:

- Ensure the security of the existing trout cod population in the Murray River by maintaining and restoring, where necessary, the aquatic habitat in that locality, and through habitat protection mechanisms.
- Establish and protect a minimum of two new self-sustaining populations of trout cod at selected locations throughout the species' former range.
- Reduce fishing related mortality of trout cod by setting appropriate regulatory controls and by maximising angler compliance.
- Increase scientific knowledge of the distribution, population size, ecological requirements, and historical and existing genetic status of trout cod.
- Improve our understanding of the threats to the survival of trout cod, and contribute to management actions to ameliorate identified threats.
- Coordinate and initiate new community awareness and education programs relating to trout cod.
- Coordinate and support appropriate actions by the community and government to provide a strategic, regional approach to trout cod survival and effective threat management.
- Increase awareness of the status of and threats to trout cod, and enhance community support for recovery actions.
- Assess the outcomes of past and current recovery actions and the species' conservation status.

5.2 Performance criteria

The success of the plan will be measured against the criterion that:

- The status of trout cod is revised from 'endangered' to 'vulnerable' and eventually delisted from the schedules of the *Fisheries Management Act 1994* within 15 years.

Criteria for evaluating the effectiveness of individual components of the recovery plan are outlined under each recovery action.

6. Recovery actions

6.1 National recovery plan

6.1.1	Maintain contributions to national recovery plan.
	<ul style="list-style-type: none"> • Continue membership of National recovery team. • Continue cooperative involvement and liaison, including information exchange, with other State/Territory agencies involved in trout cod recovery. • Continue to assist with the implementation of the National trout cod recovery plan.
Responsibility:	NSW DPI
Performance criteria:	<ul style="list-style-type: none"> • Membership of National recovery team maintained. • Regular communication with National recovery team members and other agency representatives involved in trout cod recovery. • Assistance to implement of National recovery actions maintained.

6.2 Habitat protection and restoration

Note: Some of these issues will also be addressed through the development and implementation of Threat Abatement Plans for ‘installation and operation of instream structures and other mechanisms that alter natural flow regimes’ and ‘degradation of native riparian vegetation along NSW water courses’.

6.2.1	Ensure that the risk of degradation of trout cod habitat is minimised.
	<ul style="list-style-type: none"> • Ensure that councils, government agencies and other relevant organisations are aware of the location of important areas for trout cod, for example by providing maps of known and potential habitat and the location of significant populations. • Provide information to relevant stakeholders including local councils and government agencies to support appropriate environmental planning and impact assessment procedures. • Negotiate with relevant local councils in regard to local environmental plans, development control plans and other planning documents, regarding the type and scale of development permitted near key areas known to support trout cod. • Encourage the adoption of land use ‘best practice’ (e.g. agriculture, industry) to assist in minimising adverse impacts on stream flows, habitat connectivity, riparian vegetation and water quality.
Responsibility:	NSW DPI, local councils, DEC, catchment management authorities.
Performance criteria:	<ul style="list-style-type: none"> • Negotiations held and appropriate information (e.g. maps of known and potential habitat, impact assessment guidelines etc.) provided to relevant stakeholders. • Consultation with councils undertaken regarding local environmental plans, development control plans and future urban development plans. • Consultation and communication regarding relevant land use activities undertaken with key industries. • Key habitats maintained in good condition.

6.2.2	Investigate options and implement measures that provide increased protection and rehabilitation opportunities for key areas of trout cod habitat.
	<ul style="list-style-type: none"> • Prepare and implement a strategic plan for the protection and rehabilitation of key trout cod habitats. • Identify and implement the most appropriate mechanisms to enhance the protection and rehabilitation potential of key trout cod habitat. • Investigate the use of critical habitat protection as a means of protecting key trout cod habitats.
Responsibility:	NSW DPI, locals councils, catchment management authorities
Performance criteria:	<ul style="list-style-type: none"> • Habitat protection and rehabilitation plan implemented. • Key habitats identified and under increased protection. • Potential trout cod habitats identified and restored (where appropriate).

6.2.3	Actively promote trout cod habitat protection and/or rehabilitation within broader natural resource management programs in NSW.
	<ul style="list-style-type: none"> • Work with community groups, relevant natural resource management agencies, local councils, landholders etc to identify, restore and protect known and potential trout cod habitats with the aim of protecting existing trout cod habitats and populations, and re-establishing additional viable populations. • Seek funds to undertake priority rehabilitation and restoration work (e.g. restoring fish passage, re-snagging activities, riparian revegetation, implementing mitigation measures for cold water pollution etc.) at key sites through grant schemes or other sources. • Develop guidelines and principles to assist in determining the flow requirements of trout cod, and distribute this information to relevant natural resource management committees and agencies. • Continue to support habitat rehabilitation / restoration activities throughout the range of trout cod through existing programs including the Weir Review Program and related programs. • Encourage the identification, assessment and modification of natural resource management plans and policies (including catchment action plans, water management plans, vegetation management plans, and other natural resource management plans) which may influence the recovery of trout cod or their habitat (e.g. appropriate environmental flow recommendations).
Responsibility:	NSW DPI, local councils, DIPNR, DEC, water management forums, catchment management authorities.
Performance criteria:	<ul style="list-style-type: none"> • Degraded areas of potential trout cod habitat identified and rehabilitation work at key sites completed in accordance with targets. • Funding for rehabilitation and restoration works sought. • Guidelines of the flow requirements of trout cod developed and distributed to relevant agencies and natural resource management committees. • Relevant land, water and other natural resource plans and policies identified and assessed. • Negotiations held with responsible natural resource agencies where a need for modification of plans or policies has been identified.

6.3 Reduce the impact of Illegal fishing and incidental capture

6.3.1	Reduce or prevent fishing induced mortality.
	<ul style="list-style-type: none"> • Maintain regulations in the trout cod protection area between Yarrawonga and Tocumwal. • Investigate the impact of incidental capture on trout cod. • Assess the need for modifying existing regulations/activities to restrict methods likely to induce high levels of mortality or severe injury. • Maximise angler compliance through enhanced community advisory and education activities (see action 6.7) and through effective law enforcement. • Implement targeted enforcement activities by regional DPI Fisheries Officers. • Investigate options to improve reporting illegal activities and providing feedback on actions taken.
Responsibility:	NSW DPI
Performance criteria:	<ul style="list-style-type: none"> • Seasonal closure and ban on set lines maintained. • Report on hooking impacts completed. • Regulations assessed and modified (where required). • Improved public awareness of trout cod protection regulations. • Targeted enforcement of trout cod regulations by NSW DPI. • Enhanced public reporting and feedback mechanism.

6.4 Minimise risks from inter-specific competition and introduced species

6.4.1	Minimise the risk of impacts associated with stocked, translocated and introduced species on trout cod.
	<ul style="list-style-type: none"> • Implement the Freshwater Fish Stocking Fishery Management Strategy (FMS) to prevent significant impacts from stocking on trout cod populations and increase law enforcement activities to maximise compliance. • Encourage community identification and reporting of introduced species throughout the range of trout cod through the Protected, Threatened and Pest Species Sighting Program. • Monitor populations of non-endemic fish species at key sites and undertake eradication and/or control programs where appropriate. • Study interactions between introduced species (such as trout, carp, redbfin and goldfish) and trout cod to better establish the degree of threat posed by such species.
Responsibility:	NSW DPI
Performance criteria:	<ul style="list-style-type: none"> • All stocking proposals in the range of trout cod reviewed and assessed. • All stocking will be in accordance with the Freshwater Fish Stocking FMS. • Additional law enforcement activities carried out. • Improved community awareness and reporting of introduced species throughout the range of trout cod. • Improved understanding of the specific threats of introduced species (ie salmonids, carp) on trout cod. • Monitoring and eradication / control program for non-endemic fish species developed and implemented (ongoing).

6.5 Establish new self-sustaining populations through stocking

6.5.1	Enhance the strategic conservation stocking program.
	<ul style="list-style-type: none"> • Select and prioritise potential new stocking sites. • Identify funding opportunities to support and / or expand the conservation stocking program. • Develop a strategy to ensure maximum viability of trout cod stocking events. This may include for example, determining the optimum stocking density and best times for stock release to maximise survival. • Implement a comprehensive monitoring program (including genetic monitoring) to assess stocking survival and subsequent reproduction of stocked populations.
Responsibility:	NSW DPI
Performance criteria:	<ul style="list-style-type: none"> • Sufficient abundance and recruitment data collected to allow assessment of stocking program success. • New stocking sites identified and prioritised. • Additional funding opportunities identified. • Trout cod conservation stocking strategy developed to maximise the effectiveness of stocking events. • Monitoring program established and implemented. • Foster collaborative research projects with universities.

6.5.2	Maintain genetic management protocols for the trout cod conservation stocking program.
	<ul style="list-style-type: none"> • Maintain strict genetic management protocols for the breeding of trout cod. • Introduce a tagging program for the broodstock released from the breeding program to prevent repeated use. • Continue marking of all stocked fish. • Periodically review and assess the genetic management protocols for the breeding of trout cod to ensure the use of 'best practice' and maintenance of genetic diversity.
Responsibility:	NSW DPI
Performance criteria:	<ul style="list-style-type: none"> • Compliance with genetic management requirements. • Broodstock tagging program implemented. • Marking of all stocked fish continued. • Genetic management protocols periodically reviewed / assessed and updated (if required).

6.6 Research and monitoring

6.6.1	Monitor trout cod populations and contribute to research requirements in conjunction with other agencies.
	<ul style="list-style-type: none"> Actively seek funds to initiate research and monitoring programs through grant schemes or other sources. Contribute to research to improve understanding of the size, distribution and ecological requirements of trout cod, as well as the species' historical and existing genetic status. Undertake research to assist in clearly identifying the precise impacts of known and potential threats to trout cod. Establish and undertake regular monitoring surveys for trout cod to assess the species' conservation status and the effectiveness of recovery actions.
Responsibility:	NSW DPI
Performance criteria:	<ul style="list-style-type: none"> Additional funding obtained to implement research and monitoring activities. Increased knowledge of trout cod ecology, genetics, distribution and population structure. Improved understanding of the impact that various identified threats have on trout cod. Response to recovery plan actions assessed. Foster collaborative research projects with universities.

6.7 Enhance community understanding, involvement and support

6.7.1	Increase community awareness and support of trout cod issues and recovery actions.
	<ul style="list-style-type: none"> Produce information brochures and other advisory materials and distribute to relevant stakeholders including local councils. Develop and distribute an education kit for use in schools. Maintain the Fishcare Volunteers program, with emphasis on trout cod issues in the Murray, Murrumbidgee and Macquarie River catchments. Where appropriate actively encourage community involvement in aspects of trout cod recovery including for example, research and monitoring programs. Install signs and / or interpretative displays at appropriate locations to assist in raising awareness of the identification and protected status of trout cod.
Responsibility:	NSW DPI, local councils
Performance criteria:	<ul style="list-style-type: none"> Advisory material printed, distributed to key stakeholders and widely available. Education kit developed and supplied to local schools. Community involved in various recovery programs for trout cod. Number of Fishcare volunteer/angler contacts. Signs or interpretative displays installed.

6.7.2	Enhance angler knowledge of and skills in trout cod identification, and the protected status of the species.
	<ul style="list-style-type: none"> • Install advisory signs which differentiate between Murray cod and trout cod at appropriate locations (such as re-introduction sites). • Develop and distribute (eg via Fishcare volunteers) advisory material specifically targeting anglers.
Responsibility:	NSW DPI
Performance criteria:	<ul style="list-style-type: none"> • Signs installed at appropriate access points. • Advisory material widely distributed to local anglers. • Surveys to determine the level of improvement in angler knowledge and skills undertaken as a basis for developing future communication strategy.

6.7.3	Improve understanding about the traditional and cultural importance of trout cod to indigenous communities.
	<ul style="list-style-type: none"> • Continue to implement the NSW Indigenous Fisheries Strategy. • Encourage and support the involvement of indigenous communities in implementing trout cod recovery actions.
Responsibility:	NSW DPI
Performance criteria:	<ul style="list-style-type: none"> • NSW Indigenous Fisheries Strategy progressively implemented. • Indigenous communities involved in all aspects of recovery plan implementation.

7. Social, economic and cultural issues

Potential social and economic impacts have been considered during the development of this recovery plan, and the objectives and actions (see sections 5 and 6) have been formulated with the aim of minimising any potential adverse impacts.

The main social and economic effects are likely to result from management of water flows and development proposals in general. Overall, however, the effects of the recovery plan are expected to be positive. Continued liaison with developers, landholders, irrigators, local councils and the community will help to minimise any social effects arising from the conservation of trout cod.

7.1 Fishing

Trout cod exist in a region where fishing is a major recreational and tourist activity. The direct economic value of the recreational fishery in the range of trout cod is unknown, but is likely to be in the order of tens of millions of dollars per year, and the tourism income generated by the fishery is likely to be critical to the survival of a number of businesses in the region (NSW Fisheries 2002a). Any actions which restrict present levels of angling tourism in the range of trout cod are likely to have some social and economic impacts.

As previously discussed (section 4.3), regulations are in place in NSW to prevent the harm or capture of trout cod. The last review of freshwater recreational fishing regulations occurred in 1997 and resulted in an extension of the trout cod closure in the Murray River below Yarrowonga Weir (Talbot 1998 cited in NSW Fisheries 2002a). In addition, an environmental impact statement and fishery management strategy is currently being prepared for the NSW recreational fishery. This strategy will aim to address recreational fishing impacts on threatened species as well as minimising any potential adverse social and economic impacts.

Recovery actions under this plan will help to improve awareness of existing fishing regulations among the recreational fishing community. In addition, interested anglers will have the opportunity to become involved in some aspects of the recovery program, for example by becoming trained Fishcare Volunteers.

In the long term, if the recovery program for trout cod is successful there is the potential for possible future legalisation of catch-and-release fishing or controlled harvest fishing for trout cod in inland rivers, which could lead to the growth of fishing-based tourism and greater economic and social benefits for regional communities.

7.2 Environmental flows

A primary action of trout cod recovery identified under this plan is to protect and enhance habitat values, of which a major component is providing for appropriate flows in all streams in the natural range of the species. There is a need for the recovery program to work within broader natural resource management programs in NSW to ameliorate the impacts of these changes. In this plan, responsibility has been allocated to all agencies involved in the water reform process, as well as community-based natural resource management committees to address these issues. The plan aims to encourage the adoption of flow rules conducive to the survival of trout cod and to maintain a suitable aquatic ecosystem within its natural range.

In NSW, flow management rules (including bulk access regimes and environmental flows) for most regulated rivers are being formalised through 10-year water sharing plans, developed by regional Water Management Committees under the *Water Management Act 2000*. Water sharing plans have already been gazetted for 35 areas and implementation programs have been developed. NSW DPI has been involved in this process and has helped to influence allocations of environmental water under bulk access regimes (BARs). In some areas NSW DPI is participating in discussions to determine the most appropriate delivery of these flows, with a view to supporting the recovery of a range of threatened aquatic species. The development of water sharing plans is designed, among other aims, to provide greater security for water users by defining access rights to water. Each water sharing plan establishes a BAR for the extraction of water under access licences. If the BAR is adjusted during the 10 year tenure of the plan, the state government may be liable to pay compensation unless provisions for adjustment are incorporated in the plan.

An additional process to develop water sharing plans for the remainder of NSW streams is currently underway.

The decision-making process for the establishment of the water sharing plans includes a requirement to undertake a socio-economic assessment of the impact of the plan. In most cases, flow modelling and water use information is limited. The assessments are generally qualitative, using demographic and extractive and non-extractive use of water and their trade-offs. Thus, while the needs of threatened species have been considered they have been weighed against social and economic factors.

7.3 Development

Under the *Environmental Planning and Assessment Act*, the potential impacts of a development on any threatened species must be considered by the authorities responsible for its approval. If a major impact is likely, the developer must prepare a species impact statement (SIS) as part of their proposal. Any decision about this type of development by a consent authority must also be approved by the Director-General of NSW DPI.

These protective laws may be seen as an economic burden by developers who may be required to contract consultants to prepare a species impact statement as well as bear the costs involved in the delay, conditional approval or rejection of a proposal. The legislation may also represent a burden to the consent or determining authorities if they lack the appropriate expertise and information needed to assess development proposals.

However, these legal requirements arise from the 'endangered' status of trout cod under the *Fisheries Management Act 1994*, rather than as a consequence of the recovery plan. The recovery plan will help to ease some of the economic effects by distributing relevant information to those involved in the assessment of impacts, particularly to consent and determining authorities.

7.4 Indigenous communities

A process to assess the cultural significance of trout cod to local Aboriginal people has started in consultation with Local Area Land Councils and Elders Groups. It will also consider the effects of the recovery program and the level of community interest in participating in recovery activities.

Local aboriginal groups will be encouraged to take part in activities that are part of the recovery plan. Any proposal that could affect places of cultural importance will need to be discussed in direct consultation with local groups.

7.5 Costs of implementation

The main costs of implementing this recovery plan relate to habitat restoration, research, monitoring, community liaison and education.

Many of these costs will be met by NSW DPI and other government departments or funded through external grant programs such as the Natural Heritage Trust or Recreational Fishing Trusts. Community groups that take part in surveying, monitoring or habitat restoration may also be funded by grants to complement their in-kind contribution.

Wherever possible, recovery activities for trout cod will be linked to existing government or community programs to prevent duplication, in particular via the catchment management process.

8. Recovery actions to date

The following section summarises NSW contribution to the actions in the national recovery plan, as well as a number of prominent actions undertaken by other jurisdictions.

8.1 National trout cod recovery plan

Trout cod have been the subject of a National recovery plan since 1994, as well as an action plan in both the ACT and Victoria. The National recovery plan was developed by the National recovery team 1994 with representatives from relevant jurisdictions. A revised recovery plan for trout cod was developed in 1998, and a further revision of the National recovery plan commenced in 2004/05. The overall objective of the plan is to down-list trout cod from Critically endangered to Vulnerable within 25 years. The plan sets out three specific recovery objectives and criteria and 7 actions needed to achieve recovery. Funding to implement the National recovery plan was obtained from the Endangered Species Program of the (then) Australian Nature Conservation Agency, from the Murray Darling Basin Commission and from respective State agencies in the ACT, NSW and Victoria. Implementation of the National recovery plan has seen major advances in the understanding of the ecology of trout cod.

8.2 Habitat protection and restoration

Improving instream habitat is an on-going activity. There is a range of government programs and initiatives aimed at protecting and/or restoring river habitats, which in turn assists in reducing the various threats to trout cod. Examples include the Water Reform Program, State Fishway Program, the Murray Darling Basin Native Fish Strategy, Landcare and Rivercare programs, the Carp Assessment and Reduction Program and the NSW Salinity Strategy.

8.3 Fishing impacts

Trout cod have been totally protected under NSW legislation since 1992. Fisheries officers regularly patrol trout cod habitat areas to ensure compliance with protective provisions.

The section of the Murray River between Yarrawonga and Tocumwal where the primary remnant trout cod population exists is considered a special protection zone. In this area, unattended set lines are not permitted, and there is a closed season for all fish species over the Murray cod and trout cod breeding season (1 September to 30 November).

8.4 Captive breeding and stocking programs

Both NSW DPI and the Victorian Fisheries operate captive breeding programs for trout cod. In NSW, trout cod are bred at NSW DPI Inland Fisheries Research Centre at Narrandera. Since 1986 a total of over one million fingerlings have been stocked in the Murray, Murrumbidgee and Macquarie catchments. Since 1993 all hatchery produced trout cod within NSW have been chemically marked using either strontium chloride, oxytetracycline or alizarin complexone. This ensures that all hatchery raised fish can be differentiated from wild-bred fish by otolith (ear bone) examination. A stocked trout cod population in Loombah Weir - Victoria has been successful in natural recruitment with small juveniles caught that were considerably younger than stocked fish (Douglas and Brown 2000).

During the 18 years of the stocking program, a number of stocking sites and strategies have been used. However, in 1995 NSW Fisheries (now part of NSW DPI) adopted a strategy whereby only a small number of sites are stocked with large numbers of trout cod on an annual basis. The primary stocking sites include Angle Crossing, Wantabadgery, Collingullie, Narrandera and Yanco in the Murrumbidgee River system and Namina Falls and Devils Elbow in the Macquarie River system. Further monitoring is required to determine the outcomes of this particular stocking strategy.

8.5 Survey and monitoring

Monitoring of re-stocked trout cod populations has been undertaken since 1990 by NSW DPI, Victorian Department of Sustainability and Environment and Environment ACT (see Douglas *et al.* 1994, Faragher *et al.* 1993). Surveys of the single remnant population in the Murray River were undertaken in 1995 - 1996 as part of the National Trout Cod Recovery Plan. The aims of the surveys included assessment of the survival and abundance of restocked populations, investigation of the dispersal of trout cod from stocked sites, identification of micro-habitat requirements at different life history stages, and investigation of the size-structure of populations.

While not directly targeting trout cod, surveys and research programs undertaken by NSW DPI provide incidental and valuable data on trout cod.

8.6 Community education

NSW DPI has undertaken various activities targeted at increasing public awareness of trout cod issues. These activities include installation of advisory signage, magazine and Internet articles, brochures and field day displays.

Various community education initiatives have also been undertaken as part of the National Trout Cod Recovery Plan including the design and construction of a mobile information display with a video unit that is utilised in various community forums. Information on the recovery of trout cod has also been presented in the biannual 'Codwatch' newsletter of which 15,000 copies are distributed.

9. Implementation and costs

The DPI has a statutory responsibility to prepare and lead the implementation of this recovery plan. However, the success of the plan in recovering trout cod to a position of viability in nature will depend on the involvement of other agencies, organisations and individuals who have a role in activities that affect the species. Public authorities must take any appropriate action available to them to implement the measures for which they have an identified responsibility in a recovery plan. Similarly, consent and determining authorities must consider relevant recovery plans when exercising decision-making functions under Part 4 & 5 of the *Environmental Planning and Assessment Act 1979*. Such authorities, when considering an activity that may impact on trout cod or its habitat, must consider the provisions of this plan.

The main implementation costs relate to research, community liaison and education, habitat restoration and monitoring. Many of these costs will be met by relevant state government agencies or funded through external grant programs such as the Natural Heritage Trust. Community groups that take part in surveying, monitoring or habitat restoration may also be funded by grants to complement their in-kind contribution.

Wherever possible, recovery activities for trout cod will be linked to existing government or community programs to prevent duplication, in particular via Catchment Action Plans.

10. Monitoring, evaluation and review

The performance criteria of de-listing trout cod from 'endangered' to 'vulnerable' under Schedule 5 of the *Fisheries Management Act 1994* will be the primary measure used to assess the success of the actions within this plan.

The recovery plan recognises the need for a strategically focused monitoring program to enable the effectiveness of recovery actions to be evaluated.

The recovery plan will be audited and reviewed every three years. The audit will determine whether the implementation of recovery actions has occurred and the success of the actions in recovering trout cod to a position of viability in nature.

The recovery plan will be subject to major statutory review within ten (10) years from the date of publication.

11. References

- ACT Government, 1999. Trout Cod (*Maccullochella macquariensis*): An endangered species. Action Plan No. 12. Environment ACT, Canberra.
- Bearlin, A. A. & Tikel, D. 2002. Conservation genetics of Murray-Darling Basin fish; silver perch, Murray cod and trout cod. In Managing Fish Translocation and Stocking in the Murray-Darling Basin Workshop held in Canberra, 25-26 September 2002: Statement, recommendations and supporting papers. Phillips, Bill (Compiler), February 2003.
- Brown, A., Nicol, S. & Koehn, J., 1998. Trout cod (*Maccullochella macquariensis*) Recovery Plan. Aquatic Ecosse Pty. Ltd. & Department of Natural Resources and Environment, Victoria.
- Brown, A., & Nicol, S., 1998. Trout cod recovery plan: draft final report. Department of Natural Resources and Environment, Melbourne, Victoria.
- Cadwallader, P.L. 1979. Distribution of native and introduced fish in Seven Creeks River System, Victoria. *Australian Journal of Ecology* 4: 361-385
- Douglas, J. W., Gooley, G. J. & Ingram, B. A., 1994. Trout Cod, *Maccullochella macquariensis* (Cuvier) (*Pisces: Percichthyidae*), *Resource Handbook and Research and Recovery Plan*. DCNR, Victoria.
- Douglas, J.W. and Brown, P. (2000). Notes on successful spawning and recruitment of a stocked population of the endangered Australian freshwater fish, trout cod, *Maccullochella macquariensis* (Curvier) (*Percichthyidae*). *Proc. Linn. Soc. NSW* 122:143-147.
- Erskine, W.D., 1990. Hydrogeomorphic effects of river training works: the case of the Allyn River, NSW. *Australian Geographical Studies* 28: 62-76.
- Erskine, W.D., 1992. Channel response to large-scale river training works: Hunter River, Australia. *Regulated Rivers: Research and Management* 7: 261-278.
- Erskine, W.D., 2001. Geomorphic evaluation of past river rehabilitation works on the Williams River, New South Wales. *Ecological Management and Restoration* 2: 116-128.
- Faragher, Brown & Harris, 1993. Population surveys of the endangered fish species trout cod (*Maccullochella macquariensis*) and eastern cod (*M. ikei*). Report for Australian National Parks and Wildlife service Endangered Species Program. NSW Fisheries Research Institute, Cronulla.
- Gehrke, P.C. & Harris, J.H., 1996. Fish and fisheries of the Hawkesbury-Nepean river system. NSW Fisheries Office of Conservation. Sydney.
- Gilligan, D. M. 2005. *Fish communities of the Murrumbidgee catchment: Status and trends*. NSW Department of Primary Industries, Final Report Series (No. 75)
- Gilligan, D. M., & Schiller, C. 2003. *Downstream transport of larval and juvenile fish*. NSW Fisheries Office of Conservation, Final Report Series, Narrandera.
- Gippel, C.J., 1995. Environmental hydraulics of large woody debris in streams and rivers. *Journal of Environmental Engineering* 5: 77-87.
- Growns, I., Wooden, I., Schiller, C., In press. Use of instream wood habitat by trout cod (*Maccullochella macquariensis* (Cuvier)) in the Murrumbidgee River. *Pacific Conservation Biology*. 10:4, pp 261-265.

- Harris, J. H. & Rowland, S. J. 1996. Australian freshwater cods and basses. Pp 150-163 in McDowall, R. (ed). *Freshwater fishes of south-eastern Australia*. Reed Books, NSW.
- Harris, J.H. & Dixon, P.I. 1988. Hybridization between trout cod and Murray cod. *Isozyme Bulletin* 19: 39.
- Ingram, B.C & Richardson, B.A. 1989. Trout Cod (first edition). AGFACTS, F3.2.6. NSW Agriculture & Fisheries, Sydney.
- Ingram, B.A., Barlow, C.G., Burchmore, J.J., Gooley, G.J., Rowland, S.J. & Sanger, A.C., 1990. Threatened native freshwater fishes in Australia - some case histories. *Journal of Fish Biology* 37 (Supplement A): 175-182.
- Jarman, P.J. 1996. Realism in Response to the Ecological Performance of Populations in Recovery Programs. Pp 185-189 in Stephens, S. & Maxwell, S. (eds). *Back from the Brink: Refining the Threatened Species Recovery Process*. Surrey Beatty & Sons, Sydney.
- Jerry, D. R., Elphinstone, M. S. & Baverstock, P. R. 2001. Phylogenetic relationships of Australian members of the family Percichthyidae inferred from mitochondrial 12S rRNA sequence data. *Molecular Phylogenetics and Evolution* 18(3): 335-347.
- Keenan, C. P., Watts, R. J. & Serafini, L.G. 1995. Population genetics of Golden Perch (*Macquaria ambigua*), Silver perch (*Bidyanus bidyanus*) and ell-tailed catfish (*Tandanus tandanus*) within the Murray-Darling basin. *Final report of Natural Resources Management Strategy, project No. N262*.
- Koehn, J.D., & O'Connor, W.G. 1990. Biological Information for Management of Native Freshwater Fish in Victoria. Department of Conservation and Environment Freshwater Fish Management Branch, Arthur Rylah Institute for Environmental Research, Victoria.
- Koehn, J. 2001. Ecological Impacts of Cold Water Releases on Fish and Ecosystem Processes. In Thermal Pollution of the Murray-Darling Basin Waterways Workshop held at Lake Hume 18-19 June 2001. Statement and recommendations plus supporting papers. Phillips, Bill (ed), December 2001.
- Lawrence, B. W., 1991. *Fish management plan*. Murray-Darling Basin Commission, Canberra.
- Lyon, J., Lennie, R., Ryan, T. & Todd, Charles. 2002. *Physical and Biological Impacts of Cold Water Dam Releases* (Abstract). Proceedings of the Annual Conference of the Australian Society for Fish Biology, Cairns, Queensland, 14-17 August 2002.
- Morris, S.A., Pollard, D.A., Gehrke, P.C. & Pogonoski, J.J. 2001. Threatened and Potentially Threatened Freshwater Fishes of Coastal New South Wales and the Murray-Darling Basin, Report to Fisheries Action Program and World Wide Fund for Nature by NSW Fisheries Office of Conservation, Cronulla.
- Mounke, M.I. & Childress, W.M. 1994. Hooking Mortality: A Review for Recreational Fisheries. *Reviews in Fisheries Science*, 2(2): 123-156.
- Nicol, S., Lieschke, J., Lyon, J. and Hughes, V. (2002) Resnagging revolution: River habitat rehabilitation through resnagging. Department of Natural Resources and Environment (Melbourne).
- NSW Fisheries 1999. Policy and Guidelines Aquatic Habitat Management and Fish Conservation (Eds). A.K. Smith and D.A. Pollard) NSW Fisheries, Port Stephens Research Centre.
- NSW Fisheries. 2001. Cold Water Pollution. Fishnote DF 95. NSW Fisheries, Inverell.

- NSW Fisheries. 2002a. Species Impact Statement Fishing in the Lower Murray River Catchment, Public consultation document, NSW Fisheries, Port Stephens Research Centre.
- NSW Fisheries. 2002b. Survey of Recreational Fishing in New South Wales. Interim Report, December 2002.
- Rowland, S.J., 1985. Aspects of the Biology and Artificial Breeding of the Murray cod, *Maccullochella peelii peelii* and the Trout Freshwater Cod, *M. macquariensis* sp. nov. Ph.D. Thesis, Macquarie University, 253 pp.
- Rowland, S.J. and Tully, P. (2004). Hatchery quality assurance program for Murray cod (*Maccullochella peelii peelii*), golden perch (*Macquaria ambigua*) and silver perch (*Bidyanus bidyanus*). NSW Department of Primary Industries.
- Thain, M. & Hickman, M. 2001. The Penguin Dictionary of Biology. 10 edition. Penguin Books, Victoria, Australia.
- Thorncraft, G. & Harris, J. H. 1997. *Rock-ramp and lock fishways as tools for solving fish-passage problems in New South Wales, Australia*. Proceedings of the Second National Fishway Technical Workshop, Rockhampton, June 1997 (A. P. Berghuis, P. E. Long and I. G. Stuart eds) pp. 203-226. Department of Primary Industries, Brisbane.
- Wager, R., & Jackson, P. 1993. *The Action Plan for Australian Freshwater Fishes*. Australian Nature Conservation Agency, Canberra.
- Wajon, S. 1983 Hybridization between Murray cod and trout cod in Cataract Dam, NSW. BSc (Hons). Thesis Uni of NSW, Sydney.
- Young, W. J. (ed.) 2001. *Rivers as Ecological Systems: The Murray-Darling Basin*. Murray-Darling Basin Commission, Canberra.

Appendixes

Appendix 1: Required contents of a recovery plan

Extract from NSW *Fisheries Management Act 1994*, Part 7A

220ZN Contents of recovery or threat abatement plans

(1) Recovery plans

A recovery plan must:

- a) identify the threatened species, population or ecological community to which it applies, and
- b) identify any critical habitat declared in relation to the threatened species, population or ecological community, and
- c) identify any threatening process or processes threatening the threatened species, population or ecological community, and
- d) identify methods by which adverse social and economic consequences of the making of the plan can be minimised, and
- e) state what must be done to ensure the recovery of the threatened species, population or ecological community, and
- f) state what must be done to protect the critical habitat (if any) identified in the plan, and
- g) state, with reference to the objects of this Part:
 - (i) the way in which those objects are to be implemented or promoted for the benefit of the threatened species, population or ecological community, and
 - (ii) the method by which progress towards achieving those objects is to be assessed, and
- h) identify the persons or public authorities who are responsible for the implementation of the measures included in the plan, and
- i) state the date by which the recovery plan should be subject to review by the Director.

Appendix 2: Genetic guidelines for the conservation stocking program

Published guidelines for the hatchery production of Australian native fish recommend an effective population size (N_e) of 100 for threatened species (Rowland and Tully, 2004). This number should prevent loss of fitness through inbreeding depression and will result in an approximate loss of one per cent of genetic variation.

- Progeny from AT LEAST 5 pairs to be stocked at each site.
- This requires that eggs from each pair be incubated separately
- Stock the larvae from 5 pairs into each pond, or
- Pool fry from 5 pairs after harvest.

As far as is practically possible, the same number of offspring from each pair should be stocked into the wild. Equalising family sizes effectively doubles the available genetic variation in the recovering population. It would be beneficial for us to adapt a strategy that equalised family sizes. This would require that offspring from all pairs be kept independently throughout the entire breeding process. The same number (roughly) of offspring from each pair could then be stocked at each re-introduction site. However to incorporate equalised family sizes into the recovery plan is logistically difficult.

Ideally use single cross matings (1 Female x 1 Male). (*Easier to manage*) OR

Cross every female with every male. DO NOT mix eggs from several females or milt from several males. Each female's eggs must be divided into the same number of portions as the number of males in the breeding program. Each portion of eggs should be the same size. Do the same with males (quantities of milt not important, as eggs are the limiting factor). Fertilise each portion of eggs from individual females with milt from each of the males. (*Genetically more beneficial but very hard to achieve*).

If males do not produce enough milt for fertilisation they should not be used that season. If they again fail to produce sufficient milt the following season they should not be used in the program. Therefore a few excess males may be required as backups.

Ideally NO individuals will be bred from more than once in the program. Therefore all broodstock should be replaced each year (assuming no recapture of broodfish). However, as a minimum, AT LEAST some broodfish should NOT have been used in a previous season. This number depends on the length of the breeding program. The minimum number to be replaced each year is given in Table 1.

Collect broodfish from 3 or more sites. As far as possible, set up pairs with individuals from different locations. Collect broodfish before May.

Do not use larger females (> 10kg). Use broodfish 2-5kg.

Table 1: Minimum number of broodfish required to achieve an effective population size N_e of 100 in 1 to 5 year breeding/stocking program, i.e. if the program last one year 50 pairs must be used, if it lasts five years 10 different pairs are to be used each year.

Breeding seasons	Minimum new breeding pairs / season.
1	50
2	26
3	18
4	14
5	10