

The status, threats and management of freshwater cod species *Maccullochella* spp. in Australia

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Abstract

All four Australian freshwater cod species; Murray cod (*Maccullochella peelii peelii*), Trout cod (*M. macquariensis*), Eastern freshwater cod (*M. ikei*) and Mary River cod (*M. peelii mariensis*) are declared threatened under national legislation (Environment Protection and Biodiversity Conservation Act 1999) or under various State/Territory legislation. Whilst the species occupy different geographical areas and have widely differing historical ranges, the causes of decline and current threats to each species are surprisingly similar, with over-fishing and habitat degradation considered the most important.

Management regimes for the four cod species vary. Trout cod and Eastern freshwater cod are now protected from fishing, because of their small population sizes and extremely restricted distributions. In contrast, Mary River cod are stocked in selected impoundments to provide a recreational fishery. Murray cod is an icon species for recreational anglers and is widely fished for throughout the Murray-Darling Basin. Commercial fishing for Murray cod has recently ceased, and there are restrictions on the recreational fisheries in each State including a closed season, bag limits and size limits. There have been stocking programs for each species, however the scope and purpose of these programs has varied. Numbers of Murray cod stocked, for example, are an order of magnitude higher than for the other cod species. Stocking programs for Trout cod, Mary River cod and Eastern freshwater cod have a conservation focus while Murray cod stocking is primarily to provide recreational fishing opportunities.

Recovery plans are in place or being prepared for each species. Successful conservation and management activities for Mary River cod and Eastern freshwater cod have had significant involvement from local community groups, whilst

Trout cod recovery and management is essentially run by government fisheries and conservation agencies. Successful conservation management and the recovery of Murray cod populations will require the cooperation and support of a range of agencies and community organisations. To effectively engage the community on Murray cod recovery efforts, a population-based recovery program may be preferable to the species-based approaches used for other Australian freshwater cods. Broad-scale closures to recreational fishing are unlikely to be supported by recreational anglers and are not appropriate for Murray cod. The benefits of local closures or other population protection measures, however, are worth considering. For Murray cod to remain a prized recreational species, the full range of threats must be addressed in a coordinated manner by both the community and government agencies to ensure that cod populations are rehabilitated across its historical range.

Introduction

There are four freshwater cod species or subspecies in the genus *Maccullochella* in Australia; Murray cod (*Maccullochella peelii peelii*), Mary River cod (*M. peelii mariensis*), Trout cod (*M. macquariensis*) and Eastern freshwater cod (*M. ikei*). Murray cod and Trout cod are the only species occurring in the Murray-Darling Basin (**Figure 1**). Prior to the 1970s only one cod species (Murray cod) had been recognised, with Trout cod only formally described in 1972 (Berra & Weatherley 1972). Trout cod had however, been suspected of being a separate species for many years (see J.O. Langtry reported in Cadwallader 1977). The two coastal cod species (Mary River cod and Eastern freshwater cod) were later identified and described by Rowland (1985, 1993).



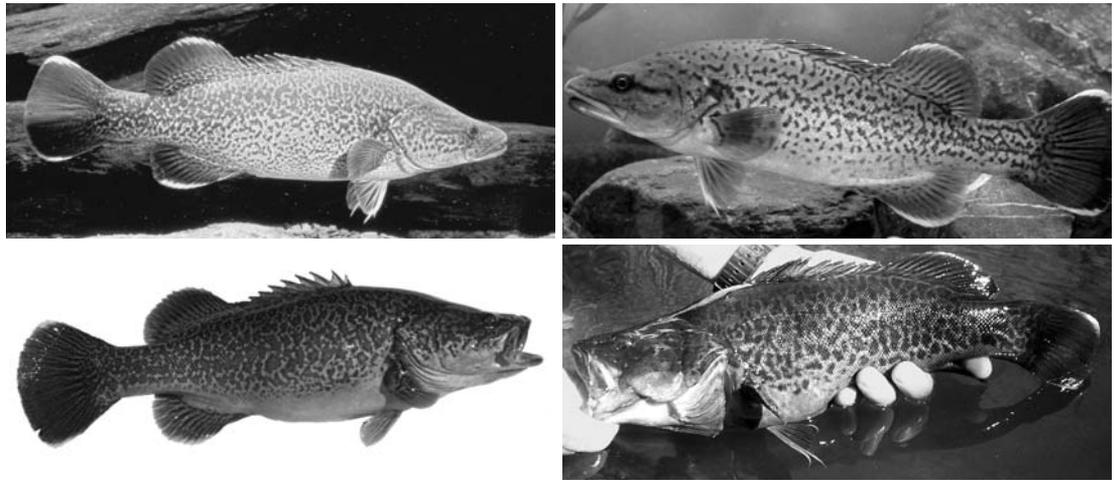


Figure 1. The four Australian freshwater cod species. (clockwise from top left: Murray cod; Trout cod; Mary River cod; Eastern freshwater cod). (Photo credits respectively: Gunther Schmida; Esther Beaton; Bob Simpson; NSW Fisheries).

All four freshwater cod species are declared threatened under the national Environment Protection and Biodiversity Conservation Act 1999 or various State/Territory legislation. Murray cod is considered the least threatened of the four having only been listed as vulnerable nationally in 2003; it is not listed in NSW, Queensland, ACT or South Australia (**Table 1**).

Recovery programs have been in place for several years for the other cod species, and an examination of the success and focus of these programs provides useful insights for how to best manage Murray cod recovery.

Table 1. Summary of distribution and conservation status of Australian freshwater cod.

Species	Distribution	State/Territory conservation status	EPBC ¹ status	ASFB ² Status
Trout cod	Murray-Darling Basin in Vic, NSW, ACT	ACT: Endangered NSW: Endangered Vic: Threatened ³	Endangered	Critically Endangered
Eastern freshwater cod	Clarence and Richmond Rivers in NSW	NSW: Endangered	Endangered	Endangered
Mary River cod	Mary and Brisbane Rivers in Qld	Qld: Protected	Endangered	Critically Endangered
Murray cod	Murray-Darling Basin in Qld, NSW, Vic, SA, ACT	Vic: Threatened ³ ACT: not listed NSW: not listed Qld: not listed SA: not listed	Vulnerable	not assessed

1 Environment Protection and Biodiversity Conservation Act 1999

2 Australian Society for Fish Biology 2004

3 Trout cod assessed as Critically Endangered and Murray cod assessed as Endangered (DSE 2003)

Ecology and social values of Australian freshwater cod

All four cod species are large freshwater fish, with maximum sizes in excess of 15 kg and all except Trout cod with individuals in excess of 38 kg recorded historically. Consequently, it is not surprising that all have been popular target species for recreational anglers.

Trout cod

Trout cod was once one of the premier sporting fish in the Murray-Darling Basin, being actively sought by anglers. They were renowned for their fighting qualities, and were reported to be more aggressive and fight longer than the closely-related Murray cod (Berra 1974; Cadwallader 1977). Trout cod was the first Murray-Darling species for which a national recovery program was established (Douglas *et al.* 1994), with hatchery production and restocking commencing in the late 1980s. This recovery plan has since been updated (Brown *et al.* 1998; Trout Cod Recovery Team 2004), and as such, it is a flagship species for fish recovery programs in the Basin.

The species occupies a range of habitats including riffles, runs and pools but is usually associated with deeper water and instream cover such as logs and boulders (Douglas *et al.* 1994; Ingram & Douglas 1995; Grown *et al.* 2004). Sexual maturity is reached at 3–5 years of age with spawning occurring in spring. Eggs are large (2.5–3.6 mm diameter), adhesive, (Ingram & Rimmer 1992) and probably deposited on hard substrates such as logs and rocks (Cadwallader 1979; Koehn & O'Connor 1990). They appear to have a shorter spawning period than Murray cod, which occurs after water temperatures exceed 15°C. Spawning times can overlap with Murray cod (Koehn & Harrington in press b) and hybridisation with Murray cod has been reported (Douglas *et al.* 1995; Wajon 1983). Hatching occurs after 5–10 days with larvae about 6–9 mm long (Ingram & Rimmer 1992; Ingram & Douglas 1995); when about 11 mm in length, larvae enter the drift for around 4 days (Humphries & Lake 2000; Gilligan & Schiller 2003; Koehn & Harrington in press a). Diet includes fish, crustaceans and aquatic insect larvae (Ingram & Douglas 1995; Lintermans 1995). Like all of the freshwater cod species in Australia, Trout cod was a top predator and provided an important

role in structuring fish communities. Recent research into Trout cod movements utilizing radiotelemetry has demonstrated that adult fish in lowland rivers display relatively restricted movement (less than 500 m) centred around a 'home site', but occasionally undertake exploratory movements, of 20–60 km involving a return to their home site (Ebner, Thiem & Lintermans, unpublished data). In upland streams, these dispersal or exploratory movements are much more restricted, probably by habitat limitations such as chutes, waterfalls and cascades (Ebner *et al.* 2005).

Mary River cod

Mary River cod were an important food source for both Indigenous Australians and early European settlers in south-east Queensland. More recently, their large size and aggressive feeding habits made them a popular target for anglers. Hatchery production and restocking commenced in the early 1980s, however, a detailed recovery plan was not implemented until 1996. While the ultimate aim of the recovery plan is to restore cod populations in their historic habitats, the plan also allows for limited take by anglers in a small number of water storage impoundments. Recent research (Simpson & Mapleston 2002) has shown that Mary River cod can move long distances within their home streams, but at other times may remain within a limited home range for up to several years. Their diet is known to include fish, crustaceans, and small birds and mammals.

Eastern freshwater cod

Eastern freshwater cod are thought to be largely opportunistic feeders, consuming a variety of food that includes water fowl, snakes, frogs, crustaceans, molluscs' terrestrial animals as well as eels and a range of fish species including their own young (Harris & Rowland 1996). Recent studies have shown that Eastern freshwater cod appear to display high degrees of plasticity in forage selection, seemingly dictated by the seasonal availability of different food types (Butler 2001; G. Butler unpublished data). Eastern freshwater cod are assumed to prefer clear, slow-flowing rivers or creeks, with rocky or gravel substrate and in-stream cover of rocks, timber or tussocks (Rowland 1993, 1996). However, this may reflect the present restricted range of the species, with no known surveys



conducted when it was more widely dispersed. Eastern freshwater cod spawn from late August through until November each year, displaying high levels of parental care both post-spawning and post-hatch (G. Butler unpublished data). Research into the feeding preferences, habitat preferences and movement patterns using radio tagging techniques, as well as a variety of larval and juvenile experiments is currently being undertaken.

Unlike the Murray cod, little is known of the cultural importance of Eastern freshwater cod to the local Aboriginal people of the Northern Rivers of NSW. Early European settlers valued Eastern freshwater cod highly as a table fish. Reports of cod appearing on Coaching Station menus are common, with the proprietor often guaranteeing the freshness of the catch by only obtaining the cod subsequent to the diner placing their order. This apparent abundance of cod also meant that they were used to feed livestock including a number of piggeries located in both the Clarence and Richmond systems.

In the 1900s, Eastern freshwater cod continued to be valued for their eating quality, with their popularity appearing to increase in direct relationship with their increasing rareness. Even following the fishing prohibition implemented in the 1980s, poaching continued, with set lines and gill nets most commonly used. Over the last 10 or so years, there has been an apparent decline in the use of nets and set lines, probably due to the increasing numbers of recreational fishers and an increased awareness about the cod in the community. However, the increase in recreational fishing has resulted in an almost 'underground' catch-and-release fishery for cod. While prohibited, this fishery has extended to local fishing guides offering interstate and overseas clients the opportunity to fish for cod in pristine environments. The beneficial and detrimental aspects of such a fishery are currently unknown.

Murray cod

Murray cod is by far the largest and most widespread cod species. Cod are widely sought by anglers and are now the only species that can be legally kept (except for a limited number of impoundments in Queensland where Mary River cod are stocked for recreational purposes).

This makes them the most significant native angling species in the Murray-Darling Basin. This iconic species has cultural values to both Indigenous and non-indigenous communities. Some aspects of the biology of Murray cod are reasonably well known (see Rowland 2005), and several recent studies have provided new information. Murray cod larvae have been collected in drift samples in flowing waters (Humphries & Lake 2000; Gilligan & Schiller 2003; Koehn & Harrington in press a), and while larval nursery areas have not been identified, young-of-year fish have been collected in the main river and flowing anabranch channels but not in offstream waters such as billabongs (Koehn & Harrington in press a). Spawning occurs regularly in spring (Rowland 2005; Humphries 2005; Koehn & Harrington in press b), with adhesive eggs being laid on hard substrates (Rowland 1983b). Structural Woody Habitat has been shown to be an important preferred habitat for both adults and juveniles (Koehn 1997; Koehn & Nicol 1998). Pre-spawning, upstream movements are undertaken with some adults having been recorded to travel up to 120 km (Koehn & Nicol 1998).

The cultural significance of Murray cod to Aboriginal communities, early explorers and settlers, and past and present inland communities are discussed in Rowland (2005) and Sinclair (2005a).

Being such a large species, Murray cod has often been sought as 'trophy fish' as well as for consumption. Recent newspaper photographs of the capture of large fish have, however, caused considerable public debate over whether or not these fish should be kept or released. This debate highlights a change in public attitude to the species, also exhibited by an overall trend toward catch-and-release by many anglers (Park *et al.* 2005). Murray cod is however, a species that is readily recognised by the public and is identified as a reference for the successful management of Murray-Darling Basin rivers.

Distribution, abundance and history of declines

Two of the four cod species in Australian freshwaters (Mary River cod and Eastern freshwater cod) have relatively small historic and current distributions, as may be expected for taxa with no marine tolerance in coastal catchments (**Table 2**). In contrast, the two Murray-Darling Basin species (Murray cod and Trout cod) had significantly larger historic distributions. It is unclear, however, whether the area of occupancy of Trout cod was unbroken from south of the Murray to the Macquarie drainage, or whether the Macquarie River populations were always isolated. The historic distribution and decline of each of the cod species is presented below.

Trout cod

Because of early confusion regarding the identification of Trout cod as a separate species, some information on the historic distribution of Trout cod is unclear. However, examination of museum records, old angler reports and other historic data sources provides a broad picture of its former distribution and abundance. The species was originally described in 1829 from a specimen collected in the Macquarie River, from where it has not been subsequently recorded other than a single unconfirmed record from the Turon River in the 1970s (Morris *et al.* 2001). J. O. Langtry's fishery investigations of the Murray in 1949-50 (Cadwallader 1977) recorded Trout cod as present in the Murray River between

about Mildura and the junction with the Ovens River above Yarrowonga weir. He recorded the species as relatively abundant between the Barmah Lake (near Echuca) and Yarrowonga weir. The present distribution extends from the Yarrowonga weir downstream to Barmah, a distance of approximately 200 km of river. The species is no longer present in the Murray River upstream of Yarrowonga Weir. Trout cod were formerly present in the Murrumbidgee River, with records from near Deniliquin in the early 1900s as well as museum specimens from near Narrandera, Hay and Wagga Wagga (Berra 1974; Douglas *et al.* 1994). A population persisted in the Canberra region until the late 1970s, but it is now extinct (Berra 1974; Lintermans *et al.* 1988). The species was also formerly found in the Ovens River in Victoria (in abundance – Cadwallader 1977), as well as the Goulburn, Campaspe, Broken, King, Buffalo and Mitta Mitta rivers (Cadwallader & Gooley 1984; Douglas *et al.* 1994). Natural populations of Trout cod no longer occur in any of these rivers (Douglas *et al.* 1994, Koehn *et al.* 1995). The translocated population in Lake Sambell in Victoria no longer exists, and the only wild population apart from that in the Murray is in a short section of Sevens Creek where individuals were translocated from the Goulburn River in the 1920s. In summary, Trout Cod are now restricted to two localized populations, one (natural population) in a 200 km section of the Murray River downstream of Yarrowonga and a second (translocated population) in a 15 km reach of Seven Creeks upstream of Euroa in Victoria.



Table 2. General distribution, period of decline and current distribution of Australian freshwater cod.

Species	Distribution	Historic Abundance	Period of Decline	Approximate Current Distribution (River kms)
Trout cod	Southern Murray-Darling Basin	Abundant in southern range	1950-70s	~ 200 km
Eastern freshwater cod	Clarence and Richmond rivers	Abundant	1920s and 1930s	~300 km
Mary River cod	Brisbane-Stanley, Albert-Logan, Coomera and Mary river basins	Abundant	Prior to 1930s	~300-500 km
Murray cod	Murray-Darling Basin	Abundant (commercial fishery)	1920s and 1930s; then 1950s	Thousands of km

Mary River cod

Freshwater cod were present in a number of south-east Queensland coastal catchments at the time of European settlement, including the Mary, Brisbane-Stanley, Albert-Logan and Coomera basins. It has never been confirmed that the cod in these river systems all belonged to the same species. By the 1970s, cod had apparently disappeared from all but the Mary River. Early accounts of cod in the Mary River can be found in a report on the voyage of H.M.S Challenger (Wyville Thomson 1880), and in a report by the Queensland Commissioner of Fisheries (Saville-Kent 1890). These and later accounts typically referred to the abundance of cod throughout the Mary system, and to the fact that they appeared identical to the Murray cod from western rivers. Anecdotal accounts suggest that anglers had recognized that minor differences existed between cod from the Mary and Murray Rivers long before the scientific community confirmed these differences using electrophoretic protein analysis, morphometric analysis, osteology and otolith structure (Rowland 1985, 1993).

By the time the distinct taxonomic status of the Mary River cod was confirmed, populations in the Mary River basin were largely confined to parts of Obi Obi Creek, Tinana-Coondoo Creek, Six Mile Creek, and Widgee-Glastonbury Creek (Simpson 1994). A targeted riverine restocking program commencing in 1997, in conjunction with habitat rehabilitation works, appears to have subsequently increased the abundance and range of cod in the Mary system, and efforts are now focusing on restoring populations in the Brisbane-Stanley, Albert-Logan and Coomera Rivers (Simpson & Jackson 1996).

Eastern freshwater cod

Historical accounts from the 1800s and early 1900s indicate that large populations of Eastern freshwater cod were once present in the Clarence and Richmond systems of northern New South Wales (Bawden 1888; Rowland 1985, 1993). Reports from early European settlers indicate that eastern cod were plentiful throughout the extremities of both systems, with frequent catches recorded of individual cod in-excess of nine kilograms (Rowland 1993). However, despite the apparent abundance of cod, a dramatic decline in the population occurred in both catchments throughout the late 1800s and early 1900s. In the Richmond system this largely

coincided with the construction of the north-coast railway, with rail crews dynamiting many sections of the river adjacent to the new railway (Rowland 1993). These activities in conjunction with several large fish kills ultimately brought about the almost total extirpation of the species across the entire catchment by the late 1930s. No authenticated reports of Eastern freshwater cod have been recorded from the Richmond River system since this period.

The major decline in the Eastern freshwater cod population within the Clarence catchment also occurred primarily throughout the 1920s and 1930s (Merrick & Schmida 1984; Rowland 1985, 1993; Faragher & Harris 1993). However, the decline of cod in the Clarence system is primarily attributed to a series of mass fish kills that occurred during the late 1920s and 1930s. Generally these kills are considered to have been due to a rapid deterioration in water quality throughout the catchment, seemingly brought about by a series of extenuating natural circumstances. This included an extended period of drought, followed by extensive bushfires and almost immediate heavy rainfall (Rowland 1985, 1993; A. Butler personal communication). The resulting accumulation of allochthonous material within the waterways probably increased biological oxygen demand to such an extent that localised extinctions were reported to have occurred in many of the Clarence systems smaller sub-catchments. The intense rainfall is also thought to have facilitated an increase in the release of contaminated waters from the tailing dams of gold, silver and tin mines once prevalent in the upper waters of the catchment, further degrading water quality (Hall 1977; Wilkinson 1980).

As with the Richmond River, large sections of the lower Clarence catchment were also subject to the use of dynamite for fishing. Again this was associated primarily with the building of the north-coast railway system during the 1920s and 1930s, with rail crews reported to have regularly supplemented their diet with cod (Rowland 1985, 1993; Faragher & Harris 1993). Eastern freshwater cod numbers continued to decline throughout the Clarence catchment over the intervening period, due largely to unsustainable fisheries practices, with the population most likely reaching their lowest abundance in the late 1960s and early 1970s. By this time only one small self-sustaining population remained in the

Mann-Nymboida River, a sub-catchment of the Clarence, where isolated pristine habitats persisted (Merrick & Schmida 1984; Rowland 1985, 1993, 1996; Faragher & Harris 1993; Harris & Rowland 1996). Subsequent conservation actions taken in the mid and late 1980s such as fishing prohibitions and restocking programs have seen the beginnings of recovery, with Eastern freshwater cod now regularly reported throughout both the Richmond and Clarence River systems.

Murray cod

Murray cod was an abundant species, with explorers' journals and early commercial fishery reports noting the size and numbers of cod present (Rowland 1989, 2005). Murray cod formed a major part of the diet of Aboriginal tribes living adjacent to inland waters. The explorer John Oxley wrote in 1820 that the Lachlan River

is rich in the most excellent fish, procurable in the utmost abundance. One man in less than an hour caught eighteen large fish, one of which was a curiosity from its immense size and beauty of its colours.....It weighed an entire 70 pounds..... Most of the other fish taken this evening weighed from fifteen to thirty pounds each (Rowland 1985, 1989)

There are similar enthusiastic historical reports from many of the rivers in the Basin.

There has been a significant decrease in the abundance of Murray cod from historical levels. The commercial fishery for cod (which developed in the mid to late 1800s) peaked in the early 1900s and then declined; although there was another smaller peak in the early 1950s, the catch had decreased significantly by the mid 1960s and remained at low levels through to the 1990s (Rowland 1985, 1989; Reid *et al.* 1997; Ye *et al.* 2000; Kearney & Kildea 2001).

The commercial fishery ceased across the Basin in 2003 with an increasing focus on aquaculture to supply fish for the table. Whereas Murray cod was once readily caught at many locations, it is now patchily distributed, with few locations containing abundant cod. The NSW Rivers Survey in which electrofishing techniques were used to sample 40 randomly selected sites throughout the Basin, failed to catch a single cod in the Murray drainage, indicating that this once widespread species was now patchily distributed (Harris & Gehrke 1997). However, there is some evidence of a recent recovery in Murray cod

populations in NSW, although not to pre-decline levels (see Rowland 2005). There is concern for the conservation status of Murray cod in Victoria, where it is now considered endangered, particularly with the loss of the Mitta Mitta River population following the construction of Lake Dartmouth (Koehn *et al.* 1995) and recent fish kills in the Ovens River, Goulburn River and Broken Creek (Koehn 2005b).

Murray cod as a threatened species.

The recent Commonwealth listing of Murray cod as a threatened species has been somewhat controversial, particularly within some parts of the recreational fishing sector which believe Murray cod to still be abundant. It is important to understand why this opinion persists in parts of the community, because without agreement on the status of the species, support for coordinated and comprehensive recovery actions will be difficult to secure. Possible reasons that Murray cod are not perceived as threatened by some members of the community include:

- Loss of inter-generational memory of past abundances may have downsized expectations
- Lack of knowledge of declines and localised extinctions in other parts of the range
- Increasing gear and angler efficiencies have allowed reasonable, localised catch returns
- The broad distribution of Murray cod lessens the perceived seriousness of localized cod losses
- The true status of Murray cod may have been masked by management activities such as stocking

Loss of inter-generational memory

The commercial fishery for Murray cod was well developed by the late 1800s, with a peak in the overall commercial catch in 1918. Concerns about Murray cod stocks were expressed as early as 1880, and by the mid 1930s the commercial fishery had declined to an unprofitable level for large-scale operators with a second major decline occurring in the 1950s (Rowland 1989). The majority of current anglers probably use the relatively low abundance of the late 1960s, 1970s and early 1980s as their baseline in assessing the



relative abundance of cod. There would be relatively few active anglers that were fishing for cod prior to the 1950s (they would now be at least 60-70 years of age), and very few anglers that could relate to the pre-1930s cod stocks. This use of this benchmark has probably resulted in a lowered expectation of abundance. In the late 1800s, a good days fishing might have landed tens of cod for a fishing group, and there are numerous old photos of such catches. Today, good cod fishing probably involves fewer cod being caught, although angler satisfaction may remain high.

Lack of knowledge of status across the species' range

Knowledge of most anglers is relatively localised, coming from their area of residence or favourite fishing location. There is often little understanding of the overall status of a species across its entire range. Captures are remembered, rather than absence of captures. Localised extinctions and losses over small parts of the range are often missed or forgotten.

Increased gear and angler efficiencies

The reliability of angling equipment has improved immensely in recent decades, with improvements in rods, lines and reels potentially allowing a greater proportion of hook-ups to be successfully landed. Improved knowledge of the general ecology and habitat preferences of native fish species and the use of echosounders have improved angling success. Greater publicity of fishing 'hot-spots', improved angler access and use of GPS technology have also facilitated more accurate targeting of fishing locations. The prevalence of light aluminium boats and reliable outboard motors has also meant that relatively remote river reaches can be easily accessed by the general community. For all of the above reasons, Murray cod have remained a significant and valued component of the recreational fishery, even though there is convincing evidence that their abundance has declined significantly from pre-European levels.

The broad distribution of Murray cod

Murray cod has the broadest distribution of the four freshwater cod species, and is recorded from thousands of kilometres of streams over almost the entire Murray-Darling Basin. Because of this broad distribution, the loss of local populations does not create the same sense of urgency that is

apparent with decline of the more restricted cod species. For example the loss of the Murray cod population in the Molonglo River after heavy metal pollution from the Captains Flat mines (Lintermans 2002) may not have been perceived as a catastrophic loss as there were still ample cod in the nearby Murrumbidgee River. Similarly, the loss of the cod population downstream of Dartmouth dam as a result of coldwater pollution (Koehn *et al.* 1995) did not cause significant community concern as other fishing opportunities remained in nearby waters such as the Murray River and Lake Hume.

Stocking programs

Since the development of hatchery techniques for Murray cod and other native species (Rowland 1983a,b, 1985, 1988; Cadwallader & Gooley 1985) in the late 1970s, there have been numerous stocking programs for this species in the Murray-Darling Basin (Phillips 2003). In 2002/03, a total of 189,950 Murray cod were stocked in Victoria, plus 582,115 in New South Wales, and smaller numbers in the Australian Capital Territory and Queensland. Approximately one million Murray cod are now stocked annually in eastern Australia (**Figure 2**). These stocking programs have provided immense benefits to recreational anglers and have boosted the availability of cod for recreational anglers in some parts of the Basin. Such stocking programs have the potential to mask the true status of cod, and whilst these stocked individuals may live for many years and provide benefit to recreational anglers, their abundance does not accurately represent the true status of wild cod stocks. The success of stocking programs is also a double-edged sword, in that it is seen by some as the panacea to all fisheries problems (Harris 2003). This perception lessens the impetus to sustainably manage fisheries and address other more serious environmental problems that may imperil fish species or communities. However, it must be noted that the majority of Murray cod are stocked in impoundments, rather than rivers, and so the contribution of stocked individuals to the perceived recovery in riverine cod stocks may not be as significant as the total stocking figures suggest (see Rowland 2005). It is known that there is upstream and downstream movement of fish stocked in impoundments (see Phillips 2003), with many stocked fish being washed out of dams into downstream river reaches. The extent of this spread, however, is unknown.

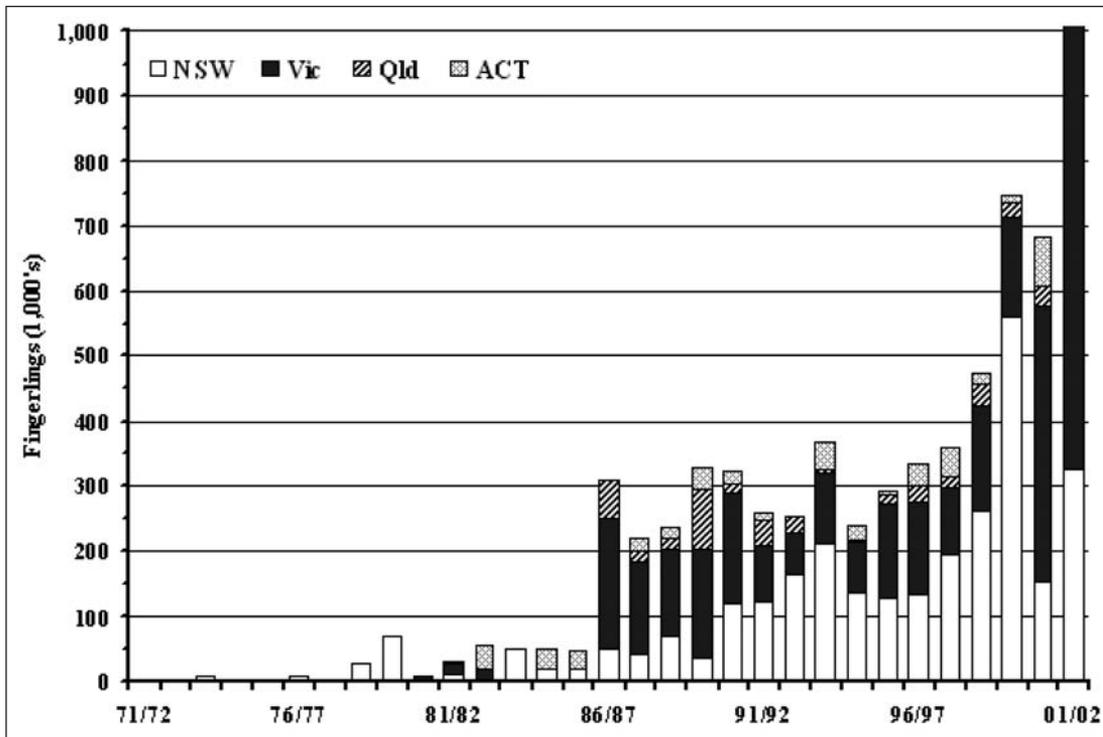


Figure 2. Numbers of hatchery-produced juvenile Murray cod released annually for stock enhancement purposes in Victoria, NSW, Queensland and the ACT since 1971/72 (From Ingram & De Silva 2004.)



Threats to cod

Whilst all four freshwater cod have some particular localised threats, there are a number of threats that have affected multiple species (Table 3). The majority of the threats are the ‘usual suspects’ that have been implicated in the decline of many of the Basin’s fish species (MDBC 2004). However, there are several threats that are particularly pertinent to a large, long-lived species such as cod. These include the risk of hybridisation between species and subspecies, the impacts of overfishing and a range of direct and indirect threats outlined by Koehn (2005a).

Although commercial fishing for all freshwater cod species has now ceased, there is still a high demand from recreational fishers (both legal and illegal) that can pose an ongoing risk to all four cod species. The popularity of Murray cod as a target for recreational fishing is legendary, with this species the most sought-after in the Murray Darling Basin. Even within fisheries regulations, overfishing can threaten populations (Nicol *et al.*, 2005). It is estimated that more than 470,000 Murray cod were caught in the Basin in 2000-01 with 77 % of these released (Henry & Lyle 2003; Park *et al.* 2005).

Table 3. Threats to Australian freshwater cod.

	Trout cod	Eastern freshwater cod	Mary River cod	Murray cod
<i>Habitat loss & degradation</i>			☒	
sedimentation		☒	☒	
desnagging	☒		✓	☒
Water extraction	☒		☒	☒
Loss of riparian vegetation		☒	☒	☒
Thermal pollution	☒		✓	☒
<i>Flow regulation</i>	☒		✓	☒
<i>Barriers to fish movement</i>	☒	✓	✓	☒
<i>Poor water quality (incl fires)</i>	☒	☒	✓	☒
<i>Overfishing</i>	☒	☒	☒	☒
<i>Hybridisation with other cod</i>	✓	☒	✓	
<i>Competition with other cod</i>	☒			
<i>Genetic impacts from stocking</i>	☒	☒	☒	✓
<i>Alien species</i>	☒	☒	✓	☒
<i>Disease</i>	✓	☒		☒

Key: ✓ = minor threat ☒ = major threat

Learning from recovery activities for Eastern freshwater Cod, Mary River cod and Trout cod.

Recovery programs for cod species other than Murray cod have been established since the 1980s, and there are valuable lessons to be learnt from these programs which, at least initially, have heavily relied on stocking as a major recovery activity (Table 4). For the two cod species with the most restricted distributions (Eastern freshwater cod and Mary River cod), there has been significant community involvement in the recovery process. The recovery program for Eastern freshwater cod has benefited from the establishment of Project Big Fish, a community group that has provided a public focus for the recovery actions. Project Big Fish has conducted a variety of community awareness activities for Eastern freshwater cod including:

- displays at shows, field days, shopping centres and environmental expos
- an internet site

- open days at Booma, a commercial hatchery
- restocking workshops
- brochures and newsletters
- presentations to schools, community groups, fishing clubs and local government
- public releases of fingerlings involving local schools, ABC documentary and video units
- media releases and interviews.
- an Eastern Freshwater Cod Museum at Booma hatchery

The involvement of a local commercial fish hatchery in breeding and stocking Eastern freshwater cod (Booma Hatchery) has also facilitated greater community interest and ownership of the recovery effort.

Table 4. Stocking programs for freshwater cod species.

	Declared Threatened/ protected	Stocking Program Commenced	Total Number Stocked (prior to 2004)	Commercial, non-govt hatcheries involved?	Recreational Fishing Allowed?
Trout cod	Pre-1984 (Lake 1971)	1986	(Vic) 417,350 (NSW) 749,020	No	No
Eastern Freshwater cod	1984	1988	210,000	Yes	No
Mary River cod	1994	1983	416,300	Yes	Yes (in 9 stocked dams only)
Murray cod	2003	late 1970s	(Vic) 2.89 mill. (NSW) 2.85 mill. (ACT) 405,160 (Qld) 320,000*	Yes	Yes

* number stocked prior to April 2001

Similarly, the Mary River cod recovery program has had a significant community input with the recovery team including a variety of local community representatives as well as a community-based education officer. To maintain the community link with Mary River cod, the species is stocked into a number of local dams where it can be legally fished, ensuring that the species remains in the public eye.

The higher level of community input into the Mary River cod and Eastern freshwater cod recovery efforts has been largely facilitated by the small geographic distribution of the species, that gives a sense of proximity and immediacy to recovery activities. By contrast, the recovery program for Trout cod has been almost exclusively conducted by state fisheries and conservation agencies, with minimal interest and community input. The national Trout Cod Recovery Team has not been able to secure a community representative, despite recognition within the recovery team of the benefits of such representation. Also, the Trout cod recovery effort has been dispersed over a much larger geographic area, and so has lacked the fine-scale, local focus of the recovery efforts for the two cod species outside the Basin.

Trout cod has been a rare and protected species for many years, and so the opportunities for anglers to legally interact with the species have been greatly reduced. This lack of direct interaction between fish and anglers militates

against the fostering/development of new 'champions' for the species, with only the stories from 'old timers' remaining to identify the sporting values/desirability of the species. In fact, the inability to legally retain the species anywhere in its range can create negative feelings towards Trout cod. At a number of sites where the species has been stocked or re-introduced, anglers consider Trout cod a pest because small individuals compete with and consume valuable baits, but when caught cannot be kept. Such situations demonstrate the need for increased education programs for anglers, who often fail to understand fish population dynamics and how such a locally abundant species can be listed as endangered. Fortunately, there are still substantial recreational fishing opportunities for Murray cod that retain the species in the public eye and provide man V's fish interactions that maintain and enhance its iconic status. If the community is to remain an active and committed partner in recovery activities (as it should), it is vitally important that it retains this capacity to interact with Murray cod. Commercial fishing for Murray cod has ceased and broadscale closures to recreational fishing would not be acceptable to the angling community and are unlikely to be appropriate for Murray cod. However, the benefits of local closures or other population protection measures are worth investigating (see Harris 2005), although community endorsement/participation is essential to their success.



The problems of scale

The conservation and restoration of broadly distributed species such as Murray cod are a challenge to fisheries and conservation agencies. The previous species-based approaches have allowed the disappearance of many local populations, and if unchecked can lead to the 'death by a thousand cuts' syndrome. The loss of local populations can lead to fragmentation of a species range and increase the risks of further population losses. Recent examples of lost or severely depleted populations for Murray cod include fish kills in the Broken Creek, Darling River downstream of Menindee, and the Mitta Mitta River below Dartmouth (see Koehn 2005b; Koehn *et al.* 1995; Sinclair 2005b). The loss or depletion of local cod populations cannot be easily rectified, with substantial stocking programs required and significant time lags apparent before numbers of adult cod recover (Koehn 2005b). The chances of recovering the original genetic diversity in such populations are non-existent to slim, as hatchery brood stock are genetically depauperate compared to wild stocks (Bearlin & Tikel 2003). In recent years, the shift in focus from species-based conservation to biodiversity conservation has facilitated the conservation and improved management of local populations for a number of species, although this approach has not been widely adopted by some fisheries or water management agencies (see Sinclair 2005b). The advantages of trying to conserve fish species with relatively small distributions (Mary River cod, Eastern freshwater cod) that have been alluded to earlier (increased public ownership and involvement) may also be available to widespread species such as Murray cod. However, a different approach is required. Whereas the Mary River cod and Eastern freshwater cod recovery programs have secured public involvement through a species-based focus, widespread species such as Murray cod may require a population focus to secure public interest and engagement. With a population-based approach, local or regional communities will still be able to focus on recovery activities for their local cod population, without becoming 'lost' in a big picture, whole-of-species recovery program. There would still be a requirement for Basin-wide, overarching objectives and activities in a Murray cod recovery plan, with such items

largely the provenance of State fisheries agencies, but community involvement would be enhanced by defining local or regional activities, targets and monitoring approaches.

Conclusions

Common threats operate across the four species of Australian freshwater cod. Recovery activities for three of the species have been in place for many years. The value and importance of local community involvement in recovery activities has been clearly demonstrated for the two coastal drainage species Eastern freshwater cod and Mary River cod. A key to the success of recovery activities for Murray cod may be the translation of this 'local' approach via a population rather than species basis for this widely distributed species of the Murray-Darling Basin.

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