

Maccullochella peelii peelii (Murray Cod, Cod, Goodoo)

Advice to the Minister for the Environment and Heritage from the Threatened Species Scientific Committee (TSSC) on Amendments to the list of Threatened Species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

1. Scientific name, common name (where appropriate), major taxon group

Maccullochella peelii peelii (Murray Cod, Cod, Goodoo) - Following taxonomic revision, the name of this species as listed under the EPBC Act is now *Maccullochella peelii* (Murray Cod) as at 17/08/2011.

2. National Context

The Murray Cod occurs naturally in the waterways of the Murray-Darling Basin (ACT, SA, NSW and Vic) and is known to live in a wide range of warm water habitats that range from clear, rocky streams to slow flowing turbid rivers and billabongs. The upper reaches of the Murray and Murrumbidgee Rivers are considered too cold to contain suitable habitat.

Some translocated populations exist outside the species' natural distribution in impoundments and waterways in NSW and Vic. There have been numerous attempts to translocate populations of Murray Cod by government authorities, acclimatisation societies and private individuals primarily for the purpose of expanding its range. Many translocated populations persisted for several years though few, if any, established self-sustaining populations. Those translocated populations that currently exist in NSW and Vic. are maintained by the release of hatchery bred fish. Populations previously translocated within Qld and WA no longer exist, though some specimens may exist in the aquarium trade (Cadwallader and Gooley 1984, Kearney and Kildea 2001, Llewellyn and MacDonald 1980, Morrissy 1970).

The Murray Cod is not listed under ACT, SA, NSW or Qld threatened species legislation. It is listed as threatened under Victorian threatened species legislation and classified as vulnerable by the Victorian Department of Natural Resources for management purposes. It is also listed in Vic. as a member of the 'Lowland Riverine Fish Community of the Southern Murray-Darling Basin', and in NSW it is identified as a member of the endangered ecological community 'Aquatic Ecological Community in the Natural Drainage System of the Lower Murray River Catchment'.

3. How judged by TSSC in relation to the EPBC Act criteria.

TSSC judges the species to be eligible for listing as vulnerable under the EPBC Act. The justification against the criteria is as follows:

Criterion 1 - Decline in numbers

The size of the Murray Cod population has declined substantially. The decline probably began post European settlement and since the late 1940s has been documented in commercial fishing data.

The Murray Cod is a long lived species that is highly territorial and very aggressive, with a life span estimated to be as high as 75-114 years. The population of mature fish is vulnerable to population decline due to habitat degradation, fishing (commercial, recreational and illegal) and reduced recruitment success.

Broad scale, systematic surveys of Murray Cod populations have not been undertaken. In the absence of good population survey data, commercial fishing data (annual catch weight) has been used to provide an indication of changes in the population size. There are limitations to the value of the commercial fishing data which are discussed below, however, the annual commercial catch weight data recorded for Murray Cod in NSW and SA from 1948 to 2000 is the best available index of the species' national abundance. A decline in the national population size is inferred from the annual commercial catch for both NSW and SA, the two States comprising the larger portion of the Murray Cod's range.

Over an eight year period from 1956-1964, the commercial catch in NSW declined from a maximum of approximately 140 tonnes to approximately 20 tonnes per year. The commercial catch in NSW then remained at approximately 20 tonnes per annum, except for catches of 60 and 40 tonnes in 1974 and 1975 respectively, until total closure of the commercial fishery in 2001 (Reid *et al.* 1997).

In SA there was a very similar decline during an overlapping seven year period. For the financial year 1957/58 the catch peaked at approximately 140 tonnes from which it declined to approximately 20 tonnes in 1964/65. Apart from some fluctuation in the mid and late 1960s, the SA catch averaged less than 10 tonnes per year from the early 1970s through to closure of the fishery from 1990 - 1993. After the SA commercial fishery recommenced in 1994, catches gradually increased to approximately 20 tonnes in 1999 (Ye *et al.* 2000, Kearney and Kildea 2001).

Commercial fishing of native freshwater species in Vic. is restricted to 27 lakes both within and outside the Murray-Darling Basin. Many of these lakes are physically isolated from the natural waterways of the Murray-Darling Basin and the Murray

Cod populations within them are translocated populations. The commercial fishery in Vic does not target Murray Cod, but it may be retained as bycatch. Between 1998 and 2001 a total of 105 Murray Cod were taken as bycatch in the Victorian commercial fishery, all during 2001 (Vic DNRE unpublished data).

There is no commercial fishing for Murray Cod in the ACT or Qld (Kearney and Kildea 2001).

In using the commercial fishing data in the discussion below, it is noted that the data contains inadequacies which most obviously relate to the difficulty of correlating changes in the size composition of the catch, area fished and effort expended with perceived or actual changes in the population structure and size.

The size and age at which the Murray Cod matures varies depending on location and growth rates. As an approximate guide, the species is usually considered mature at five years or 50cm, though figures of between three and six years have been reported from different studies. At maturity, Murray Cod weigh approximately 2-4kg (Morris *et al.* 2000, Kearney and Kildea 2001).

Experts report that Murray Cod grow mostly by increase in weight after 10 years of age. There is considerable variation in the size, weight and age of individual Murray Cod. The largest Murray Cod recorded, in 1902, weighed approximately 113.5kg, was 1.8m in length and had an estimated age of 75-114 years. Murray Cod of 80-90cm have been determined to be between 8 and 22 years of age. A Murray Cod of 125cm, weighing 36kg, was determined to be 34 years of age. (Rowland 1985, 1988, Anderson *et al.* 1992, Gooley 1992, Ye *et al.* 2000, Kearney and Kildea 2001).

There are anecdotal reports indicating that the average size of individual fish has decreased and that the number of fish per tonne has increased significantly. However, the number of fish per tonne has not been formally recorded. Information from reports indicate most fish caught are now less than 10kg. Larger fish of 20 - 40kg are regularly taken but in small numbers (Ye *et al.* 2000). Whilst sustained annual catch weights may be argued to indicate a sustainable fishery, the available commercial catch data do not indicate whether there has been increased effort or advances in technology or techniques that have been employed to compensate for declines in population size. Increased restrictions (regulation) on commercial fishers' access to parts of the species' range have not been correlated with the annual catch weight data, nor has the extent to which there may have been changes in the effort expended by fishers in terms of the area fished or time spent. Changes in fishing gear technology or particular fishing techniques may have resulted in more efficient and effective fishing practices or, conversely, increased regulation may have led to greater effort being expended to maintain past harvest levels.

The Murray-Darling Basin is naturally subject both to periods of drought and flood that can be correlated with El Nino - Southern Oscillation events that occur about every four to seven years (Bureau of Meteorology 2002, Cadwallader 1986, Close 1990, Jacobs 1990). Prior to significant regulation of water flow in the Murray-Darling Basin native fish were vulnerable to periods of extended drought. At such times the rivers contracted to a series of waterholes and it is likely the fish populations declined accordingly. It is therefore likely that native fish populations, including the Murray Cod, naturally experienced increases and decreases in population size (Cadwallader and Lawrence 1990).

The decline in the NSW and SA commercial catch weight from 140 to 20 tonnes per year represents a decline of approximately 85% focused over an eight year period within the last 50 years. The Murray Cod is a long-lived species with estimates of longevity being as high as 75 - 114 years (Rowland 1988). Whilst lifespan does not equate to generation time (average age of brood fish), the decline observed over the past 50 years is likely to be within three generations for the species. The decline in population size (ie. number of mature individuals) within the past 50 years could be as high as 85% based on commercial catch weight data. Given that there are likely to have been significant natural declines in the population size during times of drought and that inadequacies exist in the commercial catch data, an estimated historic decline in the order of 30% would be conservative.

Therefore, the species is **eligible** for listing as **vulnerable** under this criterion.

Criterion 2 - Geographic distribution

The Murray Cod is widely distributed in waterways of the Murray-Darling Basin. There are approximately 13 245km of waterways in the Murray-Darling Basin that may encompass areas of suitable habitat. An estimate of the extent of occurrence based on an average river width of 50m would be approximately 660km². Within this broad area of occurrence, the Murray Cod has specific habitat requirements. The Murray Cod is sedentary and territorial rather than free ranging, and has a distinct preference for woody debris (snags), debris piles and bank side vegetation that provides shelter from high water velocities. The availability of these specific habitats has been reduced since European settlement due to desnagging, habitat degradation in the form of physical fragmentation, cold water discharges from dams and other forms of pollution (Cadwallader 1978, 1986, Cadwallader and Lawrence 1990, Kearney *et al.* 1999, Kearney and Kildea 2001).

Habitat loss due to desnagging

The Murray Cod is highly dependent on instream woody structures for habitat, is highly territorial and very aggressive. (Crook and Robertson 1990).

The Murray Cod migrates upstream prior to spawning in late spring or early summer when the water attains a temperature of between 16-21°C. The adhesive eggs are laid on solid substrates, the larvae drifting down river, prior to the fry settling out in suitable protected habitat.

A study of radio-tracked fish on the Ovens River concluded that Murray Cod prefer submerged woody debris as habitat and that 80% of fish are located within 1m of a snag. In the same study it is estimated that 97% of fish have some form of woody debris within a 12 x 12m surrounding grid (Koehn 1996). Woody debris also provides protected spawning sites and suitable substrate for the deposition of adhesive eggs. Juveniles have been observed to be highly dependent on woody debris with 94% of fish in their first year being observed to be associated with woody debris. Murray Cod are highly territorial and are known to return to the same snag after the spawning migration (Koehn 1996, Koehn *et al.* 2000, Kearney and Kildea 2001).

Suitable habitat for the Murray Cod has been significantly degraded by the largely historic process of desnagging. Desnagging is primarily the removal of fallen trees and branches from the river channel. The magnitude, extent and duration of desnagging activities in the Murray-Darling Basin have been extensive and sustained. Desnagging of the Murray and Murrumbidgee River commenced in 1855. One of the dedicated snag boats removed an average of 300 - 400 snags per month for the 49 years from 1865 - 1914 (total approximately 176 400 - 235 200 snags). From 1911 through to the late 1960s, another snag boat is reported to have removed 3 million snags. Between 1976 and 1987 a total of 24 500 snags were removed from the Murray River between Lake Hume and Yarrawonga. Whilst the initial motivation for desnagging was improved passage of paddle steamer boats, that mode of transport had virtually ceased by the 1930s and desnagging was continued as a facet of 'river improvement' (Lloyd *et al.* 1991, Treadwell *et al.* 1999, Koehn *et al.* 2000).

The large reduction in snaggy habitat means that large stretches of waterways in the Murray-Darling basin do not currently contain suitable habitat. This was in part confirmed by the NSW Rivers Survey of 1996 which, over the two years of the study, failed to record any Murray Cod at the 20 randomly selected sites on the Murray River and only 52 Murray Cod at seven of the 20 randomly selected sites on the Darling River. The researchers concluded that Murray Cod populations are fragmented and patchy and their overall abundance worryingly low (Harris and Gehrke 1997).

In 1973 it was estimated that the density of snags along 330km of the Murray River between Lock 6, SA, and Wentworth, NSW, was three snags per km. Current estimates of snag densities for three sites on the Murray River range from 27 snags per km at Overland Corner, SA, to 140 snags per km at Yarrawonga, NSW (Lloyd *et al.* 1991, Treadwell *et al.* 1999). Although the entry of new snags into rivers is a natural and dynamic process, and in a few areas programs have commenced to reintroduce snags, the impact of historic desnagging activities may not be immediately reversed by cessation and reintroduction programs due to unknown timescales for snag redistribution, stabilisation, breakdown and utilisation (Gippel *et al.* 1996). The total number of snags and thus suitable habitat for Murray Cod within the Murray Darling Basin continues to be very low, very restricted and severely reduced from that available at the time of European settlement.

Habitat degradation due to physical fragmentation

State agencies have identified, within the Murray-Darling Basin, in excess of 3600 physical barriers to the movement of native fish in the form of dams, weirs, levees, causeways, culverts and road crossings (Jacobs 1990, Koehn 2001a and b, Reid *et al.* 1997). Only a small number of these have engineering works or operating procedures designed to mitigate the isolating effect of these barriers for native fish species. The upstream migration of Murray Cod before spawning has been radio tracked for distances up to 240km in the unregulated Ovens River. The same study of migration on the highly regulated Murray River concluded that the fish moved less often and not as far in comparison to those in the unregulated river (Koehn 1996). Historically the Murray Cod has been considered to be a single population with free gene flow throughout the population, however, fragmentation of the Murray-Darling Basin waterways has been severe and in many areas gene flow is now physically impossible. Whilst SA, Vic and NSW have commenced a project to address the issues of fish passage throughout the Murray-Darling Basin, fragmentation of the population remains and the threat this fragmentation poses to the long term survival of the species is yet to be successfully mitigated.

Habitat degradation due to cold water discharges from dams

Within the Murray-Darling Basin, dams are also responsible for significant habitat loss and degradation for large distances downstream due to the discharge of cold water from the lake (Astles, 2001, Blanch 2001, Kearney *et al.* 1999, Phillips 2001, Web and Ryan 2001). This cold water pollution lowers the natural water temperature in the river downstream by as much as 15°C and has its greatest impact within 100-150km downstream of the dam wall. The impact of cold water pollution may, however, extend 200-400km on individual days (Astles 2001). Cold water pollution typically occurs in spring and summer, coincident with the annual late winter - spring upstream migration and spring - early summer spawning. Spawning is temperature dependent and triggered by a rise in the water temperature to 16-21°C (Kearney and Kildea 2001). In the face of cold water pollution, spawning may be aborted or success greatly reduced (Koehn 2001a). Cold water pollution is considered to significantly degrade riverine habitat for the Murray Cod to the extent that many hundreds of kilometres are now largely unsuitable or that the species survives in affected areas at sub-optimal temperature levels.

Impact of fishing on the number of mature individuals

Fishing (commercial, recreational and illegal) is also having an impact on the Murray Cod. This is a particular threat to fish greater than 50cm, the legal minimum catch size where applied, and has been correlated to observations of low frequencies of mature fish.

Historical and anecdotal records dating from the early times of European settlement indicate that Murray Cod were abundant and of large size in the Murray-Darling Basin. The explorer John Oxley recorded in 1817 that one man caught in

the Lachlan River 18 Murray Cod in less than one hour, most weighing from approximately 7-13kg, one fish weighing approximately 32kg (Oxley, in Rowland 1989).

The recreational and commercial harvest of Murray Cod is regulated in all range states. The minimum legal catch length in all range states is 50cm, coincident with the approximate size at which Murray Cod are first reaching maturity. Only SA has a maximum size limit, 100cm. An assessment of the SA commercial Murray Cod fishery indicates it is currently reliant on fish spawned in 1989 and the early 1990s. The assessment indicates the fish of this age class are expected to remain within the allowed catch size range (50-100cm) up till about 2012 (Ye *et al.* 2000). Even though mature fish over 100cm are protected in SA, they are vulnerable to legal fishing for an extended period, approximately 15 years, after attaining maturity. The number of fish that survive that period of commercial and recreational fishing is unknown.

Recreational fishing competition data indicates that the number of fish caught greater than 50cm is declining rapidly. Murray Cod of greater than 80cm are very rarely caught. Data collated from the annual Lake Mulwala Classic fishing competition over the period 1993-2000 shows no Murray Cod caught greater than 92cm in length, approximately one-half of the maximum reported size of 1.8m for the species (Kearney and Kildea 2001, Rowland 1988). Lake Mulwala is a large warm water impoundment that is reported to support growth rates up to twice that for Murray Cod in riverine habitats. The annual Native Fish Challenge competition, also held at Lake Mulwala, only recorded single fish greater than 1m in 1995 and 2000. Graphs of the number and size of fish caught during these competitions indicate a marked decline to zero in the number of fish caught greater than the legal minimum size of 50cm, despite there being relatively consistent catches of fish in size classes below the legal minimum (Kearney and Kildea 2001). Similarly, data obtained over a five year period for a section of the Murray River between Yarrowonga and Cobram, a stretch regarded as having good habitat, showed a very low number of fish in excess of 50cm relative to the number of smaller fish. Experts attributed the low number of mature fish to angling pressure. The annual recreational catch in NSW has been estimated, on the basis of a limited sample, at 144 000, 45 100 of which are kept and 98 900 returned, though whether fish are returned because they are undersized or due to a catch and release ethic is not known (Harris and Gehrke 1997, Kearney and Kildea 2001, Cooperative Research Centre for Freshwater Ecology, unpublished data).

In addition to commercial and recreational fishing, illegal fishing of Murray Cod is reported to be substantial. It is reported that illegal practices can be very effective, often targeting fish during times of spawning migration, and that the illegal catch may exceed the total commercial catch and potentially the total recreational catch. However, there are no quantitative estimates of the extent or impact of the illegal harvest (Kearney and Kildea 2001).

Across its natural range, the number of mature fish is considered to be very low. The frequency of fish greater than 50cm compared to smaller fish is seen to decline rapidly once they grow to a harvestable and mature size. The generally low abundance of mature fish and decline in the frequency of mature fish compared to immature fish is unlikely to be explained other than by fishing (recreational, commercial and illegal).

Impact of regulated flows on recruitment

Natural recruitment success is considered to be limited and much less frequent now than in the period preceding regulation of water flows in the Murray-Darling Basin, the regulation of flow being one of several factors contributing to recruitment failure. The effects of river flow regulation were evident in the lower Murray by the late 1920s and more broadly by 1950 (Brown *et al.* 1998, Close 1990, Rowland 1989, Walker 1983, 1986, 2001, Walker and Thoms 1993). Prior to regulation of water flows in the Murray-Darling Basin, recruitment success is likely to have fluctuated from year to year, being less successful during periods of drought than during periods of high rainfall. Increased flow in late winter is widely recognised as a trigger for pre-spawning migration and spring flooding may be of particular importance for the survival of larvae (6-9mm at hatching). The successful recruitment events observed in conjunction with floods is believed to result from the development of additional food sources that are essential to the survival of large numbers of Murray Cod larvae and fry. Whilst there are some reports of successful recruitment during periods of low water flow, the bulk of research to date shows a strong correlation between large scale recruitment and spring flooding (Humphries *et al.* 1999, Kearney *et al.* 1999, Rowland 1989, Ye *et al.* 2000). Since regulation of the major rivers, spring flooding is very infrequent and the condition of floodplains has been assessed to be very poor throughout the Murray Darling Basin (Norris *et al.* 2001).

As discussed previously, recruitment success is also limited by aborted spawning in the presence of cold water releases from major impoundments when normally high water temperatures trigger spawning. Suitable habitat for the deposition of eggs, primarily woody debris, has also been removed from the river on a large scale. It has been suggested that female Murray Cod have the ability to reabsorb eggs if spawning conditions are not favourable (Pierce, in Ye *et al.* 2000). Larvae inevitably die if caught up in water supplies for irrigation and are likely to be adversely impacted if caught in water supplies for hydro-electricity generation (Koehn and Nicol 1996). The spasmodic and unreliable nature of natural recruitment in this highly regulated environment is illustrated in the current SA commercial fishery that is reliant upon size classes spawned in 1989 and the early 1990s when significant flood events occurred. There have not been significant natural recruitment events in SA since the early 1990s (Ye *et al.* 2000), though strong recruitment of native fish generally was reported for inland NSW following widespread rainfall late in 1998.

The contribution of hatchery bred Murray Cod

In addition to natural recruitment, the release of hatchery bred Murray Cod fry (juvenile fish of approximately 30-50mm) into natural populations has increased significantly in recent years, to the extent that some experts believe the Murray Cod is no longer in immediate threat of extinction. However, some experts have also challenged the conservation value of

the current stocking programs indicating that controls on the genetic management of brood stock and fry may be inadequate and a serious threat to the genetic integrity of the natural population. Existing genetic management plans, intended to ensure that the fish produced by government and private hatcheries are not repeatedly derived from limited genetic stock, would need to be fully implemented to mitigate this problem. In addition, the risk of introduction of hatchery sourced disease to natural populations is a concern to some experts and fishery managers. No hatchery bred Murray Cod are released in SA due to concerns about the possible introduction of disease (Kearney and Kildea 2001, Morris *et al.* 2000).

The survival rate of hatchery bred Murray Cod fry (30-50mm) released into the wild has not been quantified, however, international studies and expert advice indicate that the mortality is likely to be high for a range of reasons. Factors known to affect post-release survival rates of hatchery bred fish include susceptibility to stress and shock during transport and release, predation, intra and interspecies competition for food and habitat, inappropriate habitat selection, and poor survival fitness. Hatchery bred fish may also have poor recruitment success (Banks and LaMotte 2002, Eriksson and Eriksson 1993, Hesthagen and Johnsen 1992, Kelly-Quinn and Bracken 1989, Labelle *et al.* 1997, Näslund 1992, Perkins and Krueger 1995, Pitman and Gutreuter 1993, Unwin 1997). Hatchery practices are also reported to play an important role in cultivating a range of fish behaviours that may be beneficial or detrimental to survival of hatchery bred fish in the wild (Locke 1998). The extent to which hatcheries produce Murray Cod behaviourally adapted for release into the wild has not been assessed. Whilst some Murray Cod are known to survive release into the wild, experts agree that mortality is likely to be very high. One expert suggested that 80% might be a conservative estimate of mortality amongst stocked Murray Cod through to maturity.

Experts agree that assessment of the population size for conservation purposes should not include stocked fish until such time as they are mature. Assuming that Murray Cod require approximately five years to attain maturity, only fish released prior to or including 1996 are currently entering the population as mature individuals. In Vic. a total of approximately 1.288 million fry and 8000 yearling fish were released into natural and translocated populations between 1987 - 1996. In NSW a total of 1.27 million fry were released into natural and translocated populations between 1977 - 1996. In the ACT 264 000 fry were released between 1981 - 1995. Approximately 2.283 million fry have been released since 1997 in NSW, ACT and Vic. (Vic. DNRE unpublished data, NSW Fisheries unpublished data, Lintermans 2000). A significant mortality rate must be taken into account in terms of estimating the number of hatchery bred fish that may have survived to maturity in the wild. Assuming a conservative mortality rate through to maturity of 80%, an estimate of the total number of hatchery fish that to date may have attained maturity after release would be approximately 564 000.

Despite the contribution that stocked fish may make to boosting natural population numbers, the number of mature fish remains low and the relative frequency of mature fish in the population continues to decline.

Conclusion

Whilst programs are underway to rehabilitate degraded habitat and address key habitat threats, these are limited in number, in their earliest stages of implementation and the potential benefits are yet to be realised or demonstrated to result in increases in habitat availability, spawning success, gene flow, or increased population numbers. There are however, no sanctuaries or reserve systems that provide protection for mature Murray Cod. Mature individuals are vulnerable to fishing (recreational, commercial and illegal) throughout their range. The available data on the number of mature fish reflects the combined impacts of various threats and lack of protection.

Therefore, the species is **eligible** for listing as **vulnerable** under this criterion.

Criterion 3 - Population size and decline in numbers or distribution

The limited success of natural recruitment and its spasmodic and unreliable nature have been discussed under criterion 2. The benefit of hatchery bred fish for conservation purposes is debated and the concerns over genetic integrity, disease and high mortality rates have also been discussed under criterion 2. The contribution of hatchery bred fish to the current population of mature fish is considered to be limited in number and of limited conservation value due to concerns about genetic integrity. The number of mature Murray Cod is unknown, however, overall abundance of the species is accepted to be low.

The specific threat to mature Murray Cod posed by fishing (recreational, commercial and illegal) continues to the extent that the number of mature individuals is unlikely to increase and may decline further. Fishing (commercial, recreational and illegal) targets mature individuals (>50cm) and available data (discussed under criterion 2) indicate distinct declines in the overall number of mature Murray Cod and also the number of mature fish relative to immature (<50cm) fish in subpopulations throughout the species' range. These declines are unlikely to be attributable to factors other than the harvest of mature fish.

The loss of mature fish due to fishing is not being adequately compensated for by natural recruitment nor stocking of hatchery bred fish. The stocking of hatchery bred fish of uncertain genetic quality is itself a potential threat to the long term survival of the species as is the associated risk of disease introduction. The riverine habitat is generally degraded throughout the Murray Darling Basin and the specific habitat requirements of Murray Cod within that environment particularly so (Norris *et al.* 2001, Harris and Gehrke 1997). The geographic distribution of Murray Cod is considered precarious for the survival of the species and has been discussed under criterion 2.

Therefore, the species is **eligible** for listing as vulnerable under this criterion.

Criterion 4 - Population size

Whilst the number of mature individuals is limited (see criterion 3), it is not possible to put a quantitative estimate on the population size.

Therefore, the species is **not eligible** for listing under this criterion.

Criterion 5 - Probability of extinction in the wild

There is no quantitative data available against this criterion.

4. Conclusion

A conservative estimate of the magnitude of decline in the Murray Cod population size would be 30% over the past 50 years, inferred from declines in the weight of commercial catches. Whilst the Murray Cod is likely to have experienced natural fluctuation in population before regulation of the Murray Darling Basin waterways and whilst there are some inadequacies in the use of the commercial catch weight data, experts agree those data provide the best available indication of the species' abundance. The magnitude of the decline is generally supported by anecdotal reports of the Murray Cod's great abundance and large size during the early days of European settlement.

The Committee noted that care must be taken in interpreting fishery statistics from a highly variable system. However, on balance, the Committee believes that a sufficient decline has occurred to warrant a vulnerable listing.

Murray Cod have specific habitat requirements within the riverine environment, primarily the presence of large woody debris (snags). Being aggressive and highly territorial fish, the potential number of mature fish per snag is very low. The magnitude and extent of desnagging operations has reduced snag densities to the extent that much of the riverine environment does not contain suitable habitat for Murray Cod. Habitat has been further degraded and lost due to cold water pollution which affects an estimated 3000km of NSW rivers. Cold water pollution is a factor in aborted spawning and recruitment failure. The range of the Murray Cod has been severely fragmented by over 3600 physical barriers to movement in the form of dams, weirs, culverts and road crossings. The physical fragmentation of the rivers has resulted in genetically isolated subpopulations that long term may suffer from reduced genetic diversity and inbreeding depression. The high degree of regulation of river flows caused by the dams, and particularly the reduced frequency of spring flooding, is a major factor in natural spawning and recruitment failure. The geographic distribution of the Murray Cod is restricted and precarious for the survival of the species.

The continuing impact of fishing (commercial, recreational and illegal) on the population of mature fish is evident in the available data. The number of mature fish compared to immature fish declines rapidly to zero above 50cm in length - the legal minimum catch size and approximate size at which fish first attain maturity. There are no reserves to protect mature Murray Cod from fishing and the abundance of mature fish is low. Fish must survive at least 15 years in SA before they attain a size of 100cm at which they are protected by the maximum size limit. Whilst the release of hatchery bred fry has increased significantly, the possible adverse impact on the genetic integrity of the wild population is of concern to experts. Further, allowing for a generous survival rate of hatchery bred fish, the number of mature fish remains low, is unlikely to increase and may decline further due to ongoing fishing activities both legal and illegal.

Whilst programs are underway to rehabilitate degraded habitat and address key habitat threats, these are limited in number, in their earliest stages of implementation and the potential benefits are yet to be realised or demonstrated to result in increases in habitat availability, spawning success, gene flow, or population numbers.

The species is eligible for listing as vulnerable under criteria 1, 2 and 3.

5. Recommendation

TSSC recommends that the list referred to in section 178 of the EPBC Act be amended by **including** in the list in the **vulnerable** category:

Maccullochella peelii peelii (Murray Cod, Cod, Goodoo)

Publications used to assess the nomination

Abbe, T.B. and Montgomery, D.R. (1996). Large woody debris jams, channel hydraulics and habitat formation in large rivers. *Regulated Rivers: Research and Management* 12: 201-221.

Anderson, J.R., Morison, A.K. and Ray, D.J. (1992). Age and growth of Murray Cod, *Maccullochella peelii* (Perciformes: Percichthyidae), in the Lower Murray-Darling Basin, Australia, from thin-section otoliths. *Aust. J. Mar. Freshwater Res.*, 43: 983-1013.

Astles, K. (2001). Overview and knowledge gaps of cold water pollution in New South Wales. In Phillips, B. (ed) *Thermal Pollution of the Murray-Darling Basin Waterways*. Inland Rivers Network and World Wide Fund for Nature Australia, Sydney. pp 30-38

- Banks, J.L. and LaMotte, E.M. (2002). The effects of four density levels on Tule Fall Chinook Salmon during hatchery rearing and after release. *North American Journal of Aquaculture* 64: 24-33.
- Bilby, R.E and Likens, G.E. (1990). The importance of organic debris dams in the structure and function of stream ecosystems. *Ecology* 61(5): 1107-1113
- Blanch, S. (2001a). The way forward on weirs. Inland Rivers Network, Sydney.
- Blanch, S. (2001b) Thermal pollution - what we know of the situation in Queensland, the Australian Capital Territory and South Australia. In Phillips, B. (ed) Thermal Pollution of the Murray-Darling Basin Waterways. Inland Rivers Network and World Wide Fund for Nature Australia, Sydney. pp. 43-44.
- Brooks, A. (1999). Large woody debris and the geomorphology of a perennial river in southeastern Australia. In Rutherford, I and Bartley, R. (eds), Proceedings of the Second Australia Stream Management Conference Proceedings - The Challenge of Rehabilitating Australia's Streams. Volume 1. pp. 129-138 (8-11 February Adelaide, South Australia).
- Brown, A., Nicol, S., and Koehn, J. (1998), Recovery Plan for the Trout Cod *Maccullochella macquariensis*. Department of Natural Resources and Environment, Melbourne.
- Bureau of Meteorology Australia (2002) Southern Oscillation Index. <http://www.bom.gov.au/climate/glossary/soi.shtml>.
- Cadwallader, P.L. (1978). Some causes of the decline in range and abundance of native fish in the Murray-Darling River system. *Proceedings of the Royal Society of Victoria* 90(1):211-224.
- Cadwallader, P.L. (1986) Fish of the Murray-Darling system. In Davies B.R. and Walker, K.F. (eds). The Ecology of River Systems. Dr W. Junk Publishers, Dordrecht, 679-694.
- Cadwallader, P.L. and Gooley, G.J. (1984). Past and present distributions and translocations of Murray Cod *Maccullochella peelii* and Trout Cod *M. macquariensis* (Pisces: Percichthyidae) in Victoria. *Proc. R. Soc. Vict.* 96(1): 33-43
- Cadwallader, P. and Lawrence, B. (1990). Fish. In Mackay, N. and Eastburn, D. (eds) The Murray. Murray Darling Basin Commission, Canberra. pp 316-335.
- Close, A. (1990). The impact of man on the natural flow regime. In Mackay, N. and Eastburn, D. (eds) The Murray. Murray Darling Basin Commission, Canberra. pp 60-74.
- Crook, D.A. and Robertson A.I. (1999). Relationships between riverine fish and woody debris: implications for lowland rivers. *Marine and Freshwater Research* 50: 941-953.
- Davies B.R. and Walker, K.F. (1986). The Ecology of River Systems. Dr W. Junk Publishers, Dordrecht.
- Eriksson. T and Eriksson L.-O. (1993). The status of wild and hatchery propagated Swedish salmon stocks after 40 years of hatchery releases in the Baltic rivers. *Fisheries Research* 18, 147-159.
- Gippel, C. J., O'Neill, I. C. and Finlayson, B. L. 1992. The Hydraulic Basis of Snag Management. (Centre for Environment Applied Hydrology, Department of Civil and Agricultural Engineering and Department of Geography, The University of Melbourne, Melbourne). 116pp.
- Gippel, C. J., Finlayson, B. L. and O'Neill, I. C. 1996a. Distribution and hydraulic significance of large woody debris in a lowland Australian river. *Hydrobiologia* 318: 179-194.
- Gippel, C. J., O'Neill, I., Finlayson, B. L. and Schnatz, I. 1996b. Hydraulic guidelines for the re-introduction and management of large woody debris in lowland rivers. *Regulated Rivers: Research and Management* 12: 223-236.
- Gooley, G.J. (1992). Validation of the use of otoliths to determine the age and growth of Murray Cod, *Maccullochella peelii* (Mitchell) (Percichthyidae), in Lake Charlegrark, Western Victoria. *Aust. J. Mar. Freshwater Res.*, 43, 1091-102.
- Hesthagen, T. and Johnsen, B.O. (1992). Effects of fish density and size on survival, growth and production of hatchery-reared brown trout (*Salmo trutta*) in lakes. *Fisheries Research* 15: 147-156.
- Humphries, P, King A.J. and Koehn J.D. (1999). Fish, flows and flood plains: links between freshwater fishes and their environment in the Murray-Darling River system, Australia. *Environmental Biology of Fishes* 56, 129-151
- Jacobs, T. (1990). Regulation and management of the River Murray. In Mackay, N. and Eastburn, D. (eds) The Murray. Murray Darling Basin Commission, Canberra. pp. 38-58.
- Kearney, R.E., Davis, K.M. and Beggs, K.E. (1999) Issues affecting the sustainability of Australia's freshwater fisheries resources and identification of research strategies. Fisheries Research and Development Corporation, Project No. 97/142 Final Report. 114pp.
- Kearney R.E. and Kildea M.A. (2001), The status of Murray Cod in the Murray-Darling Basin. Environment Australia, Canberra. 66pp.
- Kelly-Quinn, M. and Bracken, J.J. (1989). Survival of stocked hatchery-reared brown trout, *Salmo trutta* L., fry in relation to the carrying capacity of a trout nursery stream. *Aquaculture and Fisheries Management* 20, 211-226.

- Koehn, J.D. and Morrison, A.K. (1990). A review of the conservation status of native freshwater fish in Victoria. *Victorian Naturalist* 107: 12-25.
- Koehn, J. (1994). The cod story. In the Geomorphology and Biology of Streams. Proceedings of the River Basin Management Society Summer Conference held at La Trobe University, Melbourne. 5 December 1994.
- Koehn, J. (1996) Habitats and Movements of freshwater fish in the MDB. In R.J. Banens and Lehane (eds), Proc. 1995 Riverine Environment Research Forum, pp27-32.
- Koehn, J. (2001a) Impacts of weirs on fish. In Blanch, S (ed) The way forward on Weirs. Inland Rivers Network, Sydney.
- Koehn, J. (2001b). Ecological impacts of cold water releases on fish and ecosystem processes. In Phillips, B. (ed) Thermal Pollution of the Murray-Darling Basin Waterways. Inland Rivers Network and World Wide Fund for Nature Australia, Sydney. pp 7-11.
- Koehn, J.D. and Nicol, S. (1998). Habitat and movement requirements of fish. In Banens, R.J. and Lehane, R. (eds) Proc. 1996 Riverine Environment Forum. pp 1-6. October 1996, Brisbane, Australia (Murray-Darling Basin Commission, Canberra).
- Koehn, J., Nicol, S. and Fairbrother, P. (2000). Pattern and distribution of large woody debris in the Murray River (Yarrowonga - Tocumwal). Final Report to the Murray-Darling Basin Commission on the snags pilot project. Department of Natural Resources and Environment, Heidelberg.41pp.
- Labelle, M., Walters, C.J. and Riddell, B. (1997). Ocean survival and exploitation of coho salmon (*Oncorhynchus kisutch*) stocks from the east coast of Vancouver Island, British Columbia.
- Lintermans, M. (2000) The status of fish in the Australian Capital Territory: A review of current knowledge and management requirements. Technical Report No. 15. Environment ACT, Canberra.
- Llewellyn, L.C. and MacDonald, M.C. (1980) Family Percichthyidae: Australia Freshwater Basses and Cods. In McDowall, R.M. (ed), Freshwater Fishes of South-eastern Australia, 142-149.
- Lloyd, L.N., Walker, K.F. and Hillman T.J. (1991). Environmental significance of snags in the Murray River. Department of Primary Industries and Energy, Land and Water Resources Research and Development Corporation, Australian Water Research Advisory Council completion report, Project 85/45, Canberra.
- Locke, A. (1998). Modelling the effects of poststocking survival rates on the success of stocking hatchery Atlantic Salmon in a New Brunswick river. *North American Journal of Fisheries Management* 18: 547-560.
- Mackay, N. (1990). Understanding the Murray. In Mackay, N. and Eastburn, D. (eds) The Murray. Murray Darling Basin Commission, Canberra. pp viii-xix.
- Mackay, N. and Eastburn, D. (1990) The Murray. Murray Darling Basin Commission, Canberra.
- Milne, C. (1993). Sex and the single fish. *Wildlife Australia* Spring 1993, 5-7.
- Morris, S.A., Pollard, D.A., Gehrke, P.C. and Pogonoski, J.J. (2000), 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. Project No. AA 0959.98.
- Morrissy, N.M. (1970) Murray Cod, *Maccullochella macquariensis*, in Western Australia. *The Western Australian Naturalist*, Vol 11 (6) 130-135.
- Näslund, I. (1992). Survival and distribution of pond- and hatchery-reared 0+ brown trout, *Salmo trutta* L., released in a Swedish stream. *Aquaculture and Fisheries Management* 23: 477-488.
- Norris, R.H., Liston, P., Davies, N., Coysh., Dyer, F., Linke, S., Prosser, I. and Young, B. (2001). Snapshot of the Murray-Darling Basin River Condition. Report to the Murray Darling Basin Commission, Canberra. 50pp.
- Perkins, D.L. and Krueger, C.C. (1995). Dynamics of reproduction by hatchery-origin Lake Trout (*Salvelinus namaycush*) at Stony Island Reef, Lake Ontario. *J. Great Lakes Res.* 21 (supplement 1): 400-417.
- Phillips, B. (2001). Thermal Pollution of the Murray-Darling Basin Waterways. Inland Rivers Network and World Wide Fund for Nature Australia, Sydney.
- Pitman, V.M. and Gutreuter, S. (1993). Initial poststocking survival of hatchery-reared fishes. *North American Journal of Fisheries Management* 13:151-159.
- Quinn, R.H. (1986). Research and farming of Barramundi in Queensland. *Australian Aquaculture* 7(2), 16-17.
- Reid, D.D., Harris, J.H. and Chapman, D.J. (1997) NSW inland commercial fishery data analysis. FRDC Project No. 94/027.
- Reynolds, L.F. (1983). Migration patterns of five fish species in the Murray-Darling River system. *Aust. J. Mar. Freshw. Res.*, 34: 857-71.
- Rowland, S. J. (1985). Aspects of the Biology and Artificial Breeding of the Murray Cod, *Maccullochella peelii*, and the Eastern Freshwater Cod, *M. ikei* sp. nov. (Pisces: Percichthyidae). PhD Thesis, School of Biological Sciences, Macquarie

University, North Ryde.

Rowland S. (1988). Murray Cod. Agfact F3.2.4, New South Wales Agriculture and Fisheries, Sydney.

Rowland S.J., (1989). Aspects of the history and fishery of the Murray Cod, *Maccullochella peelii* (Mitchell) (Percichthyidae). Proc. Linn. Soc. N.S.W. 111(3), 201-213.

Treadwell, S. (ed.) (1999). Managing snags and large woody debris. In Lovett, S. and Price, P. (eds) Riparian land management guidelines, Volume two: On-ground management tools and techniques. Land and Water Resources and Research Development Corporation: Canberra. pp 12-22.

Treadwell, S. Koehn, J. and Bunn, S. (1999). Large woody debris and other aquatic habitat. In Price, P. and Lovett, S. (eds) Riparian land management guidelines, Volume 1: Principles of sound management. Land and Water Resources and Research Development Corporation: Canberra. pp 79-96.

Unwin, M.J. (1997). Fry-to-adult survival of natural and hatchery-produced Chinook salmon (*Oncorhynchus tshawytscha*) from a common origin. *Can. J. Fish. Aquat. Sci.* 54: 1246-1254.

Walker K.F. (1980). The downstream influence of Lake Hume on the River Murray. In Williams W.D. (ed) An ecological basis for water resource management, Australian National University Press, Canberra, 182-191.

Walker K.F. (1983). Impact of Murray-Darling Basin development on fish and fisheries. In Petr, T. (ed) FAO Fisheries Report No. 288, Summary Report and Selected Papers presented at the Indo-Pacific Fisheries Commission on Inland Fisheries for Planners, Manila, The Philippines, 2-6 August 1982, pp 139-149.

Walker K.F. (1985). A review of the ecological effects of river regulation in Australia. *Hydrobiologia* 125, 111-129.

Walker K.F. (1986). The Murray-Darling River system. In Davies B.R. and Walker, K.F. (eds). The Ecology of River Systems. Dr W. Junk Publishers, Dordrecht, pp. 631-659.

Walker K.F. (2001). A river transformed: the effects of weirs on the River Murray. In Blanch, S. (ed) The way forward on weirs. Inland Rivers Network, Sydney. pp 7-22.

Walker K.F. and Thoms, M.C. (1993), Environmental effects of flow regulation on the lower River Murray, Australia. *Regulated Rivers: Research and Management* vol 8, 103-119.

Webb, A. and Ryan, T. (2001). Scoping study: potential for cold water releases in Victoria. In Phillips, B. (ed) Thermal Pollution of the Murray-Darling Basin Waterways. Inland Rivers Network and World Wide Fund for Nature Australia, Sydney. pp38-42.

Ye, Q., Jones, G.K., and Pierce, B.E. (2000). Murray Cod (*Maccullochella peelii peelii*) Fishery Assessment Report to PIRSA for the Inland Waters Fishery Management Committee. South Australian Fisheries Assessment Series 2000/17.