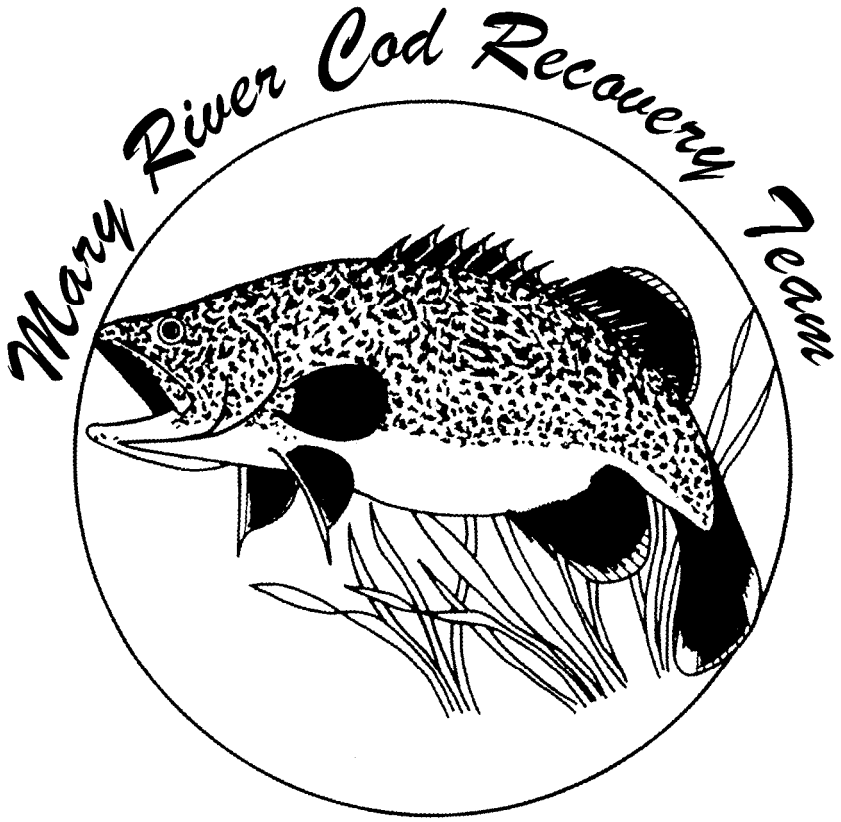
THE MARY RIVER COD
RESEARCH AND RECOVERY PLAN



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The Mary River Cod Research and Recovery Plan

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SUMMARY

Current Species Status
Endangered (Jackson 1993; Wager & Jackson 1993).
The Mary River cod (*Maccullochella peelii mariensis*) is one of Australia's most endangered fish. Natural populations of the species are now restricted to suitable areas of habitat in the Mary River system. Freshwater cod (possibly *M. p. mariensis*) were also present in the Brisbane-Stanley, Albert-Logan and Coomera Rivers at the time of European settlement. Cod are now considered very rare or extinct in these systems. It is estimated that Mary River cod now occur in less than 30% of their former known range in the Mary River system. Remnant populations may have become isolated from each other due to habitat fragmentation and the impoundment of streams.

Habitats and Limiting Factors
The Mary River cod prefers shaded pool habitats with abundant instream cover (ie. logs, log jams, rock ledges, boulders, undercut banks). The species occurs from high gradient upland streams to slow flowing lower catchment reaches. Submerged logs are thought to be used as nest sites. Individual cod may move long distances during periods of high water flow. Movements tend to be upstream in summer and downstream in autumn. Between periods of movement, cod occupy a restricted home range which they maintain for up to several years. Homing to a former home range following extensive movements has been recorded.

Activities which reduce suitable habitat and limit fish movements are a threat to the Mary River cod. Extensive land clearing in many parts of the Mary catchment has exacerbated erosion and subsequent in-filling of pools. The removal of native riparian vegetation has also led to reduced shading of watercourses, and reduced timber deadfall to provide instream cover. The net effect of these factors has been to reduce and fragment cod habitats. Other factors thought to have contributed to the decline and which limit the natural recovery of cod populations include overfishing and the impoundment and regulation of streams.

Recovery Plan Objectives
To secure and enhance populations of Mary River cod in the Mary River system, and to restore populations of cod in their historic range in south-eastern Queensland.

Recovery Criteria
Self-sustaining populations established outside the present range by 2010.
Conservation status of cod downlisted from 'endangered' to 'vulnerable' by 2010.
Distribution of cod in the Mary River system increased to encompass at least 60% of their former known range by 2010.

Actions Needed
The Mary River Cod Recovery Team was established in 1994 and produced a draft Recovery Plan in 1996. Many of the recommendations of the draft Recovery Plan have already been implemented, and significant progress has been made towards meeting many of the short term objectives. The full list of actions from the draft Recovery Plan is presented here, and progress already achieved is noted. Ongoing management to maintain populations of the Mary River cod will still be required after Recovery Plan objectives are met.

Recommended recovery actions (and *progress already achieved*) are as follows:

1. Establish a program of community involvement and education.
- 1.1. Seek public participation in developing a Recovery Plan by holding a public forums. (*completed*)
- 1.2. Appoint a part-time officer to develop and coordinate community involvement and education.(*officer appointed*)

2. Review and develop regulations and administrative procedures to ensure protection of the Mary River cod and it's habitats.
- 2.1. Develop a management plan for the cod under the appropriate legislation. (*cod protected under Fisheries Act*)
- 2.2. Develop a translocation strategy to minimise impacts of non-endemic fish introductions. (*DPI Translocation Policy*)
- 2.3. Ensure maintenance of fish passage past weirs/dams etc. in south-eastern Queensland streams. (*ongoing negotiations*)
- 2.4. Develop and implement environmental flow guidelines. (*ongoing negotiations*)
- 2.5. Seek co-operation of Resource Managers in protecting the cod and it's habitats. (*ongoing negotiations*)
- 2.6. Coordinate recovery actions/research on the cod with existing studies being carried out by other groups. (*ongoing*)

3. Develop a plan to improve hatchery production of the Mary River cod, and restock throughout the former range.
- 3.1. Develop and implement a management plan for hatchery production of cod. (*Five-Year Strategy implemented*)
- 3.2. Develop and implement restocking criteria for cod. (*Implemented*)
- 3.3. Develop and implement restocking/monitoring program for cod. (*Implemented*)
- 3.4. Develop and implement program to establish breeding populations of cod in impoundments.

4. Undertake research on key aspects of Mary River cod ecology and captive-breeding techniques.
- 4.1. Investigate movements and habitat requirements of the cod via a radio-tracking study. (*Underway*)
- 4.2. Undertake research to improve captive-breeding success, and investigate artificial enhancement of breeding in impoundments. (*Underway*)

5. Restore degraded Mary River cod habitats.
- 5.1. Develop a strategic plan for restoration of cod habitats. (*Officer appointed and plan completed*)

5.2. Implement pilot habitat rehabilitation programs in key areas of the Mary River.(*Pilot programs underway*)
5.3. Implement large-scale rehabilitation program for riparian habitats in south-eastern Queensland streams.
5.4. Implement rehabilitation program for instream habitats as per Action 5.1.

6. Develop and implement long-term monitoring program for the Mary River cod.
6.1. Develop monitoring program in consultation with experts
6.2. Implement monitoring program in Mary River and other restocking sites.

Estimated Cost of Recovery ($000's)*

	Action	Action 2	Action 3	Action 4	Action 5	Action 6	Total
Yr 1	37.1	14.2	45.0	134.4	98.2	2.2	331.1
Yr 2	25.0	54.5	44.5	103.8	121.0	54.8	403.6
Yr 3	25.0	33.7	91.6	112.7	166.0	54.8	483.8
Yr 4	25.0	18.6	89.4	62.7	166.0	54.8	416.5
Yr 5	25.0	24.4	82.4	6.2	166.0	54.8	358.8
Total	137.1	145.4	352.9	419.8	717.2	221.4	1993.8

*It is anticipated that many of the recovery actions will take significantly longer to undertake than the five year term indicated in the above table. Implementation of the Recovery Plan commenced in 1996, and it is planned to fully review actions and costing after five years (ie. 2001)

Biodiversity Benefits
Mary River cod occupy a high trophic level in the Mary River system. It is therefore likely that they exert a controlling influence over the population size of prey species (particularly decapod crustaceans and other fish species). Restoration of stream habitats to increase their suitability for cod habitation will lead to increased habitat diversity which will benefit other native aquatic and riverine species, including the little known Mary River turtle.

1. INTRODUCTION

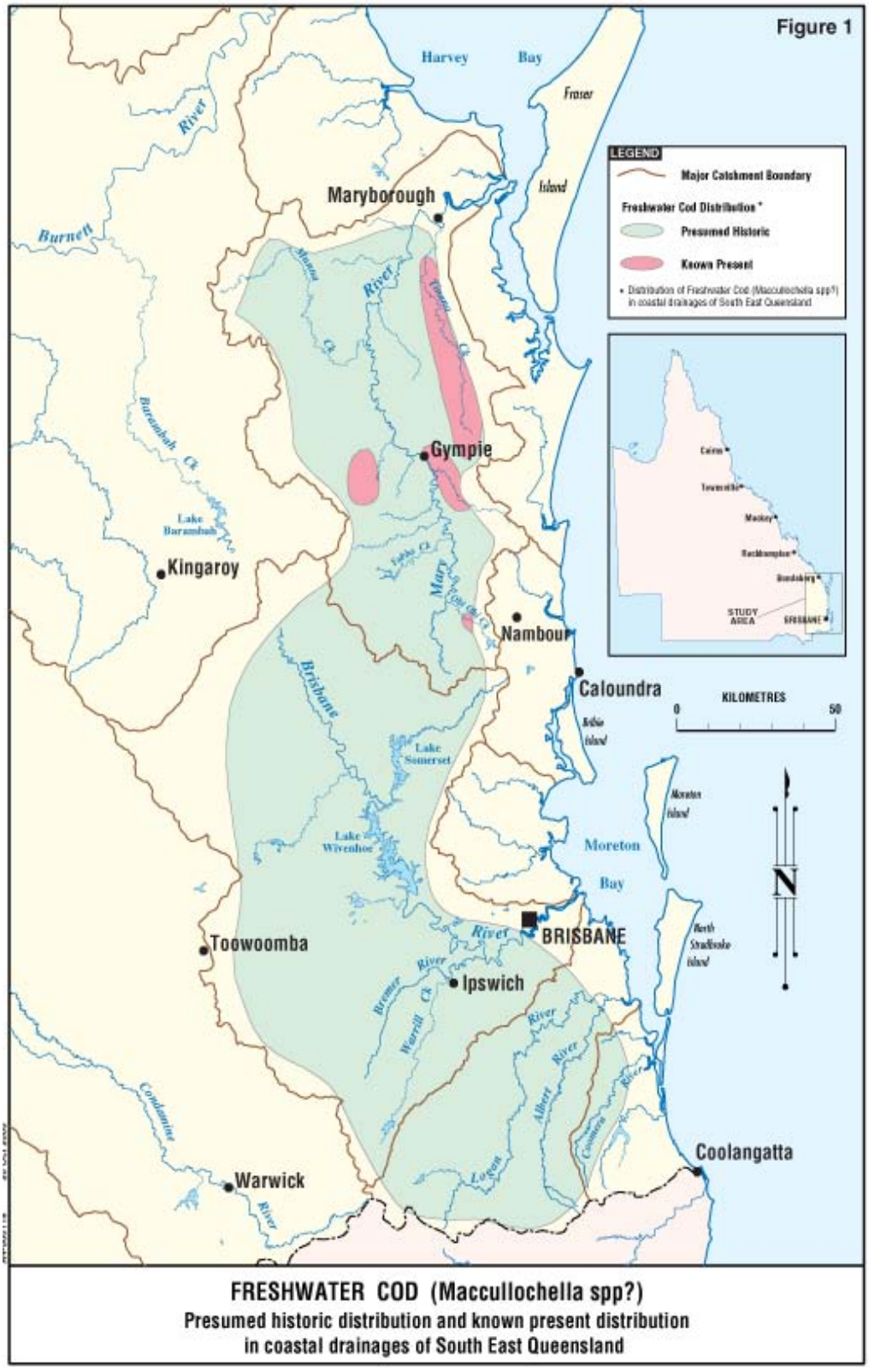
The Mary River cod, *Maccullochella peelii mariensis* (Rowland) (Percichthyidae) is an endangered freshwater fish that occurs only in the Mary River system in southeast Queensland. Despite high public interest in the species throughout the 1900s for its eating and sporting qualities, the cod has only recently been recognised as unique to the Mary River system. Prior to the 1980s, the strong morphological similarities between the Mary River cod, the eastern freshwater cod *Maccullochella ikei* (Rowland), and the Murray cod *Maccullochella peelii peelii* (Mitchell) led to the presumption that they were a single species. The taxonomic distinctiveness of the Mary River cod was formally described in 1993 (Rowland 1993).

Freshwater cod also occurred in other coastal rivers in south-east Queensland at the time of European settlement, but their specific taxonomy is not known (Rowland 1985; Wager and Jackson 1993). They have become very rare, and possibly extinct, in the Brisbane-Stanley, Albert-Logan, and Coomera River systems (Figure 1) (Wager and Jackson 1993). Within the Mary River system, the range and abundance of the Mary River cod has also declined and populations are now largely restricted to a few tributaries where relatively undegraded stream habitats remain (Rowland 1985; Simpson 1994). The Mary River cod is listed as endangered by the Australian Society for Fish Biology (Jackson 1993) and in *The Action Plan for Australian Freshwater Fishes* (Wager and Jackson 1993). Habitat changes and overfishing are considered responsible for the decline of the Mary River cod (Simpson 1994).

Recognition of the precarious status of the Mary River cod led to formation of the Mary River Cod Recovery Team in 1994. The Recovery Team produced the first draft of this Recovery Plan in 1996 and has been working towards its implementation since that time. Significant progress has already been made as outlined in later sections, but much remains to be done to ensure the long-term survival of the cod. The main factor that will determine the ultimate success or otherwise of the cod recovery program is the level of support and involvement received from local communities. Much of the control over how land and water resources are managed, and to what extent overfishing is allowed to continue, lies with the people of the Mary valley. There is a strong desire among local residents to see cod populations restored, as the species is widely recognised as an important part of the culture and history of the region. The challenge, then, is to ensure that the community feels they ‘own’ the recovery process, and become involved in specific actions, or adopt specific procedures that clearly benefit the cod.

This Recovery Plan has been developed with considerable input from the community. Information on past and present distributions, habits, and spawning biology of the cod has been provided by a variety of people with an interest and knowledge of the species. Public input into the recommended recovery actions was received via a public forum held in Gympie, and in written and verbal responses to a draft of the plan sent to local groups and individuals. The major components of the Recovery Plan are: 1) a review of available information on the species; 2) a statement of the objectives of the Recovery Plan, and the criteria by which recovery of the species will be measured; 3) a list of the actions required to assist recovery of the species; and 4) a schedule detailing the implementation and costing of recovery actions.

Figure 1. Presumed historic distribution and known present distribution of freshwater cod (*Maccullochella*) in coastal drainages of southeast Queensland.



2. REVIEW OF AVAILABLE INFORMATION

2.1. GENERAL BIOLOGY AND ECOLOGY OF THE MARY RIVER COD

2.1.1. Taxonomy and systematics

Diagnosis: Dorsal fin XI, 15; Anal fin III, 13 (III, 12-13); Pectoral fin 18 (19-20); Pelvic fin I, 5; Caudal fin 18 (16-18); Precaudal vertebrae 15; Caudal vertebrae 19 (19-20); Predorsal bones 2 (2-3). Distinguished from the nominal subspecies (*M. p. peelii*) by the combination of longer pelvic fins, deeper and shorter caudal peduncle, shorter extension of first anal pterygiophore towards vertebral column, larger sagittal otoliths and distinctive colouration, and from *M. ikei* by the combination of deeper caudal peduncle, greater postorbital head length, smaller orbit, larger interorbital width, fewer scale rows below lateral line, shorter fifth-sixth dorsal spine and shorter extension of the first anal pterygiophore (Rowland 1993).

The Mary River cod belongs to the Australian endemic freshwater fish genus *Maccullochella*, which is thought to have evolved from marine percichthyid ancestors and later invaded Australian freshwaters (MacDonald 1978). There are three species of *Maccullochella*, one of which comprises two subspecies: viz. *M. peelii peelii* (Murray cod), *M. peelii mariensis* (Mary River cod), *M. macquariensis* (trout cod), and, *M. ikei* (eastern freshwater cod) (Rowland 1993) (Table 1).

It is hypothesised that the Mary River cod is derived from ancestral stock that occurred in western drainage streams (ie. west of the Great Dividing Range) (Rowland 1993). Isolation of the cod into eastern streams could be explained by 'stream capture', where the headwaters of western drainage streams were successively ‘captured’ by eastern coastal streams during westward migration of the dividing range (Herbert 1980). Small founder populations of cod may have become isolated from the parent stock during this process, and subsequently evolved into the eastern drainage forms. It is estimated that eastern cod (ie. Mary River cod and eastern freshwater cod) diverged from the ancestral form between 1.7 and 0.8 million years ago.

The close similarities between the Mary River cod, eastern freshwater cod, and Murray cod previously led to the assumption that they were a single species. For example, reviews of the genus *Maccullochella* by Berra and Weatherly (1972) and of Australian percichthyids by MacDonald (1978) stated that the range of the widely distributed Murray cod included the Mary River in south-east Queensland and the Clarence River in north-east New South Wales. Rowland (1985, 1993) compared cod from the Murray-Darling, Clarence and Mary systems using electrophoretic protein analysis, morphometric analysis, osteology, otolith structure, and cross-breeding experiments. Although there were several features, which appeared to distinguish the two eastern drainage forms from the Murray cod (ie. phenotypes of muscle general protein and length of pelvic fins), overall, the results indicated a close relationship between the Mary River cod and the Murray cod. These results led to the description of the Mary River cod as a subspecies of the Murray cod, viz. *M. peelii mariensis*, and the eastern freshwater cod as a distinct species, *M. ikei* (Rowland 1993).

The Mary River cod is an elongate, percoid fish with concave head profile and protruding lower jaw. Back colouration varies from golden-yellow to green to dark brown, overlaid with a black to dark green mottling which sometimes extends onto the grey or whitish ventral

Table 1: Comparison of the four currently recognised taxa within the genus *Maccullochella*.

NAME	DISTRIBUTION	MAIN EXTERNAL DISTINGUISHING FEATURES	MAXIMUM KNOWN WEIGHT	A.S.F.B. CONSERVATION STATUS [8]	CONSERVATION ACTIONS UNDERTAKEN
Mary River cod *M. peelii mariensis*	Mary River (s.e. Qld); possible former distribution in Brisbane-Stanley, Albert-Logan and Coomera Rivers [4,5,6,7] (b)	Concave head profile Protruding lower jaw Relatively long pelvic fins Relatively deep, short caudal peduncle Coloration distinct from Murray cod and trout cod [6]	23.5 kg [4] (d)	endangered	Possession limit (in Mary River system): 0. Possession limit (upstream of the walls of Maroon, Moogerah, Hinze, Bill Gunn, Lake Clarendon, Wivenhoe, North Pine, Cressbrook and Somerset Dams): 1 (minimum size limit of 50 cm applies in these waters) Fingerlings stocked into impoundments throughout s.e. Qld since 1983 (Table 4), and in the Mary River and tributaries since 1998. Recovery Team formed and Recovery Plan produced
Murray cod *M. peelii peelii*	Throughout most of the Murray-Darling River system, becoming scarcer towards headwaters [1,2,3,4] (a)	Concave head profile Jaws equal, or lower jaw protruding Coloration distinct from all other taxa [6]	113.5 kg [3]	Not listed, but see Rowland (1989) for discussion of decline in distribution and numbers	Minimum size limit: 50 mm. Possession limit: 5 Closed season on the taking of any *Maccullochella* spp. in NSW and Victoria from 1 September to 30 November. Fingerlings restocked into numerous waters in s.e. Australia.
Eastern Freshwater cod *M. ikei*	Clarence and Richmond River systems (n.e. NSW) [4,5,6]	Concave head profile Protruding lower jaw Relatively long pelvic fins Coloration distinct from Murray cod and trout cod [6]	41 kg [6]	endangered	Five-year moratorium on the taking of any *Maccullochella* spp. from waters north of the Macleay River to the Queensland border. Fingerlings restocked into Clarence and Richmond Rivers to re-establish populations. Critical cod habitats entered on Register of the National Estate.
Trout cod *M. macquariensis*	Murray River below Yarrawonga Weir; upper Seven Creeks (Vic) [2,3,4,9] (c)	Straight head profile Protruding upper jaw Coloration distinct from all other taxa [6]	16 kg [1] (e)	endangered	Total prohibition on the taking of any trout cod from NSW, Victorian and ACT waters. Critical trout cod habitat in the Murray River closed to all angling from 1 September to 30 November each year. Critical trout cod habitat in Seven Creeks (Vic) closed to all angling. Recovery Team formed and Recovery Plan produced Fingerlings restocked in streams and impoundments.

(a) Murray cod have also been stocked in numerous waters outside their natural range.

(b) Mary River cod have been stocked in impoundments throughout southeast Queensland (see Table 4).

(c) Although Seven Creeks is within the presumed historic range of the trout cod, this population was established in the 1920's by translocation from the Goulburn River [7]. Trout cod have also been stocked in several waters outside their natural range [7]

(d) Unconfirmed reports indicate Mary River cod may grow to at least 37 kg (see Table2).

(e) Unconfirmed reports indicate trout cod may grow to at least twice this weight (Cadwallader and Backhouse 1983).

Sources of information: 1. Lake 1971; 2. Berra and Weatherley 1972; 3. Llewellyn and McDonald 1980; 4. Merrick and Schmida 1984; 5. Rowland 1985; 6. Rowland 1993; 7. Wager and Jackson 1993; 8. Jackson 1993; 9. Douglas *et al.* 1994.

surface. Dorsal, pectoral, caudal and anal fins are clearish to dark, with dark mottling on their bases. The soft dorsal, anal and caudal fins have thin, whitish margins, and the whitish pelvic fin has white filaments.

Merrick and Schmida (1984) reported that two distinct forms of cod are recognised by anglers in the Mary system - "sharp-nose" and "boof-headed". Boof-headed forms tend to be spotted rather than mottled. This difference in morphology and coloration was reportedly not related to size or sex. Rowland (1993) did not identify these two forms, and experience with cod broodstock at Lake Macdonald Hatchery indicates that the spotted markings, and possibly also the blunter head profile, are features that develop with age (personal communication, Gerry Cook).

Mary River cod do not grow as large as Murray cod. Merrick and Schmida (1984) list the largest known Mary River cod at 23.5 kg, although reports from local residents suggest that specimens up to 38 kg have been caught (Table 2). Cod up to 36 kg have also been reported from the Brisbane River (McKay and Johnson 1990). Murray cod have been recorded up to 113.5 kg (Llewellyn and MacDonald 1980).

2.1.2. Historical distribution

The historical distribution of freshwater cod in southeast Queensland included the Mary, Brisbane-Stanley, Albert-Logan, and Coomera River systems (Wager and Jackson 1993) (Figure 1). Cod are now very rare or extinct in all but the Mary system.

In the Mary system, cod were common throughout the main river and most tributaries in the early 1990s, and until much later in some areas (Simpson 1994; Willett [DPI Fisheries], unpublished data) (Table 2). The Queensland museum has few records of Mary River cod (Table 3), and there is very little other published information on the distribution and status of fish populations within the Mary system.

One of the earliest accounts of cod in the Mary River system can be found in the *'Report on the Scientific Results of the Voyage of the H.M.S. Challenger*' during the years 1873-76 (Wyville Thomson 1880). One of the fish captured in the Mary River near Tiaro was recorded as *Oligurus macqariensis* (the name then assigned to all species of *Maccullochella*), however no further details of numbers or sizes were reported. Macleay (1883) collected *Oligurus macquariensis* from the Mary River near Maryborough, and stated that

> "*...I cannot detect any difference between this fish and the well known 'Cod' of our western rivers...*" (p.200).

In 1890, W. Saville-Kent, then Commissioner of Fisheries in Queensland, reported that

> "*...The fish most highly valued for sport and for consumption is ... a form apparently allied to, if not precisely identical with, the celebrated Murray cod,* Oligorus macquariensis*; this species is most abundant in Tinana Creek and other tributaries of the Mary River and is not infrequently caught weighing as much as 30 or 40lb....*" (p.2).

Ogilby's (1893) discussion of the Murray cod, reported that

> "*...the same species is also found in the Mary River, Queensland...*"(p.19).

De Vis (1901) pointed out that the cod populations in the Mary and Brisbane River systems were separated from the Murray-Darling population by mountain ranges, but offered no discussion on the possible implications of this observation. Most references since 1900 simply repeat the false premise that Murray cod also occur in the Mary River (eg. Ogilby 1916; McCulloch and Whitley 1925; Whitley 1937; Roughley 1951; Grant 1965).

Table 2: Summary of anecdotal information relating to the past and present distribution of Mary River cod in the Mary River system. Information was obtained from riparian landowners (L), other residents of the Mary valley (R), recreational anglers (A), forestry workers (F), and fish hatchery operators (H).

LOCATION	SUMMARY OF ANECDOTAL INFORMATION	SOURCE
Mary River - Conondale	-cod once caught in Mary River and small tributaries, up and downstream from Conondale	L
	-decline attributed to loss of pool habitats (siltation)	
Mary River - Conondale	-grandfather used set lines to make regular catches of cod, up to ~10kg weight	L
	-major siltation didn't occur in this area until the 1955 flood – cod had disappeared long before this due to blasting with gelignite	
Mary River - Kenilworth	-"*...The Mary River has filled in since the 1920's when codfish were caught from the first bridge at Lower Kenilworth (Gheerulla) crossing...*" -"*...Fine cod were once plentiful in the Mary River from Tiaro to the headwaters. Now they are rare indeed...*"	R
Mary River - Kenilworth	-aboriginals and early settlers fished for cod -none seen since at least ~1960	L
Mary River - "Blackfellows Creek"	-83 lb cod caught in ~1926 -"*...Cod were plentiful in those days, and it was nothing to get two on a set line...*"	
Mary River - Tuchekoi	-cod abundant in 1930's -decline attributed to loss of pool habitats (siltation)	R
Mary River - Tuchekoi	-75 lb cod caught ~1920	L
Mary River - Gympie	-occasional cod still caught in town reaches	
Mary River - Curra Ck junction	-small cod (~2kg) caught about 1989	L
Mary River - Gundiah (Emery's Bridge)	-cod sufficiently abundant to be targeted by anglers prior to ~1950's -target species are now catfish and mullet	L/A
Mary River - Miva (Stantons Dairy)	-small fish caught 1991 that 'may' have been a cod	L/A
Mary River - Tiaro	-no cod caught since at least 1985, despite regular angling	A
Obi Obi Creek - gorge	-several cod up to ~5kg caught since 1992	A
Obi Obi Creek - Kenilworth	-cod once reasonably common in lower reaches of Obi Obi Ck -no known cod captures since at least 1980, but heard of some upstream in the gorge area	L
Booloumba Creek	-reasonably well known for cod, but no authenticated captures since at least ~1970 -report of a small cod caught ~1990, but sceptical as to authenticity	F
Yabba Creek	-"*...Cod were never very plentiful in Yabba Creek...*"	H
Yabba Creek - Yabba falls	-cod catching expeditions to Yabba falls made on horseback by land-owners from Brisbane River catchment in 1930's/40's	L
Yabba Creek - below Borumba Dam	-cod once plentiful, but generally considered to have disappeared around 1960's	L/A/T
Yabba Creek - below	-small cod have reappeared in creek since stocking in Borumba Dam	H/A/R

LOCATION	SUMMARY OF ANECDOTAL INFORMATION	SOURCE
Borumba Dam		
Kandanga Creek	-several land-owners knew that cod were once present in the creek, but had heard of no recent captures	L
Amamoor Creek	-cod present up until at least 1990	L
Amamoor Creek	-various sites once known as good 'cod-holes', but no definite captures since at least 1980	F
Glastonbury/Widgee/ Station Creeks	-a few cod still present (D. Willett 1990, unpublished data)	L/A/H
Wide Bay Creek - Kilkivan	-large, deep pools once contained cod -decline attributed to loss of pools (siltation)	R
Wide Bay Creek - Sexton	-last known cod capture in ~1964 in a pool that has since silted up -admitted to netting the creek in the past, but said that only mullet and catfish were ever caught	L
Munna Creek - Miva area	-severe drought conditions in early 1940's led to large fish kills, including many cod -cod have been very rare or absent since	L
Munna Creek - Miva area	-cod once present, but none seen since ~1950's	L
Munna Creek -"Miva Station"	-land-owner stated cod were still present in the creek, but denied fisheries officers access to sample (1992)	L
Tinana Creek - "Kia Ora"	-"...*Cod were quite plentiful* (~1940's)...*some of the farmers would spear them at night, the eyes showing red in the torchlight*..."	L
Tinana Creek	-cod still present upstream of Tallegalla Weir	F/H/A
Coondoo Creek	-cod still present, and caught from time to time	F/H/A
Six Mile Creek	-cod still present, and fished for by locals	L/A/H

Table 3: Summary of Mary River cod specimens lodged at the Queensland Museum.

DATE	LAT/LONG	LOCATION
18.10.33	26.42/152.52	MARY RIVER - near Witta, via Maleny
18.10.33	26.42/152.52	MARY RIVER - near Witta, via Maleny
22.09.75	26.44/152.42	MARY RIVER - headwaters
20.12.88	26.20/152.50	SIX MILE CREEK - Cooran
11.05.89	26.05/152.47	TINANA CREEK - below weir
30.04.92	25.48/152.42	TINANA CREEK - Bungawatta Station
30.04.92	26.00/152.50	COONDOO CREEK
30.04.92	26.00/152.50	COONDOO CREEK
30.04.92	26.00/152.50	COONDOO CREEK
30.04.92	26.16/152.45	SIX MILE CREEK - 10 km upstream junction

There are reports that cod are, or have been, present in the Dawson River in central Queensland (Roughley 1951; Grant 1965). The lack of earlier references to this in the literature suggest that

cod are not endemic to this river system, although they may have been introduced there. Recent surveys of the fish fauna of the Dawson River indicate that cod do not occur there (personal communication, Peter Long).

2.1.3. Present distribution

There are three areas within the Mary River system where cod are relatively abundant. These are Tinana-Coondoo Creek upstream from Tinana Barrage, Six Mile Creek downstream from Lake Macdonald, and upper Obi Obi Creek (Figure 2) (Simpson 1994, and personal observation, R. Simpson). Cod have also been reported from Widgee, Glastonbury, Amamoor, and Yabba Creeks, and parts of the Mary River since 1990. However, surveys conducted by DPI Fisheries suggest that numbers are very low (personal observations, R. Simpson). Cod are very rare or absent in many areas where they were once common.

Mary River cod have been stocked in impoundments, both within and outside the Mary River system, since 1983 (Table 4). Most stockings outside the Mary system have been into areas that once contained cod (eg. Brisbane-Stanley and Albert-Logan catchments).

Table 4: Summary of official stockings of Mary River cod in impoundments in southeast Queensland.

IMPOUNDMENT	PERIOD STOCKED	NUMBER STOCKED
Baroon Pocket Dam[a]	1991-94	4600
Borumba Dam[a]	1992-93	2150
Lake Macdonald[a]	1983-98	30000
Wivenhoe Dam[b]	1992-98	5700
Somerset Dam[b]	1988-98	6907
Cressbrook Dam[b]	1989-98	4603
Moogerah Dam[b]	1990-98	2100
Hinze Dam[c]	1991-94	6560
Maroon Dam[d]	1987-98	2510
Lake Samsonvale[e]	1993-95	1960

([a] = Mary River catchment; [b] = Brisbane River catchment; [c] = Nerang River catchment; [d] = Albert-Logan River catchment; [e] = North Pine River catchment)

2.1.4. Life history

The present knowledge of reproduction and early life history of the Mary River cod is based on experience with captive fish in hatcheries. There are no recorded observations of the spawning behaviour of wild fish, and no studies into reproductive physiology have been conducted. Most information has come from the work of Gerry Cook at a fish hatchery in Cooroy. The following section summarises Gerry's experiences with cod breeding over the last twenty years.

Mary River cod form pairs and spawn annually around spring. The male selects and guards the nest site, which is a hollow pipe or purpose-built nesting box in hatchery ponds. It is therefore

presumed that hollow logs are used as nests in the wild. Spawning takes place soon after the water temperature rises to 20^0C, and may involve considerable aggression between the spawning pair. The female is frequently injured before she can escape the guarding male. The eggs are deposited as a layer inside the nest where they adhere to the hard surface of the pipe or log, although they are sometimes scattered around the nest site following fighting. The opaque eggs which measure 3.0 - 3.5 mm in diameter are guarded by the male. Hatching commences towards the end of the fourth day at 21^0C, and is usually completed by the end of the seventh day. Newly hatched cod larvae are 5 - 7 mm long. The male continues to guard the brood until they disperse to search for food around seven to nine days after hatching. The fecundity of Mary River cod is not well known, but experience suggests that around 2000 eggs per kilogram of the females weight can be expected. Some females may spawn more than once in a season. Mary River cod fry may grow to 50 mm in less than 10 weeks in plankton-rich hatchery ponds. They are harvested for stocking at 30 to 50 mm, by which time they are aggressive predators.

It is not known if Mary River cod will breed in impoundments, however breeding success and recruitment among impoundment populations of other Australian percichthyid fishes is often very low or non-existent (Barlow, 1991). Natural spawning of Mary River cod in hatchery ponds at least suggests that there is a potential for impoundment populations to become self-sustaining, given that suitable conditions are provided.

Observations by anglers and in hatcheries indicate that the Mary River cod feeds mainly on fish and large crustaceans (yabbies and shrimp). There are also reports of small birds, bats and water rats in the stomach contents of angled specimens.

2.1.5. Movements and homing

Merrick and Schmida (1984) reported that Mary River cod migrate from the main river into smaller tributaries in late winter. Other accounts suggest that cod become very active and disperse to the upper reaches of tributary streams during high stream flows in summer (personal communication, Gerry Cook). Recent radiotracking work (unpublished data, R. Simpson) indicates that both of these may be true to some extent. Adult cod may move in excess of 30 km either upstream or downstream during high stream flows at any time of year. There is a tendency for cod to move upstream in spring and summer and downstream in winter. However, some fish are much less apt to move than others and may stay within a restricted area, or 'home range', for several years. Home ranges of cod measure from 100 to 1000 m in length, and usually include two to four 'core areas' where a fish spends a large proportion of its time. The core area often comprises a large log or log pile. Feeding and patrolling movements within the home range are most common from dusk to dawn.

Homing behaviour is common among Mary River cod. Individual fish may return to a previous home range after an absence of at least eight months and a return journey of at least 70 km. The same core areas are often utilised upon return. Cod are also able to find their way back to a specific tributary after an extended period in the main river or in other tributaries. The ability to home is probably achieved by a combination of olfactory and visual senses as has been demonstrated with other fishes.

2.1.6. Habitat preference

Mary River cod occur in a variety of habitat types within the Mary River system, from high gradient, rocky, upland streams, to large, slow-flowing pools in lowland areas. Anecdotal

accounts by anglers and landowners often describe the ideal cod habitat as comprising deep, shaded, slow flowing pools with plenty of snags and log-piles. Similar habitat types are utilised by the closely related Murray cod and trout cod in the Murray River system (Cadwallader and Backhouse 1983; Douglas *et al.* 1994).

Simpson (1994) described the habitats occupied by cod in the Mary River system. Six Mile Creek and Tinana-Coondoo Creek, which are considered the best remaining areas for cod, provide abundant instream timber and are heavily shaded by overhanging vegetation compared to many other parts of the Mary system. Streambed substrates are usually fine sand or mud. Conversely, cod habitats in Obi Obi Creek are deep and rocky, with little instream timber or overhanging vegetation. Therefore, cod may inhabit a variety of broad habitat types, however they have a strong preference for areas that provide heavy cover. In a radiotracking study of cod conducted over two years and involving more than 600 observations (unpublished data, R. Simpson), the tagged fish were located within 1 m of instream timber more than 90% of the time. There was a strong preference for log piles and large individual logs over smaller logs or other types of cover. Areas of open water were usually avoided. Relatively shallow parts of the stream were sometimes occupied provided there was abundant cover. Cod were frequently found immediately downstream of a constriction of the stream (eg. a riffle) where food was presumably concentrated by the water flow.

Physicochemical parameters vary widely across the range of the cod. The waters of Six Mile and Tinana-Coondoo Creeks tend to be acidic (pH 6.0 - 6.5), relatively high conductivity (eg. 0.8 mS/cm), often low in dissolved oxygen due to low flows, and typically stained dark by organic leachates. Conversely, Obi Obi Creek tends to be alkaline (~pH 7.3), low conductivity (eg. 0.1 mS/cm), high in dissolved oxygen, and relatively clear (Simpson 1994). Although the physicochemical preferences of the Mary River cod are not known, they appear to tolerate a relatively wide range of conditions. Like many native fish, the cod's tolerance of variable water quality is probably an adaptation to the drought/flood cycles that occur in Australian waterways.

2.2 REVIEW OF EXISTING POPULATIONS

2.2.1. Tinana-Coondoo Creek

Tinana-Coondoo Creek drains 1310 km^2 in the northeast of the Mary basin (Figure 2) and has a mean annual discharge of approximately 313 000 ML (Queensland Water Resources 1993). This represents 13.7% of the Mary River catchment area and 12.1% of the total discharge volume of the Mary River. Land use is dominated by state forest pine plantations, sugar cane production along the lower reaches of Tinana Creek, and mixed agriculture and livestock production in the upper Tinana catchment. Most of Coondoo Creek and its tributaries flow through exotic pine plantations.

Tinana-Coondoo Creek provides one of the best refuges for cod in the Mary system. The sub-catchment is relatively large and well forested (including extensive areas of exotic pine trees), and human population density is low. Significant riparian buffer strips of tall, native vegetation remain intact in most areas. These provide abundant shading of the streambed, a diversity and abundance of instream cover (logs, logjams, branches, overhanging vegetation) and help to maintain bank stability. Large, deep, permanent pools are present throughout Coondoo Creek, and Tinana Creek below its junction with Coondoo Creek, although these are often separated by

long stretches of relatively shallow stream habitat (Simpson 1994). Streams in this area have not been affected by anthropogenic siltation to the extent seen in many parts of the Mary catchment.

Existing water storages on Tinana Creek include Tinana Barrage (AMTD[1] 1.6 km), Teddington Weir (AMTD 15.8 km), and Tallegalla Weir (AMTD 37.5 km) (Figure 2). These supply water for irrigation within the Tinana Creek area, and urban use in Maryborough (Queensland Water Resources 1993). Fishways have been constructed on Tinana Barrage and Teddington Weir, however both are considered largely ineffective in passing fish (Hajkowicz and Kerby 1992). The Queensland Department of Natural Resources plans to upgrade the fishway on Tinana barrage (personal communication, Errol Beitz). These reservoirs, and the tidal barrage on the lower Mary River, limit the potential for movement and interbreeding of cod from Tinana Creek with those in the rest of the Mary system.

Australian bass (*Macquaria novemaculeata*) have recently been recorded at several sites in Tinana and Coondoo Creeks (personal observation, R. Simpson). This species was not found during electrofishing surveys carried out in 1992-3. Although the bass occurs naturally in the lower reaches of Tinana Creek, recent captures in upstream areas may be the result of stocking by recreational anglers. Introduced golden perch (*Macquaria ambigua*) are present in Tinana Creek, however their abundance appears to be very low (personal observation, R. Simpson).

Tinana-Coondoo Creek is a well-known source of Mary River cod for recreational anglers and hatchery operators. Regulations now prohibit the taking of cod from any waters in the Mary catchment, and also prohibit any angling in two key areas of Tinana-Coondoo Creek However the large areas of State Forest in the Tinana-Coondoo catchment make enforcement difficult. Evidence of angling activity, including forked sticks, discarded fishing line, lures, and even maggot bags suspended over the water, can still be found (personal observation, R. Simpson).

The range of Mary River cod in Tinana-Coondoo Creek extends at least thirty kilometres up Coondoo Creek, and downstream in Tinana Creek to at least Tallegalla Weir (and probably further) (Figure 2). This makes a total stream length of at least 70 km, only 25-30% of which (ie. 17-21 km) comprises large pool habitats that are likely to provide permanent habitat for cod (Simpson 1994). Based on this data and electrofishing surveys, the cod population in this creek system is estimated at around 250 individuals (personal communication, J. Koehn).

2.2.2. Six Mile Creek

Six Mile Creek drains 310 km^2 in the east of the Mary basin (Figure 2) and has a mean annual discharge of 136 000 ML (Queensland Water Resources 1993). This represents 3.2% of the Mary catchment area and 5.3% of the total discharge volume of the Mary River. Much of the Six Mile Creek catchment area is used for agriculture and livestock production.

Although large areas of the Six Mile Creek catchment have been cleared for crop and animal production, riparian vegetation is generally in good condition. Stream habitats tend to be heavily shaded, and provide abundant cover for cod (Simpson 1994). Pools in Six Mile Creek are not very large or deep (compared, for example, to many in Tinana Creek), and are often separated

[1]Adopted Middle Thread Distance - indicates the distance upstream from the point of outflow of a stream.

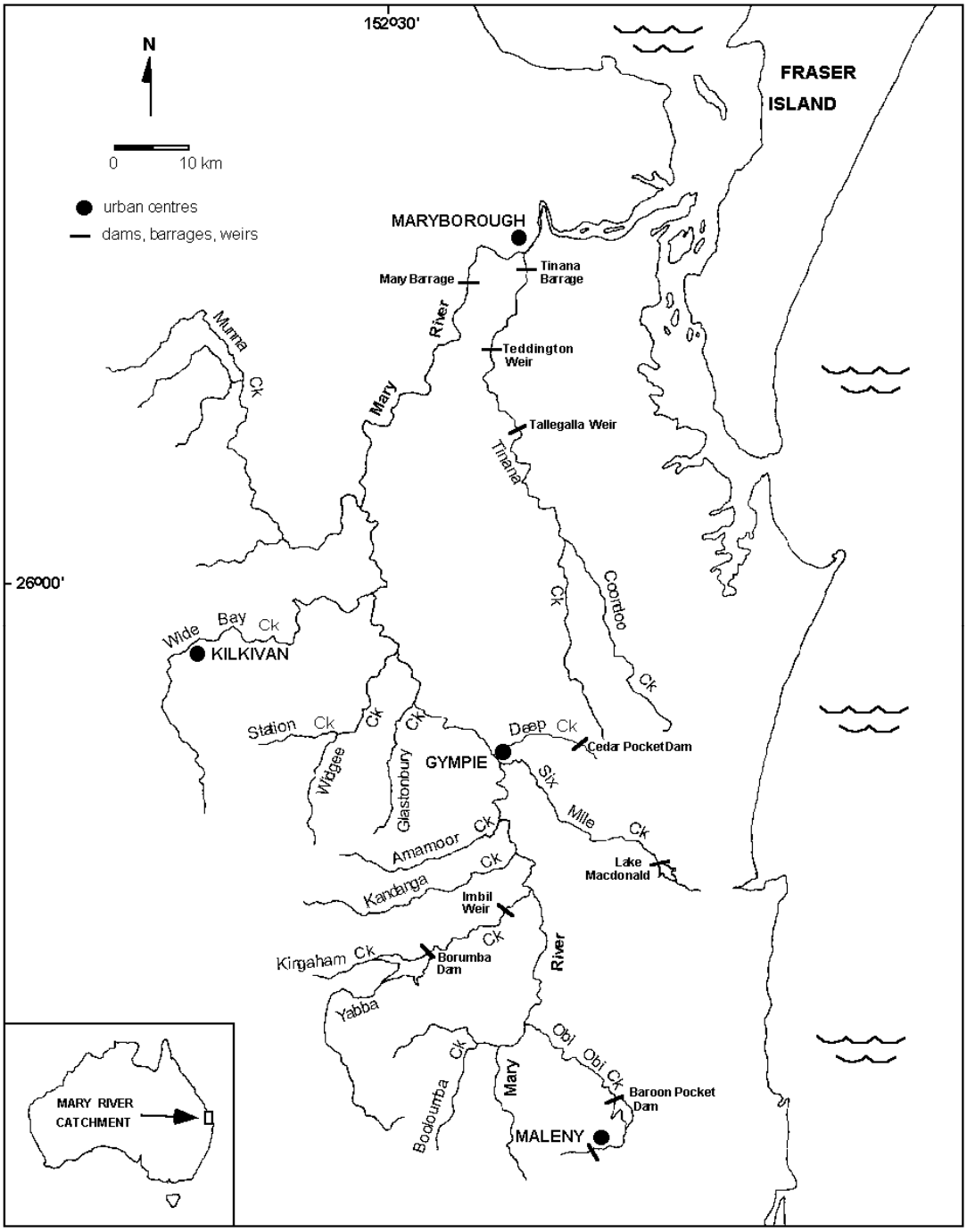


FIGURE 2: The Mary River system, south-east Queensland

by long stretches of shallow riffle and run habitats. However, the cod population appears to be relatively healthy. The stocking of cod in Lake Macdonald since the early 1980s has probably helped supplement the riverine population downstream. Golden perch and Australian bass are also relatively common in Six Mile Creek as a result of stocking in Lake Macdonald.

Lake Macdonald, at AMTD 55 km on Six Mile Creek, provides water for urban use in the adjacent Sunshine Coast area (Queensland Water Resources 1990). The dam wall restricts the upstream movement of fish (including cod), although downstream movements are thought to occur (personal communication, G. Cook). A water supply treatment plant at Lake Macdonald discharges effluent into Six Mile Creek. Accidental spillage of alum sludge from the treatment plant was thought to be responsible for a fish kill in Six Mile Creek in 1990 (unpublished data, Queensland Fisheries). The reduced downstream flows resulting from diversion of water from Lake Macdonald is considered a potential threat to the Six Mile Creek cod population (Simpson 1994).

Six Mile Creek is well known as a cod stream by recreational anglers and hatchery operators. Accessibility is relatively good via the numerous road crossings or private property, although the heavily vegetated and steep banks probably help to limit fishing opportunities. Landowners report that it is not uncommon to see anglers walking along the creek.

Mary River cod inhabit most of Six Mile Creek below Lake Macdonald (Figure 2). This represents a stream length of approximately 40 km, less than half of which comprises permanent pool habitats (Simpson 1994). Based on this data and electrofishing surveys, the cod population is estimated at around 250 individuals (personal communication, J. Koehn).

2.2.3. Obi Obi Creek

Obi Obi Creek drains 202 km^2 in the south of the Mary catchment (Figure 2) and has a mean annual discharge of 156 000 ML (Queensland Water Resources 1993). This represents 2.1% of the Mary River catchment area and 6.1% of the total discharge volume of the Mary River. Dairy farming and some agricultural production dominate the lower Obi Obi valley. The area between these downstream floodplains and Baroon Pocket Dam (AMTD 26.4 km) is steep, rugged country with limited access, and includes Obi Obi Gorge National Park.

The Baroon Pocket Dam wall (AMTD 27 km) is an impassable barrier to upstream movement of fish. Cod occurred upstream of the dam site prior to its construction, and were stocked in Lake Baroon in 1992 and 1993. There are concerns that the changed flow regime and increased siltation in Obi Obi Creek resulting from the construction of Baroon Pocket Dam may adversely affect the cod population (personal communication, R. Wager).

Introduced golden perch relatively abundant in downstream parts of Obi Obi Creek. Recent reports by anglers indicate that golden perch and Australian bass (*Macquaria novemaculeata*), which have been stocked in Baroon Pocket Dam, are present in Obi Obi Gorge.

Although access to Obi Obi Gorge is difficult, the resident cod population has been subject to recent angling pressure. Due to concerns over the effects of this pressure, a closure to all angling is now in place from the Baroon Pocket Dam wall downstream to Skene's Creek, a distance of approximately 4 km.

An electrofishing survey carried out in Obi Obi Creek (Simpson 1994) and information received from local landowners suggests that cod are now very rare or absent below the gorge. The total length of Obi Obi Creek inhabited by cod may therefore total considerably less than 10 km. Assuming cod are largely restricted to the Obi Obi Gorge area, the population size may be as small as 50-70 individuals. Unconfirmed evidence from anglers indicates that cod of less than 0.5 kg have been caught since 1994, suggesting that some recruitment may have occurred in recent years.

2.2.4. Overall status of cod in the Mary River system

Occasional captures of cod are reported from a number of other sites in the Mary River system, including Amamoor, Widgee, and Yabba Creeks and parts of the main river. However, surveys by DPI Fisheries indicate that numbers are very low. The total estimated number of cod from Tinana-Coondoo, Six Mile, and Obi Obi Creeks (see above) is less than 600 individuals, however the total population in the river system is likely to be considerably larger than this. There is insufficient reliable data to make a reasonable estimate of the size of the cod population in the Mary catchment.

The distribution of cod within the Mary River system appears to have declined. Anecdotal information suggests that cod do not occur in many areas where they once did, however, these observations could be equally well explained by reduced abundance and a lack of targeted sampling. Also, individual cod may move long distances within and among tributaries (unpublished data, R. Simpson) so that absence of cod from an area may be a temporary situation that changes seasonally or from year to year.

There has been a significant reduction in the size of individual cod in the Mary River system since the turn of the century. Reports of cod larger than 10 kg are now confined to historical records and anecdotal accounts from the first half of this century (Table 2). Today, cod larger than 5-6 kg are uncommon captures in the Mary River system.

Given the history of cod decline throughout southeast Queensland, the fragmentation of remnant Mary River populations, the low numbers of cod estimated to occur in the Mary, and the decline of large specimens, the Mary River cod is a critically endangered species.

2.3. REASONS FOR DECLINE OF THE MARY RIVER COD

2.3.1. Habitat changes

Extensive siltation and in filling of pools has occurred in parts of the Mary River system, particularly along the main river channel. Erosion of cleared farmland and stream banks has deposited large amounts of sand into stream channels, and the poor state of riparian vegetation in many areas contributes to continuing bank erosion during even relatively small flow events. Grazing and disturbance of banks by cattle is common, and inhibits the natural regeneration of native vegetation. The loss of deep, shaded pool habitats is probably a major reason for the rarity or absence of cod in many areas (Simpson 1994).

Other impacts commonly associated with the loss of vegetation include reduced abundance of instream timber, changes to the instream temperature regime (Theurer *et al.* 1985), changes to instream productivity (Murphy *et al.* 1981; Hawkins *et al.* 1983), loss of a nutrient source for the

stream community (Cummins 1986), and changes to the availability of certain food items (Harris 1985; Arthington 1992). All of these may have had either a direct or an indirect adverse effect of cod populations.

River 'improvement' works, including desnagging, have been carried out in parts of the Mary River in the past, although the extent of these actions is not well documented. Cadwallader (1978) suggested that snag removal in parts of the Murray-Darling River system may have limited the potential for native fish, such as the Murray cod, to breed. The same is probably true for the Mary River cod.

The Mary River cod is, at times, a highly mobile fish, and may traverse long distances to return to a previous home range (unpublished data, R. Simpson). Migration and homing are behavioural adaptations to enhance the success of a species or population, and restricting these movements may lead to the degradation of stocks (Pellett *et al*. 1998). The potential for movement of cod in the Mary River system has been limited by large dams (eg. Borumba, Baroon Pocket, and Lake Macdonald), weirs (eg. Gympie, Teddington, Tallegalla), tidal barrages (ie. Mary River and Tinana Creek), and numerous culverts and road crossings. More large impoundments are planned to meet increasing water demands in the region. It is likely that barriers to movement have, and will continue to, put pressure on cod stocks.

Changes to the instream temperature and flow regime downstream of impoundments can also adversely affect fish stocks and stream communities in general (Cadwallader 1978; Johnson 1992). Given the close correlation between cod movements and flows (unpublished data, R. Simpson), and between cod spawning and water temperature (personal communication, G. Cook), the potential for impacts on cod populations is high. The main areas of concern in regard to these impacts are Yabba Creek (Below Borumba Dam), Obi Obi Creek (below Baroon Pocket Dam), and Six Mile Creek (below Lake Macdonald).

2.3.2. Overfishing

Large numbers of cod were taken from the Mary River system in the late 1800s and early 1900s for human and animal consumption (Table 2 and Rowland 1985). The use of gelignite, nets and set lines is widely reported and considered by residents in some areas to be a major reason for the decline in cod numbers.

Mary River cod remain a popular target for recreational anglers, although the number of dedicated cod anglers has probably decreased in the latter part of this century following the decline of the species. Anglers targeting cod today concentrate most of their effort towards the three or four streams known to support remnant populations (eg. Six Mile, Tinana, and Obi Obi Creeks). Anglers may still take one cod over 50 cm (total length) per day from stocked impoundments outside the Mary River system. There is a total prohibition on the taking of cod within the Mary River catchment.

2.3.3. Introduced fishes

The effects of introduced fishes on Mary River cod, or stream communities in general, in the Mary River system are unknown. Exotic fishes previously recorded in the Mary River system include the guppy (*Poecilia reticulata*), swordtail (*Xiphophorus helleri*), and mosquito-fish (*Gambusia holbrooki*) (Pusey *et al.* 1993). The mosquito-fish has been implicated in the decline

of many freshwater fishes in Australia and worldwide (Arthington and Lloyd 1989; Lloyd 1990; Arthington 1991).

Australian fishes that have been translocated into the Mary River system include the golden perch (*Macquaria ambigua*), silver perch (*Bidyanus bidyanus*) and saratoga (*Scleropages leichardtii*). Golden perch are present, and sometimes abundant, in most areas known to support populations of cod (Simpson 1994). Like cod, they are relatively large ambush predators, and there is likely to be considerable overlap in their preferences for food and space.

The Australian bass (*Macquaria novemaculeata*) occurs naturally in the lower Mary River, and has become more abundant in upstream reaches following stocking. Like the golden perch, the bass may compete with cod for food and space, and prey on juveniles.

There are reports that Murray cod have been introduced into the Mary system on several occasions. An article from the *Maryborough Chronicle*, dated 4.6.1870, outlined a proposal to introduce Murray cod into the Maryborough Water Reservoir. Whether this occurred is not clear. Murray cod from the Condamine River were reportedly introduced into the Mary system at Obi Obi Creek in 1880 (Merrick and Schmida 1984; Rowland 1985). The cod were said to have been brought overland in milk churns, although the Kenilworth Historical Society point out that no dairying was carried out in the district until the 1890s, and the likelihood of cod surviving such a long trip is low. Also, it is unclear why such an introduction would be attempted given the reported abundance of Mary River cod. Perhaps it was because Murray cod grow larger. More recently, Murray cod are reported to have been released in the Mary River in the 1970's (personal communication, G. Cook). Rowland (1989) stated that, although Murray cod were introduced into the Mary, they can no longer be found there.

3. RESEARCH AND RECOVERY PLAN

The Mary River Cod Research and Recovery Plan was developed by the Mary River Cod Recovery Team. The Plan was completed and submitted to Environment Australia (then Australian Nature Conservation Agency) in 1996. While the principles and objectives of the Recovery Plan have not changed since that time, considerable progress has been made with some of the recommended actions. The following sections reproduce the General Principles, Objectives, Criteria, Recommended Actions, and Implementation Schedule as submitted in 1996. Section 3.3.2. has been added to provide an update on progress with recovery actions as of September 1999.

The Mary River Cod Recovery Team

The Recovery Team was established in 1994 with the following membership:

Colin Limpus (Chair) - Queensland Department of Environment and Heritage;
Peter Tierney - Queensland Department of Environment and Heritage;
Les Kropp - Land-owner/irrigator, Mary River Integrated Catchment Management Coordinating Committee;
Phil Cadwallader - Queensland Fisheries Management Authority
Jan Tilden/Maria van der Graat - National Threatened Species Network;
Gerry Cook - Lake Macdonald Fish Hatchery;
Russell Manning - Manning Fish Hatchery; Lake Macdonald Angling Club;
Steve Kelly - Mary River Integrated Catchment Management;
Jamie Pook - Australian Nature Conservation Agency;
Ed Miller - Queensland Department of Natural Resources (Water Resources);
Peter Jackson - Queensland Department of Primary Industries (Fisheries);
Bob Simpson (Secretary) - Queensland Department of Primary Industries (Fisheries);
Stuart Bunn - Land and Water Resources Research and Development Council.

Since completion of the Recovery Plan in 1996, the Recovery Team has continued to meet approximately twice yearly to review progress with recovery actions. Although membership of the Recovery Team has changed considerably since 1994 it's focus as a joint community/government team has been maintained. The current (1999) composition of the Recovery Team is:

Peter Jackson (chair)- Queensland Department of Primary Industries (Fisheries);
Doug Schulz /Peter Tierney - Queensland Department of Environment and Heritage;
Bernadette Kerby - Queensland Fisheries Management Authority
Gerry Cook – former manager of Lake Macdonald Fish Hatchery;
Vince Collis – Noosa District Community Hatchery Association;
Lionel Shambrook – Noosa District Community Hatchery Association;
Darren Knowles – Noosa District Community Hatchery Association;
Brian Stockwell – Queensland Department of Natural Resources;
Bob Simpson (Secretary) - Queensland Department of Primary Industries (Fisheries);
John Dillon – Barung Landcare Association;
Don Garnet – Queensland Boating and Fisheries Patrol;
Kevin Pengelley - Queensland Department of Primary Industries (Forestry);
Sandy Jones – Mary River Cod Community Network;
Glenda Pickersgill – Mary River Cod Habitat Officer
Ray Kelly – Noosa Shire Council

Stuart Bunn/Mark Kennard- Land and Water Resources Research and Development Council;

3.1. GENERAL PRINCIPLES

- Mary River cod recovery will not occur without community involvement and ownership in the development and implementation of a recovery plan.
- Community involvement needs to be backed by adequate biological information.
- Existing groups/networks should be used in preference to establishing new ones.
- The plan should maximise "on the ground" outcomes so that the community can relate to it.

3.2. RECOVERY OBJECTIVES AND CRITERIA

The overall objective of the Mary River cod Research and Recovery Plan is to secure and enhance populations of Mary River cod in the Mary River system, and to restore populations of cod in their historic range in south-eastern Queensland. The priority is to ensure the long-term conservation of the Mary River cod, however utilisation of the species at a sustainable level is also a goal. Because of the limited geographic range of the Mary River cod, it's vulnerability to capture and depletion, and ongoing catchment modifications, it is likely that the species will require ongoing special management to maintain populations beyond the time frame of this Recovery Plan.

1. Short-term objectives (1996 – 2000)

- Engage community involvement
- Protect existing populations from exploitation in the Mary River system
- Improve hatchery production and begin stocking to establish new populations
- Implement research to obtain data on key aspects of life history and hatchery technology, etc.

Performance criteria:

- Stakeholders identified, public forum held, and draft recovery outline developed accordingly by mid 1995
- Community cod network established by 1996 (and ongoing).
- Regulations in place to protect cod from exploitation by 1998.
- Support provided to hatcheries and five-year strategic plan for cod production implemented by 1997 (and ongoing)
- Criteria established for stocking of cod for conservation and recreation purposes and stocking commenced by 1998
- Funding for further research procured, and research initiated by 1997.

2. Medium-term objectives (by 2005)

- Encourage community ownership of cod recovery
- Implement habitat rehabilitation program in the Mary River catchment, and other target catchments, in collaboration with the community
- Implement restocking program in other target catchments
- Implement restocking program in impoundments for conservation purposes (ie. establish breeding populations**)**

Performance Criteria:

- Community cod network actively involved in cod recovery, including commencement of appropriate rehabilitation of stream and riparian habitats by 2005
- Cod released into Brisbane-Stanley, Albert-Logan and Coomera River systems according to established criteria, and with appropriate monitoring in place by 2005
- Cod stocked into selected impoundments and monitoring in place by 2005

3. Long-term objectives (by 2010)

- Mary River cod established as an important cultural icon for the Mary River catchment
- Ecological sustainability of populations in the wild
- Monitoring to ensure sustainability

Performance Criteria:

- Mary River cod a prominent focus of community activities and actions related to catchment management and environmental issues generally
- Long-term monitoring indicates new cod populations established by 2010
- Conservation status of Mary River cod downlisted from Endangered to Vulnerable (ANCA Endangered Species Program definitions) by 2010

3.3. RECOVERY ACTIONS

3.3.1. Recommended Recovery Actions

Action 1. Establish a program of community involvement/education to develop public support for the conservation of Mary River cod.

It is essential that the general community is aware of the problems faced by Mary River cod, and that they become involved in conservation and management procedures to help restore cod populations. This can be largely achieved through existing networks, including schools, land and water management groups (eg.Landcare), conservation groups, angling clubs, and local and state government authorities and departments. Information should be disseminated to people in the Mary River catchment, and in other areas where cod are likely to be restocked, via newspaper and magazine articles, the publication of resource material, production of a promotional video, public meetings, and displays at country agricultural shows. It is proposed that a part-time person be employed to develop and coordinate a program of community education and involvement as outlined above.

1.1. Hold a series of public forums to inform the public of the recovery process, seek their input in development of the recovery plan, and establish community links.

Funding already received from Endangered Species Unit.

1.2. Appoint a part-time officer to develop and coordinate a program of community education and involvement.

1.2.1. Employ a Mary River Cod Community Liaison Worker

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	1.0					**1.0**
Operating	0.55					**0.55**
Total	1.55	0	0	0	0	**1.55**

1.2.2. Contact relevant stakeholders in the catchment

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	9.2					**9.2**
Operating	1.13					**1.13**
Total	10.33	0	0	0	0	**10.33**

1.2.3. Develop a "Cod Recovery Network" with a strategy for community involvement

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	7.2	4.2	2.0			**13.4**
Operating	0.75	0	0			**0.75**
Total	7.95	4.2	2.0	0	0	**14.15**

1.2.4. Involve the network in 'on-the-ground' actions identified in the Recovery Plan

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	11.4	15.0	20.0	25.0	25.0	**96.4**
Operating	0.88	0	0	0	0	**0.88**
Total	12.28	15.0	20.0	25.0	25.0	**97.28**

1.2.5. Move responsibility from the Recovery Team to the Community Cod Recovery Network

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	4.95	5.8	3.0			**13.75**
Operating	0	0	0			**0**
Total	4.95	5.8	3.0	0	0	**13.75**

Action 2. Develop and implement regulatory and administrative actions to protect Mary River cod and their habitats.

The enforcement of appropriate capture regulations, and the implementation of management procedures at a government level, will be very important in ensuring that Mary River cod and their habitats are afforded adequate protection.

The Mary River Cod Recovery Team recommends that regulatory protection of Mary River cod and their habitats should be sought under the *Fisheries Act* 1994. The main alternative to this is to list cod under the *Nature Conservation Act* 1992. Fisheries legislation is preferred for a number of reasons. There is a general agreement between the Department of Primary Industries and Department of Environment that fish species of commercial or recreational importance are not listed under the *Nature Conservation Act* 1992, but remain under the management of the fisheries agency. The *Fisheries Act* 1994 is equipped with a range of standard, well defined and well understood regulations (eg. possession limits, fishing closures) to control the take of any nominated species. There is also a well trained patrol body (Queensland Boating and Fisheries Patrol) whose role it is to enforce regulations under the *Fisheries Act* 1994.

Despite the fact that the Recovery Team recommends that Mary River cod not be managed under the *Nature Conservation Act* 1992, the possibility of listing it as an endangered species under that act but setting regulations under the *Fisheries Act* 1994 is being investigated. In the longer term, if for any reason fisheries legislation does not achieve the desired outcomes for cod populations, listing and management under the *Nature Conservation Act* 1992 will be considered.

The Mary River Cod Recovery Team presents the following two options for regulating the take of Mary River cod under the *Fisheries Act* 1994. These options will be discussed by the Freshwater Management Advisory Committee (QFMA), and with relevant fish management/stocking groups. The regulations will become part of QFMA's Freshwater Fisheries Management Plan through the management planning process. It is intended that

regulations would be put in place for an initial period of three years, after which time the Recovery Team will review the situation.

Option 1
- **Possession limit of 0 in all riverine areas**
- **Possession limit of 1 in impoundments where cod have been stocked for recreational use**

Option 2
- **Possession limit of 0 in all riverine areas**
- **Possession limit of 1 in impoundments where cod have been stocked for recreational use**
- **Closure to all fishing in designated critical habitats of the Mary River cod (areas to be determined)**

At present, limited resources are available to police regulations in freshwater areas such as the Mary River, and extra resources should be made available to increase the presence of enforcement officers in these areas. The possibility of utilising additional departmental officers (eg. Forestry officers) to assist Boating and Fisheries Patrol inspectors should be investigated.

Protection of important cod habitats via either appropriate scale management plans, or gazettal of habitat areas under the *Fisheries Act* 1994 will be investigated. Additionally, management guidelines to ensure the long-term maintenance of cod populations and stream habitats in the Mary River system should be developed and implemented. Areas requiring attention include:

- the maintenance of environmental flows in regulated stream sections;
- restrictions on the introduction of non-indigenous fish species; and
- the maintenance of fish passage past artificial stream barriers.

The Recovery Team recommends that a moratorium should be placed on the construction of new water storage impoundments in the Mary River system until information is available to indicate the expected effect of these on cod. Areas of key habitat for Mary River cod should also be documented and distributed to natural resource managers in the Mary catchment so that these areas can be given special attention in the development of resource management plans.

The translocation of non-indigenous fishes into the Mary River is regarded by the Recovery Team as a potential danger to the protection and re-establishment of Mary River cod populations. Of particular concern is the introduction of species closely related to Mary River cod - namely Murray cod (*Maccullochella peelii peelii*) and eastern freshwater cod (*Maccullochella ikei*) - due to the potential for hybridisation. Therefore:

The Recovery Team recommends against any further introduction of non-indigenous fish species into the Mary River system (including farm dams), and in particular, highlights the potential dangers of introducing Murray cod or eastern freshwater cod.

Short term actions

2.1. Incorporate the options regulating the take of Mary River cod into QFMA's consultation process for the development of the Freshwater Fisheries Management Plan.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total

Salaries	0.5					**0.5**
Operating	0.2					**0.2**
Total	0.7	0	0	0	0	**0.7**

2.2. Prepare a document listing all key cod habitats in the Mary River, and liaise with Resource Management authorities and landholders to ensure protection of these habitats.

2.2.1. Utilise existing data to document key cod habitats in the Mary River, and identify key elements of the habitat requiring protection.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	0.5					**0.5**
Operating	0					**0**
Total	0.5	0	0	0	0	**0.5**

2.2.2. Protect key cod habitats under the *Fisheries Act* 1994 by gazettal of fish habitat areas *or* appropriate scale management plans. The steps to achieve this are:

1. Develop project proposal for declaration of fish habitat areas or management plans;
2. Prepare area of interest plan;
3. Undertake community/stakeholder consultation and amend area of interest plan as required;
4. Develop proposal plan and submit for declaration by order in council.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries		2.0	7.7	5.4	8.7	**23.8**
Operating		1.0	5.5	3.5	6.0	**16.0**
Total	0	3.0	13.2	8.9	14.7	**39.8**

2.2.3. Meet with Resource Management authorities and landholders to discuss document and strategies for protecting cod habitat.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	6.0					**6.0**
Operating	2.6					**2.6**
Total	8.6	0	0	0	0	**8.6**

2.2.4. Monitor relevant resource management documents to assess the incorporation of agreed strategies.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries		1.0	1.0	1.0	1.0	**4.0**
Operating		0.6	0.6	0.6	0.6	**2.4**
Total	0	1.6	1.6	1.6	1.6	**6.4**

2.3. Evaluate current fish translocation practices in south-eastern Queensland in consultation with local angling clubs and fish management groups, and develop a strategy to minimise impacts on cod populations.

2.3.1. Document current translocation practices in south-eastern Queensland (eg. from Fisheries, fish management group, and hatchery records).

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries		2.1				**2.1**
Operating		0.3				**0.3**
Total	0	2.4	0	0	0	**2.4**

2.3.2. Assess the likely impacts of current translocation practices on Mary River cod.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries		2.2				**2.2**
Operating		0.3				**0.3**
Total	0	2.5	0	0	0	**2.5**

2.3.3. Formulate appropriate strategy for the protection of Mary River cod in consultation with stakeholders (eg. hatcheries, fish management groups, landholders), and provide recommendations to the Queensland Fisheries Management Authority for consideration by the Freshwater Management Advisory Committee.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries		3.1				**3.1**
Operating		2.0				**2.0**
Total	0	5.1	0	0	0	**5.1**

2.4. Compile a database listing barriers to fish migration on south-eastern Queensland streams, assess the impacts of these on cod (from the results of research carried out in Action 4.1.), and ensure appropriate fishways are constructed on new barriers where required (and existing barriers, where possible). In the meantime, the Recovery Team should formally inform the relevant authorities (Department of Natural Resources - Water Commercial) that they wish to seek a moratorium on the construction of new storage impoundments in the Mary River system until it can be demonstrated that these will not have an adverse impact on cod populations, or that fishways can be constructed that would alleviate any adverse impacts.

2.4.1. Interrogate Water Resources databases and consult with regional Water Resources officers to locate and describe existing barriers on south-eastern Queensland streams.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries			5.4			**5.4**
Operating			0.8			**0.8**
Total	0	0	6.2	0	0	**6.2**

2.4.2.Assess the likely impacts of these barriers on cod using available information including data obtained from radio-tracking study.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries			1.0			**1.0**
Operating			0.2			**0.2**
Total	0	0	1.2	0	0	**1.2**

2.4.3. Identify waterways where cod migration is necessary, ensure fishways are built on new barriers in these areas, and seek construction of fishways on existing barriers.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries			5.4	3.0	3.0	**11.4**
Operating			1.7	0.7	0.7	**3.1**
Total	0	0	7.1	3.7	3.7	**14.5**

2.5. Develop guidelines for flow releases below impoundments to ensure maintenance of aquatic habitats for Mary River cod, and seek their implementation. [The timing of this action should be integrated with Water Resources timetable for the construction of proposed new impoundments on the Mary River.]

2.5.1. Facilitate the compilation of a resource document for the Mary River (including information on fish, invertebrates, hydrology, current water use, etc.), and provide specific information on Mary River cod. (Employ a biologist for three months, operating required to obtain information from relevant experts.)

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries		14.1				**14.1**
Operating		5.0				**5.0**
Total	0	19.1	0	0	0	**19.1**

2.5.2. Hold a three day workshop (including one day of field observation) involving relevant experts to identify key components of the hydrological cycle necessary for the protection of the riverine ecosystem, and produce a document summarising outcomes of the workshop. (Employ a biologist for one month - operating required to cover fees of relevant experts and production of document.)

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries		5.9				**5.9**
Operating		9.0				**9.0**
Total	0	14.9	0	0	0	**14.9**

2.5.3. Request early implementation of the Water Allocation Management Plan (WAMP) process in the Mary River, and contribute the information pertaining to cod into this process.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries		1.5				**1.5**
Operating		0				**0**
Total	0	1.5	0	0	0	**1.5**

2.6. Establish appropriate linkages with existing studies on fluvial processes in the Mary River.

2.6.1. Identify existing projects/initiatives, etc, in the Mary River, and determine opportunities for linkages with these projects.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	1.4	1.4	1.4	1.4	1.4	**7.0**
Operating	0.8	0.8	0.8	0.8	0.8	**4.0**
Total	2.2	2.2	2.2	2.2	2.2	**11.0**

2.6.2. Develop joint projects and joint funding proposals where appropriate for projects relevant to the Recovery Plan.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	1.4	1.4	1.4	1.4	1.4	**7.0**
Operating	0.8	0.8	0.8	0.8	0.8	**4.0**
Total	2.2	2.2	2.2	2.2	2.2	**11.0**

Action 3. Develop and implement management procedures for the captive breeding and restocking of Mary River cod into suitable habitats.

Hatchery-bred Mary River cod have been stocked into impoundments in south-eastern Queensland to provide a recreational angling resource since 1983. Approximately 90% of the cod stocked in impoundments were produced at the local council-funded Lake Macdonald fish hatchery. Funding for this hatchery has recently been withdrawn by the Noosa Shire Council. As there are no private hatcheries currently producing Mary River cod in consistent numbers, it is a high priority to restore funding to the Lake Macdonald hatchery.

Investigations should be carried out to determine the optimum fingerling size for stocking, and to investigate the use of artificial breeding habitats to enhance breeding of cod in impoundments.

Stocking of cod in impoundments should continue for both recreational and conservation purposes, and a program of restocking in rivers should commence to restore or enhance riverine populations. As well as the Mary system, other rivers that historically contained populations of cod (ie. Brisbane-Stanley, Logan-Albert, and Coomera Rivers) should be considered for restocking. Criteria to assess the suitability of sites in the Mary River and elsewhere for restocking with cod are being developed (Table 5).

Short term actions

3.1. Develop and implement management plan for hatchery production of cod.

3.1.1. Convene a two-day workshop involving key experts (eg. biologists from interstate Fisheries agencies involved in breeding freshwater cod, geneticist, hatchery operators) to develop a management plan for hatchery production of Mary River cod. The management plan must address measures to ensure the long-term hatchery production of cod. (Prepare an agenda paper for consideration by QFMA's Freshwater Management Advisory Committee.)

Operating includes travel and accommodation costs for interstate experts.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	0.8					**0.8**
Operating	1.8					**1.8**
Total	2.6	0	0	0	0	**2.6**

3.1.2. Liaise with hatchery operators involved in Mary River cod production to ensure implementation of management plan, and review it's effectiveness.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	0.8	0.8				**1.6**
Operating	0.2	0.2				**0.4**
Total	1.0	1.0	0	0	0	**2.0**

3.1.3. Liaise with Noosa Shire Council, state Fisheries agency, and ANCA to reinstate funding to the Lake Macdonald hatchery.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	30.0	30.0	30.0	30.0	30.0	**150.0**
Operating	10.0	10.0	10.0	10.0	10.0	**50.0**
Total	40.0	40.0	40.0	40.0	40.0	**200.0**

3.1.4. Negotiate with relevant local and state authorities and hatchery operators to secure the long-term hatchery production of cod.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries		2.0				**2.0**
Operating		0				**0**
Total	0	2.0	0	0	0	**2.0**

3.2. Develop and implement criteria for stocking cod for conservation and recreational purposes.

3.2.1. Develop criteria for restocking Mary River cod for conservation and recreation purposes based on existing criteria (eg. trout cod) in consultation with relevant experts. (Prepare an agenda paper for consideration by QFMA's Freshwater Management Advisory Committee.)

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	1.0					**1.0**
Operating	0.4					**0.4**
Total	1.4	0	0	0	0	**1.4**

Medium term actions

3.3. Develop and implement restocking and monitoring program for south-eastern Queensland streams, with priority being given to the Mary River.

3.3.1. Develop a strategic plan for the restocking of cod in south-eastern Queensland streams using criteria developed in Action 3.2. (Prepare an agenda paper for consideration by QFMA's Freshwater Management Advisory Committee.)

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries		1.3				**1.3**
Operating		0.2				**0.2**
Total	0	1.5	0	0	0	**1.5**

3.3.2. Undertake restocking according to strategic plan and availability of fingerlings. Monitoring to be undertaken as part of Action 6. (Operating includes purchase of cod fingerlings from hatcheries)

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries			1.0	1.0	1.0	**3.0**
Operating			20.5	20.5	20.5	**61.5**
Total	0	0	21.5	21.5	21.5	**64.5**

3.4. Develop and implement program for establishing breeding populations in impoundments for conservation purposes, and monitor the effectiveness of this program.

3.4.1. Develop program based on existing information on survival and breeding success of cod in impoundments where they have been stocked, and the results of research carried out in Action 4.2.4.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries			1.4			**1.4**
Operating			0.8			**0.8**
Total	0	0	2.2	0	0	**2.2**

3.4.2. Implement program, and liaise with fish management groups to monitor it's success. (Operating includes purchase/construction of artificial spawning sites)

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries			16.9	16.9	16.9	**50.7**
Operating			11.0	11.0	4.0	**26.0**
Total	0	0	27.9	27.9	20.9	**76.7**

Action 4. Undertake research to increase knowledge of the biology and requirements of Mary River cod, and to improve techniques for their captive-breeding.

Many aspects of the biology and ecology of Mary River cod are poorly known. No detailed studies on wild fish have been undertaken, and most of the available knowledge is based on experience in hatcheries, or on anecdotal information supplied by anglers and land-owners. The study of Simpson (1994) provided details of the historic and present distribution of cod, and outlined the habitat types that apparently provide the basic requirements for cod habitation. More specific details of their habitat requirements for breeding and successful recruitment are not available. Juvenile cod have been notoriously difficult to catch in the wild, so little is known of their specific requirements for food, habitat, or movement.

Although techniques for the hatchery production of Mary River cod have been developed over a number of years, many aspects of the spawning and rearing process are still poorly understood. There appears to be considerable potential to 'fine-tune' hatchery techniques so that the quantity and quality of cod produced can be maintained at a consistently high level.

4.1. Use radio-tracking equipment to investigate the extent and timing of migratory and localised movements of Mary River cod, and thereby gain a better understanding of their habitat requirements.

There is anecdotal evidence that adult cod migrate upstream in early summer during high stream flows, but the extent, exact timing, and reasons for this supposed migration are not known. Many questions concerning the movements and habitat requirements of Murray cod in Victoria are being answered by a radio-tracking project, funded by the Murray-Darling Basin Commission. Radio-transmitters are surgically implanted in the fish, which can then be tracked by land, boat, or air. Invaluable information on Murray cod movements and habitat requirements at different times of the year and under different environmental conditions has already been acquired using this method. One of the main advantages of radio-tracking is that it provides a great deal of information from a relatively small number of fish. This would be of obvious benefit in studying an endangered fish like the Mary River cod, where minimal disturbance to populations is a desirable aim of any study.

4.1.1. Purchase radio-tracking equipment.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	0.7	0.3				**1.0**
Operating	20.3	4.2				**24.5**
Total	21.0	4.5	0	0	0	**25.5**

4.1.2. Undertake training in the implantation of transmitters in fish and the use of monitoring equipment.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	0					**0**
Operating	1.1					**1.1**
Total	1.1	0	0	0	0	**1.1**

4.1.3. Implant radio-transmitters in ~5 individuals from each of the four known populations of Mary River cod in the Mary River system.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	9.0	6.0				**15.0**
Operating	5.7	1.4				**7.1**
Total	14.7	7.4	0	0	0	**22.1**

4.1.4. Monitor movements of tagged individuals at intervals over a period of two years using light aircraft and a light punt. Monitoring will be most intensive around the breeding season (June to October) and during the summer months when most movements are thought to occur.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	25.0	28.0				**53.0**
Operating	17.0	17.0				**34.0**
Total	42.0	45.0	0	0	0	**87.0**

4.1.5. Analyse data, and formulate appropriate habitat enhancement and protection measures based on results obtained.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	0.3	0.7				**1.0**
Operating	0.3	0.5				**0.8**
Total	0.6	1.2	0	0	0	**1.8**

4.2. Review existing procedures for hatchery production of Mary River cod, and carry out research into areas needing improvement.

Procedures for the captive-breeding of Mary River cod have been developed, however considerable losses of eggs and larvae still occur at times. Therefore, improved guidelines for captive-breeding need to be developed. In particular, investigations should be undertaken into broodstock conditioning and maintenance, management and handling of eggs, disease and parasite control in eggs and larvae, and larval nutrition.

An investigation into enhancement of breeding in impoundments using artificial spawning structures will also be undertaken.

4.2.1. Develop more effective broodstock management techniques, including the establishment of appropriate methods for marking individuals and recording broodstock history.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	7.5	7.5				**15.0**
Operating	4.0	3.0				**7.0**
Total	11.5	10.5	0	0	0	**22.0**

4.2.2. Develop egg management procedures to minimise fungal disease outbreaks.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	7.5	7.5				**15.0**
Operating	4.0	2.0				**6.0**
Total	11.5	9.5	0	0	0	**21.0**

4.2.3. Develop larval management procedures to minimise disease outbreaks in grow-out ponds.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	7.5	7.5				**15.0**
Operating	4.0	2.0				**6.0**
Total	11.5	9.5	0	0	0	**21.0**

4.2.4. Develop artificial spawning structures for use in impoundments, and assess their usage by resident Mary River cod.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	7.5	7.5				**15.0**
Operating	2.5	2.5				**5.0**
Total	10.0	10.0	0	0	0	**20.0**

4.3. Carry out mitochondrial DNA analyses of available Mary River cod to determine whether Murray cod genetic material is present, and to assess the genetic variability within and between known populations of Mary River cod.

4.3.1. Collect tissue samples from Mary River cod broodstock held in hatcheries, and from Museum and other scientific collections, and carry out genetic assays on these.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	5.0					**5.0**
Operating	5.5					**5.5**

Total	10.5	0	0	0	0	**10.5**

4.3.2. Provide ongoing support to hatcheries and to the Mary River cod monitoring program by genetically assessing new broodstock, and providing a basis for identification of re-caught hatchery progeny.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries		3.2	3.2	3.2	3.2	**12.8**
Operating		3.0	3.0	3.0	3.0	**12.0**
Total	0	6.2	6.2	6.2	6.2	**24.8**

4.4. Investigate the swimming capabilities and appropriate fishway designs for Mary River cod.

4.4.1. Identify the timing and extent of movements by Mary River cod. (see Action 4.1).
4.4.2. Carry out appropriate trials to determine the swimming ability and behaviour of Mary River cod in experimental fishways if movement requirements are identified.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries			36.0	36.0		**72.0**
Operating			70.5	20.5		**91.0**
Total	0	0	106.5	56.5	0	**163.0**

4.4.3. Ensure appropriate fishways are constructed on new barriers where required (and existing barriers, where possible).(see Action 2.3.)

Action 5. Develop and implement programs to rehabilitate riparian and instream habitats in the Mary River system, and other south-eastern Queensland streams targeted for restocking with cod.

Short term action

5.1. Develop a plan of action for the rehabilitation of instream and riparian habitats in south-eastern Queensland to provide suitable habitat for Mary River cod .

5.1.1. Identify areas in the Mary River, and other south-eastern Queensland streams, deemed to contain suitable habitats for cod. Develop a plan of action whereby habitat rehabilitation works would serve to expand and eventually connect these areas with each other. High priority for habitat rehabilitation works should initially be given to areas known to already support populations of cod.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	1.4					**1.4**
Operating	0.8					**0.8**
Total	2.2	0	0	0	0	**2.2**

5.1.2. Document existing information on habitat rehabilitation programs, and assess their significance and potential application to cod. Liaise with relevant Resource Management agencies and research organisations to identify opportunities for expanding existing habitat rehabilitation programs into key cod habitats

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	1.4					**1.4**
Operating	0.8					**0.8**
Total	2.2	0	0	0	0	**2.2**

Medium term actions

5.2. Implement pilot habitat rehabilitation programs in key areas of the Mary River in collaboration with local community and Land and Water Resources Research and Development Council (LWRRDC) Riparian Zone Program.

5.2.1. Investigate the feasibility and costing of instream habitat rehabilitation works by undertaking a small-scale project in the Mary River in collaboration with Bob Newbury (Newbury Hydraulics Ltd.)

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	5.0					**5.0**
Operating	30.0					**30.0**
Total	35.0	0	0	0	0	**35.0**

5.2.2. Implement small-scale riparian rehabilitation works in the Mary River, and other south-eastern Queensland streams, in consultation and collaboration with the local community, Forestry, and LWRRDC. Existing riparian management projects should also be supported, to ensure that necessary medium/long-term monitoring of revegetated plots is carried out. Early results from such projects have clearly demonstrated the adverse affects of livestock trampling on regeneration and establishment of seedlings, so flood-proof fencing to exclude stock from regeneration plots is considered a high priority. The development and implementation of a strategic plan to maintain riparian seed-source trees is also vital to the long-term success of revegetation projects and should be supported.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	35.0	70.0	35.0	35.0	35.0	**210.0**
Operating	19.0	29.0	24.0	24.0	24.0	**120.0**
Total	54.0	99.0	59.0	59.0	59.0	**330.0**

5.2.3. Establish methodologies for monitoring the effectiveness of habitat rehabilitation works, and implement appropriate monitoring programs.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	4.0	14.0	14.0	14.0	14.0	**60.0**
Operating	0.8	8.0	8.0	8.0	8.0	**32.8**
Total	4.8	22.0	22.0	22.0	22.0	**92.8**

5.3. Implement large-scale rehabilitation program for riparian habitats in the Mary River catchment, and other south east Queensland streams, and monitor their effectiveness in enhancing cod habitat (monitoring should be coordinated with the monitoring program for cod - see Actions 3.3 and 6).

5.3.1. Staged implementation program for large-scale riparian rehabilitation works according to plan of action (see Action 5.1.1.). Costing for this action will depend on the outcomes of a number of other actions. In particular, data on the areas targeted for rehabilitation, the severity of habitat degradation, and the outcomes of pilot schemes will be required to accurately determine costs. A report is currently being prepared by Queensland Department of Primary Industries (Forestry - Gympie) to provide cost analyses for riparian rehabilitation works in the Mary River catchment.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries						
Operating						
Total					**To be determined**	

5.4. Implement selected instream rehabilitation works on south-eastern Queensland streams where riparian rehabilitation has stabilised banks.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries			35.0	35.0	35.0	**105.0**
Operating			50.0	50.0	50.0	**150.0**
Total	0	0	85.0	85.0	85.0	**155.0**

Action 6 **Develop and implement a long-term monitoring program for assessment of the status of Mary River cod.**

6.1. Develop long-term monitoring program in consultation with relevant experts.

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	1.4					**1.4**
Operating	0.8					**0.8**
Total	2.2	0	0	0	0	**2.2**

6.2. Implement long-term monitoring program (utilising standardised sampling methodology at a number of sites both within and outside current range of cod. Include replicates.) in key areas of the Mary River and other restocking sites. (Employ biologist and technician for four months each year - operating includes vehicle-hire costs and field allowances)

Estimated cost ($000's)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries		44.0	44.0	44.0	44.0	**176.0**
Operating		10.8	10.8	10.8	10.8	**43.2**
Total	0	54.8	54.8	54.8	54.8	**219.2**

3.3.2. Summary of progress with recovery actions (August 1999)

Action 1. Community involvement / education

1.1. Hold a series of public forums to inform the public of the recovery process, seek their input in development of the recovery plan, and establish community links.

A public forum was convened by the Mary River Cod Recovery Team at Gympie on 28.2.95. Forty-seven community and government representatives attended, and a variety of views and opinions on the content of the draft Recovery Plan were put forward. The general response to the recommended measures was positive – the main point of conjecture related to prioritisation of actions. For example, some individuals saw breeding and restocking of cod as the single most important action, while others focused more on the need for habitat rehabilitation. The Recovery Plan was subsequently developed with high priority given to the concurrent implementation of a range of actions.

The forum was seen by the Recovery Team as a success in terms of establishing communication with the local community. This has subsequently been invaluable in aiding the implementation of various recovery actions.

1.2. Appoint a part-time officer to develop and coordinate a program of community education and involvement.

Funding from the Natural Heritage Trust was obtained in 1996 to employ a Mary River Cod Community Network Coordinator. The position is part time (3 days / week), and current funding carries the position through until July 2000. Activities of the officer to date have included:

- production and distribution of a regular newsletter;
- holding information evenings in regional centres in the Mary River catchment;
- development of an activity program for schools;
- providing displays at rural shows and field days;
- liason with Landcare and other community groups;
- establishing a network of community people interested in cod recovery.

Action 2. Regulations and administrative procedures

2.1. Incorporate the options regulating the take of Mary River cod into QFMA's consultation process for the development of the Freshwater Fisheries Management Plan.

New regulations limiting the take of Mary River cod were brought in in 1998. A possession limit of zero now applies to Mary River cod in the Mary River system. Small sections of Tinana Creek, Coondoo Creek and Obi Obi Creek are now closed to all angling. A possession limit of one cod >50 cm length is still permitted in nine stocked impoundments outside the Mary River catchment.

2.2. Prepare a document listing all key cod habitats in the Mary River, and liaise with Resource Management authorities and landholders to ensure protection of these habitats.

While this exercise has not been formally undertaken, a considerable network of government officers and community people are now aware of key cod areas and requirements. Issues of concern are usually relayed to the Mary River Cod Recovery Team.

2.3. Evaluate current fish translocation practices in south-eastern Queensland in consultation with local angling clubs and fish management groups, and develop a strategy to minimise impacts on cod populations.

The Queensland Department of Primary Industries Fish Translocation Policy recognises the potential threat to endangered species of fish translocations, however, it does not specifically prohibit the release of golden and silver perch into the Mary River system. Fish stocking groups are encouraged to release Australian bass and Mary River cod in preference to non-native species.

2.4. Compile a database listing barriers to fish migration on south-eastern Queensland streams, assess the impacts of these on cod (from the results of research carried out in Action 4.1.), and ensure appropriate fishways are constructed on new barriers where required (and existing barriers, where possible). In the meantime, the Recovery Team should formally inform the relevant authorities (Department of Natural Resources - Water Commercial) that they wish to seek a moratorium on the construction of new storage impoundments in the Mary River system until it can be demonstrated that these will not have an adverse impact on cod populations, or that fishways can be constructed that would alleviate any adverse impacts.

Applications to construct new barriers in south-eastern Queensland are now subject to assessment and approval by DPI Fisheries. The requirements of Mary River cod are given high consideration in carrying out these assessments.

2.5. Develop guidelines for flow releases below impoundments to ensure maintenance of aquatic habitats for Mary River cod, and seek their implementation. [The timing of this action should be integrated with Water Resources timetable for the construction of proposed new impoundments on the Mary River.]

Specific guidelines for environmental flows to maintain habitats for Mary River cod have not been developed. However, DPI Fisheries provides input into the development of flow release regimes based on available information. The known requirements of the Mary River cod and other aquatic species are given high priority in these considerations.

Action 3. Captive breeding and restocking.

3.1. Develop and implement management plan for hatchery production of cod.

A Five-Year Strategic Plan for the production of Mary River cod at Lake Macdonald Hatchery (Cooroy) was produced in 1997. The plan includes recommendations for collaboration with other fish hatcheries. A steering committee including representatives from DPI and Noosa Shire Council oversee implementation of the plan. Daily operations of the hatchery are managed by the Noosa District Community Hatchery Association who report to the steering committee via quarterly meetings.

3.2. Develop and implement criteria for stocking cod for conservation and recreational purposes.

Criteria for the stocking of cod have been developed, partly based on criteria developed for trout cod in Victoria and New South Wales.

3.3. Develop and implement restocking and monitoring program for south-eastern Queensland streams, with priority being given to the Mary River.

In 1998, approximately 40 000 Mary River cod fingerlings were stocked in the Mary River system for conservation purposes, and in impoundments outside the Mary River for recreational purposes. A monitoring program is planned to commence in late 1999.

3.4. Develop and implement program for establishing breeding populations in impoundments for conservation purposes, and monitor the effectiveness of this program.

Only limited effort has been directed towards this action. Trials in 1998 involving the placement of artificial breeding structures in an impoundment were hampered by excessive growth of an exotic aquatic weed species.

Action 4. Research

4.1. Use radio-tracking equipment to investigate the extent and timing of migratory and localised movements of Mary River cod, and thereby gain a better understanding of their habitat requirements.

A radio-tracking study of Mary River cod commenced in 1997 with funding from Environment Australia and Queensland Department of Primary Industries. The study, due to finish in December 1999, has been very successful in identifying movement patterns and habitat utilisation by the cod.

4.2. Review existing procedures for hatchery production of Mary River cod, and carry out research into areas needing improvement.

Review and improvement of hatchery procedures is an ongoing process. The development of a Five-Year Strategic Plan for hatchery production of cod (see 3.1.) has helped to clarify the objectives and focus the activities of the breeding program. Some research into intensive rearing of cod fingerlings indoors has already been undertaken with very promising results. A combination of this method, and the more traditional outdoor pond rearing saw a record production of more than 40 000 cod fingerlings in the 1998 season.

4.3. Carry out mitochondrial DNA analyses of available Mary River cod to determine whether Murray cod genetic material is present, and to assess the genetic variability within and between known populations of Mary River cod.

This potentially expensive exercise has not been undertaken. Genetic management of wild and stocked cod populations has followed a conservative approach based on the advice of geneticists from Queensland Department of Primary Industies and interstate.

4.4. Investigate the swimming capabilities and appropriate fishway designs for Mary River cod.

This work has not been carried out, but results from the radio tracking study of Mary River cod have provided some information on the ability of cod to negotiate stream barriers under various flows. It is very likely that the vertical-slot fishway designs developed in New South Wales and Queensland will be suitable for cod.

Action 5. Habitat rehabilitation.

Stream habitat rehabilitation works are being undertaken on a number of fronts in the Mary River catchment. Various Landcare groups, local council-funded groups and Department of Natural Resources programs are implementing on-ground works, often using the Mary River cod as a focus.

A Mary River Cod Habitat Mapping and Extension Officer was employed in 1997 to develop a plan for the rehabilitation of cod habitats in the Mary River system. The project was recently (1998) extended to facilitate the implementation of on-ground works in identified priority areas. Part of this officers role is also to provide advice to land-owners on appropriate habitat rehabilitation methods.

Action 6. Monitoring program.

A dedicated monitoring program for cod has not been implemented.

It is planned to commence a monitoring program for stocked cod in parts of the Mary River system in late 1999. Cod fingerlings will be marked with subcutaneous VIE (Visual Implanted Elastomer) tags so they can be identified as hatchery-produced individuals. Monitoring will be carried out biannually at selected locations.

3.5. IMPLEMENTATION SCHEDULE

As indicated in the Recovery Objectives and Criteria (section 3.2.), it is anticipated that action will be required until at least 2010 to secure populations of Mary River cod. The following schedule estimates the costs for the first five years of this process (ie. 1996-2001). It is planned to fully review and update this implementation schedule in 2001.

Action No.	Description	Priority	Feasibility	Cost estimate					Total
				Year 1	Year 2	Year 3	Year 4	Year 5	
1	**Establish program of community involvement/education**								
1.1.	Hold public forum to initiate community involvement	1	100%	Funds already received from ANCA					
1.2.	Employ part-time person to develop education/extension program								
1.2.1.	Appoint part-time person	1	100%	1.55	0	0	0	0	1.55
1.2.2.	Contact relevant stakeholders in the catchment	1	100%	10.33	0	0	0	0	10.33
1.2.3.	Develop a "Cod Recovery Network"	1	90%	7.95	4.2	2.0	0	0	14.15
1.2.4.	Involve the Network in on-the-ground actions	1	90%	12.28	15.0	20.0	25.0	25.0	97.28
1.2.5.	Move responsibility from Recovery Team to Network	1	90%	4.95	5.8	3.0	0	0	13.75
2	**Develop and implement regulatory and administrative actions**								
2.1.	Include cod regulation options in QFMA Management Plan	2	100%	0.7	0	0	0	0	0.7
2.2.	Protect cod habitats								
2.2.1.	Document key cod habitats	2	80%	0.5	0	0	0	0	0.5
2.2.2.	Gazette key cod habitats	2	50%	0	3.0	13.2	8.9	14.7	39.8
2.2.3.	Publicise habitat protection measures	2	100%	8.6	0	0	0	0	8.6
2.2.4.	Monitor habitat protection measures	2	90%	0	1.6	1.6	1.6	1.6	6.4
2.3.	Develop translocation strategy to minimise impacts on cod								
2.3.1.	Document current translocation practices in s.e. Qld.	2	100%	0	2.4	0	0	0	2.4
2.3.2.	Assess likely impacts of current translocation practices on cod	2	50%	0	2.5	0	0	0	2.5
2.3.3.	Formulate appropriate translocation strategy	2	90%	0	5.1	0	0	0	5.1

Action No.	Description	Priority	Feasibility	Cost estimate					Total
				Year 1	Year 2	Year 3	Year 4	Year 5	
2.4.	Finalise and implement procedures to maintain fish passage								
2.4.1.	Locate and describe existing barriers on s.e. Qld streams	2	100%	0	0	6.2	0	0	6.2
2.4.2.	Assess likely impacts of barriers on cod	2	80%	0	0	1.2	0	0	1.2
2.4.3.	Ensure suitable fishways are built where required	2	80%	0	0	7.1	3.7	3.7	14.5
2.5.	Develop and implement environmental flow guidelines for cod								
2.5.1.	Compile resource document for Mary River	2	90%	0	19.1	0	0	0	19.1
2.5.2.	Hold a workshop to identify environmental flow requirements of cod	2	90%	0	14.9	0	0	0	14.9
2.5.3.	Seek flow releases to meet cod's needs	2	80%	0	1.5	0	0	0	1.5
2.6.	Establish linkages with existing studies in the Mary River								
2.6.1.	Identify existing studies, and determine opportunities for linkages	2	100%	2.2	2.2	2.2	2.2	2.2	11.0
2.6.2.	Develop joint projects/proposals relevant to the cod Recovery Plan	2	90%	2.2	2.2	2.2	2.2	2.2	11.0
3	**Develop and implement plan for captive-breeding and restocking**								
3.1.	Develop and implement management plan for captive-breeding								
3.1.1.	Convene 2-day workshop to develop captive-breeding management plan	1	100%	2.6	0	0	0	0	2.6
3.1.2.	Liaise with hatchery operators to implement and review management plan	1	100%	1.0	1.0	0	0	0	2.0
3.1.3.	Restore funding to Lake Macdonald hatchery	1	100%	40.0	40.0	40.0	40.0	40.0	200.0
3.1.4	Develop a plan to ensure the long-term security of hatchery production	1	80%	0 0	2.0 0	0 0	0 0	0 0	2.0 0
3.2.	Develop and implement stocking criteria for conservation/recreation	2	90%	1.4	0	0	0	0	1.4
3.3.	Develop and implement stocking/monitoring program for cod in s.e Qld								
3.3.1.	Develop strategic plan for cod restocking using criteria in Action 3.2.	2	100%	0	1.5	0	0	0	1.5
3.3.2.	Undertake restocking as per strategic plan (monitoring - see Action 2.7.2.)	2	80%	0	0	21.5	21.5	21.5	64.5
3.4.	Develop and implement program to establish breeding populations in dams								
3.4.1.	Develop program based on existing data, and results from Action 4.2.4.	2	60%	0	0	2.2	0	0	2.2

Action No.	Description	Priority	Feasibility	Cost estimate					Total
				Year 1	Year 2	Year 3	Year 4	Year 5	
3.4.2.	Implement program, and liaise with fish management groups to monitor success	2	60%	0	0	27.9	27.9	20.9	76.7
4	**Research wild populations and captive-breeding techniques**								
4.1.	Investigate movements and habitat requirements using radio-tracking								
4.1.1.	Purchase radio-tracking equipment	1	100%	21.0	4.5	0	0	0	25.5
4.1.2.	Undertake training in radio-tracking techniques	1	100%	1.1	0	0	0	0	1.1
4.1.3.	Implant transmitters in cod from all areas of the Mary River	1	80%	14.7	7.4	0	0	0	22.1
4.1.4.	Monitor movements of tagged cod for two years	1	90%	42.0	45.0	0	0	0	87.0
4.1.5.	Formulate habitat protection/enhancement measures based on results	1	90%	0.6	1.2	0	0	0	1.8
4.2.	Undertake research to improve captive-breeding success, and investigate artificial enhancement of breeding in dams								
4.2.1.	Develop improved broodstock management techniques	1	80%	11.5	10.5	0	0	0	22.0
4.2.2.	Develop improved egg management procedures	1	80%	11.5	9.5	0	0	0	21.0
4.2.3.	Develop improved larval management procedures	1	80%	11.5	9.5	0	0	0	21.0
4.2.4.	Develop artificial spawning structures for cod in impoundments, and assess their use by resident cod	2	60%	10.0	10.0	0	0	0	20.0
4.3	Investigate genetic composition of available Mary River cod via mitochondrial DNA analysis								
4.3.1.	Carry out mitochondrial DNA analysis on hatchery broodstock and preserved cod specimens to determine whether Murray cod genetic material is present, and advise hatcheries accordingly	1	90%	10.5	0	0	0	0	10.5
4.3.2.	Carry out mitochondrial DNA analysis on new cod broodstock, and assist in the monitoring program (Action 2.7) by genetically typing hatchery progeny	1	90%	0	6.2	6.2	6.2	6.2	24.8
4.4.	Investigate the potential for Mary River cod to utilise fishways								
4.4.1.	Identify the extent and timing of movements of Mary River cod	1	80%	see Action 4.1					
4.4.2.	Investigate the swimming ability and behaviour of cod in fishways	2	75%	0	0	106.5	56.5	0	163.0

Action No.	Description	Priority	Feasibility	Cost estimate					Total
				Year 1	Year 2	Year 3	Year 4	Year 5	
4.4.3	Ensure suitable fishways are built where required	2	80%	see Action 2.4.3.					
5	**Restore Mary River cod habitats**								
5.1.	Develop a strategic plan for restoration of cod habitats in s.e.Qld								
5.1.1.	Identify areas of suitable cod habitat, and develop a plan to expand and connect these	1	100%	2.2	0	0	0	0	2.2
5.1.2.	Investigate opportunities for collaborating with existing works	1	100%	2.2	0	0	0	0	2.2
5.2.	Implement pilot habitat rehabilitation programs in key areas of the Mary R								
5.2.1.	Undertake small-scale instream rehabilitation works	1	100%	35.0	0	0	0	0	35.0
5.2.2.	Implement small-scale riparian rehabilitation works	1	100%	54.0	99.0	59.0	59.0	59.0	330.0
5.2.3.	Establish monitoring methodology for habitats, and implement monitoring	1	100%	4.8	22.0	22.0	22.0	22.0	92.8
5.3.	Large-scale rehabilitation program for riparian habitats in S.E Qld streams								
5.3.1.	Staged implementation of riparian rehabilitation and monitoring as per Action 5.1.	1	60%						To be determined
5.4.	Implement rehabilitation program for instream habitats as per Action 5.1.	1	60%	0	0	85.0	85.0	85.0	255.0
6	**Develop and implement long-term monitoring program for cod**								
6.1.	Develop monitoring program in consultation with experts	1	100%	2.2	0	0	0	0	2.2
6.2.	Implement monitoring program in Mary River and other restocking sites	1	90%	0	54.8	54.8	54.8	54.8	219.2
	TOTAL COST			**331.1**	**403.6**	**483.8**	**416.5**	**348.8**	**1993.8**

3.5. POTENTIAL SOCIAL AND ECONOMIC IMPACTS OF THE RECOVERY PROCESS

It is anticipated that the implementation of recovery actions will lead to long term social and economic benefits to residents of the Mary River catchment. These more than balance any perceived short-term adverse impacts.

Regulations
The imposition of strict regulations on recreational angling for Mary River cod will affect the activities of only a limited number of anglers. Recreational angling bodies including SUNFISH and the Australian National Sportfishing Association are in favour of the new regulations. There are still opportunities for anglers to catch and keep a Mary River cod in stocked impoundments outside the Mary River system, or to practice catch-and-release within the catchment. The extent of areas closed to all angling to protect cod populations is very small. Only three areas, with a combined stream length of approximately ten kilometres, are affected. Most of this is within State Forest, which already imposes controls on recreational angling under the *Forestry Act 1959.*

As the primary objective of this recovery plan is "…To secure and enhance populations of Mary River cod in the Mary River system….", it is anticipated that some of the recommended angling restrictions would be relaxed in the long term. The potential for recreational anglers to target and catch a cod will then be much better than at present.

Water Storage Impoundments
This recovery plan recommends "…that a moratorium should be placed on the construction of new water storage impoundments in the Mary River system until information is available to indicate the expected effect of these on cod..." (p. 38). Specific areas of concern are changes to water quality and flow regimes and the obstruction of fish passage. These factors are already subject to increasing scrutiny from resource managers and the wider community for their potential adverse impacts on stream biota and habitats in general. Management actions to ameliorate their adverse effects, including providing for environmental flow requirements and constructing fishways, may increase construction and operating costs of an impoundment. However, the potential long-term social and economic benefits of maintaining a healthy, intact environment far outweigh any short-term costs. Proactive management to circumvent problems of depleted fish populations, polluted or eutrophic water bodies and hazardous algal blooms will always be a better, and usually a cheaper, option than reactive management to try and fix the problem once it has become serious enough to attract political interest

Fish Translocations
This Recovery Plan recommends that there should be no "…further introduction of non-indigenous fish species into the Mary River system (including farm dams)…"(p.39). While the impacts on cod populations of previous fish introductions into the Mary River system are unknown, there are many examples in the scientific literature of such translocations leading to reduced abundance, and even extirpation, of resident species. The Queensland Department of Primary Industries Fish Translocation Policy allows for continued stocking of golden perch and silver perch in the Mary River system in line with past practice. While silver perch appear not to be very abundant, golden perch are relatively common (Simpson 1994) and may compete with Mary River cod for food and habitat. There is support from some recreational anglers for the continued stocking of golden and silver perch in impoundments in

the Mary River system. A ban on further stocking of these species could be partly compensated by increased stocking of Mary River cod and Australian bass (both native to the Mary River system), but would draw opposition from some parts of the community.

Habitat Rehabilitation

The rehabilitation of instream and riparian habitats is often a costly and slow process. The types of rehabilitation that would benefit Mary River cod are in line with general stream and riparian works that are already being implemented and (in some cases) gaining community acceptance in the Mary catchment. These works are often carried out with funding from both government agencies and landholders. There may be opportunities to specifically target critical areas for Mary River cod with funding that is now, and will become, available.

Carrying out habitat rehabilitation works on private land will not become a legislated requirement – rather, the present system of landowners voluntarily seeking technical and funding assistance is expected to grow through the demonstration of successful projects. However, it is hoped that local council by-laws limiting the clearing of riparian vegetation become more widespread and better enforced so as to protect existing habitats.

While there are few, if any, anticipated adverse social or economic impacts of habitat rehabilitation actions, the potential for social and economic gains is significant. The benefits of good water quality, productive waterways, reduced levels of bank erosion (and therefore minimal loss of productive land area through erosion during floods) and a generally healthy, intact riverine ecosystem will be enjoyed by the whole community.

3.6. TERMINATION CRITERIA AND MANAGEMENT PLAN DEVELOPMENT

The Recovery Team has the responsibility of overseeing the implementation of this Recovery Plan. This role of the Recovery Team can cease when it is clear that the recovery actions are on track and will proceed without the teams further input. The following criteria will be used to assess the appropriate stage for the Recovery Team to cease meeting on a regular basis:

- Cod Recovery Network established and operating effectively
- Appropriate regulations in place to protect cod and their habitats
- Administrative mechanisms in place to ensure that cod and their habitats are given high priority in management decisions of resource management agencies
- Long-term captive-breeding program implemented, and restocking program established
- Research program underway with ongoing commitment from relevant government agencies to seek appropriate funding
- Large-scale habitat rehabilitation program underway with ongoing commitment from relevant government agencies
- Long-term monitoring program implemented with ongoing commitment from relevant government agencies

There will be an ongoing commitment for the agency with the responsibility for the management of the Mary River cod to annually assess progress with the implementation of the Recovery Plan. If significant problems are detected, the agency should reconvene the Recovery Team for advice on overcoming these problems.

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APPENDIX 1. Costing Of Budgets

It is anticipated that many of the on-ground actions will be undertaken with assistance from volunteer labour. The time donated by volunteers has not been identified in the budgets.

1. Salaries

The costing of salary components of the Recovery Actions is based on the Queensland Public Service (Remuneration) Interim Award as from 1.5.96. Calculations are based on the following rates of pay:

Technical Officer (Level 2)	$27 772 - $32 925 per annum
Technical Officer (Level 3)	$34 905 - $37 741 " "
Biologist (Level 2)	$29 489 - $37 741 " "
Biologist (Level 3)	$39 651 - $43 295 " "
Biologist (Level 4)	$46 097 - $49 858 " "

On-costs (eg. leave loading, superannuation, administration costs) are calculated at 22% of the salary.

2. Operating

a). Field Expenses

The current Queensland Public Service Award (1996) provides the following allowances for officers undertaking field operations:

Meals	$42 per day
Incidental expenses	$10 per day
Hotel/Motel Accomodation	$55 per night
Camping Accomodation	remuneration of campsite fees

b). Vehicle Expenses

Vehicle hire expenses are included in costings for all actions requiring field work or travel for other purposes. These are based on current (February 1996) lease rates from QFLEET as outlined below. The prices given relate to the 12 month lease rate, and include 40 000 km per vehicle.

Toyota Hilux 4WD Deisel Utility Dual-cab	$439/month
GMH Commodore sedan	$220/month

3. Purchase of Materials and Equipment

The purchase of materials or equipment required to carry out any action (eg. stationery, radio-telemetry equipment) will be undertaken according to the guidelines set out in the QDPI Corporate Standard AS.12.002. 'Procurement Procedures'.

APPENDIX 2. The Mary River Cod Breeding And Restocking Program

Techniques for the captive-breeding of Mary River cod have been developed over the past sixteen years, largely through the efforts of Mr Gerry Cook at the Lake Macdonald Hatchery at Cooroy. Since 1996, daily operations at the hatchery have been managed by the Noosa District Community Hatchery Association (NDCHA), of which Mr Cook is a founding member. The NDCHA provides quarterly reports to a steering committee comprising representatives from Noosa Shire Council (who own the hatchery), Queensland Department of Primary Industries and the Mary River Cod Community Network. A Five Year Strategic Plan developed by the steering committee provides a framework for hatchery operations. The primary objective of the Lake Macdonald Hatchery is the production of Mary River cod fingerlings for a restocking program.

Funding to operate the Lake Macdonald Hatchery is provided by Noosa Shire Council and Queensland Department of Primary Industries. Additional funding for the period 1998-2001 has been provided through a Natural Heritage Trust grant. Successful operation of the hatchery relies heavily on volunteer labour.

Only one other privately owned hatchery currently has a licence to hold and produce Mary River cod. The Queensland Fisheries Management Authority has temporarily halted cod production by other hatcheries so as to protect wild stocks against depletion from broodstock collection. Fewer producers also make it a relatively simple task to manage the production of cod according to strict genetic guidelines.

Hatchery produced cod fingerlings have been stocked into south-east Queensland impoundments since 1983 (Table 4, p.9). Approximately 94% of these stocked cod were produced at the Lake Macdonald Hatchery. Riverine stocking of cod commenced in 1998, with approximately 39 000 fingerlings released at 42 sites in the Mary River system. Again, the vast majority of these were produced at Lake Macdonald. It is planned to continue to stock both riverine locations and impoundments with cod.

A summary of the breeding techniques used at the Lake Macdonald Hatchery are outlined below.

Breeding techniques

Preparation for spawning

Mary River cod are allowed to spawn naturally in earthen ponds. Hormone-induced spawning has been trialed on several occasions, and has met with variable success. Hormone-induction allows more control over the spawning process than natural spawning, but subjects the broodstock to handling stresses. Further trials with hormone-induction are warranted.

In April, ponds to be used for spawning are drained and allowed to dry. Spawning pipes are fitted with removable liners and placed in the pond. Ponds are filled with water from Lake Macdonald, and pairs of cod selected and introduced into the pond. Fights among pairs often break out as they establish new territories in the pond, and deaths have resulted. Fighting can be minimised by introducing fish into the pond at the same time rather than staggering introductions, as some fish will quickly lay claim to the whole pond if allowed.

Convenience and simplicity has dictated that pieces of fish flesh form the bulk of the diet of broodstock, although other items including squid, marine crustaceans, and frozen day-old chickens have been tried at times. The high variability in quantity and quality of eggs produced between individuals and between seasons suggests that an investigation into conditioning of broodstock is warranted. It is likely that an improved feeding regime would help ensure optimal condition of broodstock, which may then be translated into production of more eggs of high quality.

Since 1997, all cod broodstock have been individually marked with passive-integrated-transponder (PIT) tags. This allows accurate record keeping of length, weight, disease or injury management and breeding performance from year to year.

Spawning and egg management
As soon as eggs are detected in the spawning pipes (either by a diver, or by observation from the bank), the liner carrying the eggs is removed to a trough of running water in the hatchery. The liner is cut into smaller pieces which are then suspended in the water. Any clumps of eggs are gently broken up in the trough and dead eggs removed. The eggs are given a daily formalin bath (1 ppt for 30 minutes) to control fungus, and any dead eggs removed.

Fungal outbreaks have occurred on egg masses left in ponds for several days, so it is of vital importance that detection and removal of eggs from the ponds occurs as soon as possible after spawning. An improved method of egg detection and removal is needed to minimise fungal disease.

Water is circulated to the troughs via three 5 000 l tanks with thermostatically controlled heaters, and partial water changes are made at frequent intervals. Dissolved oxygen and ammonia levels are monitored daily. Both filtered water from Lake Macdonald and dechlorinated water from the domestic supply are used.

Larval management
Larvae begin to feed on brine shrimp produced in the hatchery and zooplankton from outdoor ponds around 5-7 days after hatching. Once feeding has commenced, the larvae are given a prophylactic salt bath (10 ppt for 30 minutes) every three days.

Larvae are on-grown to the desired stocking size either in outdoor ponds or in tanks and troughs indoors. Transfer to outdoor ponds occurs at 3-6 weeks of age, where the larvae rely largely on a cultured plankton bloom for food. High mortalities often occur in ponds due to predatory birds and insects and other identified causes. Indoor grow-out methods are still being developed, and early results are promising. Losses through predation are nil (apart from some cannibalism), and diseases and other problems with larval growth or health can be more easily detected and addressed. Harvest of larvae from indoor tanks is much easier and potentially less stressful to the fish than from outdoor ponds. The main problem with indoor rearing to date has been relatively slow growth of larvae. This should be overcome as optimum stocking densities and feeding regimes are determined.

Harvesting and stocking
Prior to 1998, Mary River cod fingerlings were harvested and stocked out when their total length reached approximately 50 mm (usually around ten weeks after hatching). This size is a standard requirement of the DPI Recreational Fisheries Enhancement Program. With the

commencement of riverine stocking for conservation purposes in 1998, it was decided to reduce the stocking size to between 30 and 40 mm. Harvesting the fingerlings at this smaller size generally means that a greater number are available for stocking (as the longer a fingerling is held in the hatchery, the greater it's chance of succumbing to disease, predation or other mortatility). Stocking fish at the smaller size provides a greater opportunity for natural selection (as opposed to 'hatchery selection') to operate. Fingerlings that are to be stocked in impoundments to enhance the recreational fishery are still grown to 50 mm as it is thought that the larger size provides better protection from predation.

Harvesting from outdoor ponds involves draining the pond and netting the fingerlings from a concrete sump. The process can be slow, muddy, and made difficult by large numbers of tadpoles and insect larvae which must be sorted from the fingerlings. Fingerlings raised indoors are simply netted from their tank or trough after lowering the water level. Transport of fingerlings to the stocking site is done either in large aerated carriers, or in oxygenated plastic bags.

Riverine stocking sites are selected for their apparent capacity to support the establishment of a new population. This determination is based on a visual assessment of the available habitat both in terms of quantity and condition. Highly degraded habitats, or small areas of habitat obviously isolated from other suitable areas, are avoided. The approach to stocking has been to select a reach of stream and stock fingerlings throughout. In some cases, this has included whole tributaries – in other cases, only a stretch of less than 1 km adjacent to the main river has been stocked. DPI plan to monitor the success of stockings by regular sampling at selected locations.

Genetic guidelines for the Mary River cod breeding program

Captive-breeding of Mary River cod has proceeded over the past fifteen years without clear guidelines to ensure the long-term genetic integrity of the fish produced. As the focus of the breeding program has now changed from recreational enhancement to conservation and recovery, it is a high priority that fingerlings are produced according to strict genetic guidelines (Allendorf & Ryman 1987; Brown 1987). New breeding and restocking guidelines for Mary River cod are based on those employed in the trout cod program in Victoria and New South Wales (Douglas *et. al* 1994).

Broodstock collection

Mary River cod broodstock are collected from as wide a geographic range as possible. This strategy is considered appropriate for a species that has suffered a contraction in range and abundance, and for which the genetic variability within and between remnant populations is unknown (Brown, 1987). It is unlikely that significant genetic differences have become established across the range of the cod, as any isolation of populations is likely to be a relatively recent event. However, collection of brood fish from a wide area will help ensure that any variability that does exist among remnant cod populations will be represented in the breeding program. New broodstock are sought each year following the breeding season.

Broodstock number

A target of 200 broodfish has been set for native fish propagation programs where stock rehabilitation is the objective (Brown, 1987). This is considered adequate to represent the wild gene pool. Brown (1987) recommends that the 200 fish should be collected over a period of two minimum generation intervals of the species in question (eg. about ten years for

Mary River cod), and regularly interchanged with hatchery fish. Allendorf and Ryman (1987) suggest that 25 males and 25 females represents an absolute minimum size for a founder population. Douglas *et. al* (1994) consider the 25-50 trout cod broodstock held at each of two facilities adequate to meet recommended genetic guidelines, provided they are regularly replaced with wild fish.

The current collection of Mary River cod broodstock (40-50 individuals between the two cod hatcheries) is probably adequate, as long as they are regularly replaced with wild stock.

Broodstock management
All cod broodstock are individually tagged with passive integrated transponder (PIT) tags for accurate record keeping. Tagging will also ensure that released broodstock are not subsequently re-introduced into the breeding program. Fish are paired roughly according to size, as aggressive encounters during spawning sometimes result in death, particularly of smaller individuals. A broodstock sex ratio of 1:1 is maintained if possible to maximise genetic variability of the progeny. Repeated matings between the same pair is avoided for the same reason.

Broodstock collected from areas where prior stocking has not occurred are kept separate from those collected in stocked areas (eg. Lake Macdonald). This is to minimise the chance of inbreeding. The progeny of broodstock collected from stocked areas are not used in the riverine stocking program, but are stocked in impoundments outside the Mary River system.

Stocking
Prior to stocking, fingerlings from as many different spawnings as are available are mixed. A minimum of five spawnings is recommended in order to represent 95% of the genetic variation in the base population, although rare alleles might be excluded (Brown, 1987). Fingerlings are not released into areas containing known remnant populations where they could swamp rare alleles. It is planned to stock sites for at least four consecutive years so as to maximise the genetic variability of the stocked population, and to quickly establish a broad age distribution.