The Status of Macquarie Perch *Macquaria australasica* in the Mongarlowe River in 2007 and 2008.

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A Report to the Friends of the Mongarlowe River Inc.

FRIENDS OF THE MONGARLOWE RIVER INC

preserving the integrity of our river and its catchment

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Cover Photograph: Mongarlowe River at Site 7, upstream of Bourkes Crossing. Photo Mark Lintermans.

Acknowledgments

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Executive summary

Macquarie perch *Macquaria australasica* is a nationally threatened fish species. It is listed or recommended to be listed as endangered nationally, and in all the States and Territories in which it occurs (ACT, NSW, Vic and SA (Lintermans 2007).

It has long been known that there is a population of Macquarie perch in the Mongarlowe River. Bishop and Tilzey (1978) reported on aspects of the ecology of Mongarlowe Macquarie perch in a baseline study for the proposed Welcome Reef Dam and Bishop (1979) conducted several years of research into the distribution and ecology of the species in this river. As Macquarie perch continue to decline in distribution and abundance, and in the face of increasing development pressure on Macquarie perch habitats, an investigation of the current status of the species in the Mongarlowe was initiated.

As sampling of adult Macquarie perch can be difficult without causing detrimental impacts to the captured individuals, the sampling program was structured to capture juvenile fish from the previous spawning season. A sampling technique that provides robust information on the breeding status of the population was considered suitable to provide information on whether the Macquarie perch population was 'healthy' (i.e. breeding at sustainable levels).

The aims of the current program were to:

- Investigate levels of recruitment in the Mongarlowe Macquarie perch population
- Investigate geographical and inter-annual variation in recruitment success

Six sites were sampled in 2007, with one of these sites re-sampled (Junction Pool) and an additional site (Bourkes Crossing) sampled in 2008. The sites were sampled with ten single-winged fyke nets and five small collapsible bait traps set at each site.

A total of 158 fish from six species (five native and one alien) were captured and another species (alien) was observed (Table A). The species captured were:

Native:

Macquarie perch	*Macquaria australasica*
Longfinned eel	*Anguilla reinhardtii*
Mountain galaxias	*Galaxias olidus*
Firetailed gudgeon	*Hypseleotris galii*
Carp gudgeon	*Hypseleotris spp*

Alien

Eastern Gambusia	*Gambusia holbrooki*
Carp	*Cyprinus carpio*

Non-target species captured were Platypus and Eastern snake-necked tortoise with Platypus captured at 6 sites and tortoises at 3 sites (Table B).

Table A. Number and species of fish recorded in the Mongarlowe River.

Species	Junction Pool		Riverside	Bentleys Point	Shepherds Farm	Chinamans Hole	Mongarlowe Bridge	Bourkes Crossing
	2007	*2008*	*2007*	*2007*	*2007*	*2007*	*2007*	*2008*
Macquarie perch	1	1	-	-	-	-	-	1
Longfinned eel	1		3	1	1	-	1	
Mountain galaxias	-		9	1	7	9	1	16
Firetailed gudgeon	5	5	19	4	1	-	-	
Carp gudgeon	9	4	18	27	-	-	-	
Carp	Obs	Obs	-	-	-	-	-	
Eastern gambusia	Obs	3	Obs	10	-	-	-	
Total	**16**	**13**	**49**	**43**	**9**	**9**	**2**	**17**

Table B. Number and species of non-target species captured in the Mongarlowe River.

Site	Platypus	Eastern snake-necked tortoise
Junction Pool	1	1
Riverside	1*	
Bentleys Point	1	4
Shepherds Farm		2
Chinamans Hole	1	
Mongarlowe Bridge	2	
Bourkes Crossing	1	

*plus 2 observed

The abundance of fish recorded was surprisingly low, with an average of only 19.75 fish captured per sampling night. The majority of fish sampled (148 of 158 fish) were from small-bodied species, with an extremely low number of large-bodied or angling species recorded.

Only three Macquarie Perch were captured during the sampling program with all fish being young of the year. The geographical spread of young-of-year fish detected in the current survey encompasses the full range o sites from Bourkes Crossing to Junction Pool, indicating that recruitment occurs over the full range of the species in the Mongarlowe River.

That adult Macquarie perch are still present in the Mongarlowe River is beyond question. If young-of-year fish are present, there must be adults present to produce them. There are also a number of recent records of adult Macquarie perch from the Mongarlowe River (Table 7).

The total number of Macquarie perch captured was extremely low, indicating poor recruitment by this species on both years of the survey. This lack of recruitment detected during the current project raises some concerns about the future of the population in the Mongarlowe River, with prolonged failure to recruit or prolonged low levels of recruitment a cause for concern. It is unknown whether the low recruitment detected in the current study represents the normal recruitment level for this population (i.e. a small population just ticking over). It may be that recruitment levels have been suppressed by the extended drought, which has affected Macquarie

perch populations in some rivers in the Murray-Darling Basin. Whilst the abundance of adult Macquarie perch cannot be assessed by the current survey, (because of the sampling techniques used) it seems likely that the population has declined further since the study of Bishop (1979) and Bishop and Tilzey (1978), and unless recruitment levels improve in the near future, its future looks grim.

The current survey indicates that two alien fish species (Carp and Eastern gambusia) are not distributed throughout the entire length of the Mongarlowe River, and further investigation of the distribution of these two species would be beneficial.

Recommendations

Macquarie perch

1. The genetic identity of the Mongarlowe River Macquarie perch population needs to be confirmed. It is considered likely that the Mongarlowe River population is the result of a translocation from the Murray-Darling Basin, but this needs confirmation. The genetic identity (source) of the population will influence how the population is managed.

2. Monitoring of recruitment levels should be conducted annually to determine the long-term recruitment patterns in the population. Monitoring should be conducted across the full known range of the species in the Mongarlowe. The relationship between rainfall and flow patterns should also be investigated to determine if they are correlated with recruitment success.

3. The upstream limit of the Macquarie perch population in the Mongarlowe River needs to be determined. Does the species extend into the headwaters of the Monga National Park?

4. Barriers to Macquarie perch movement in the Mongarlowe (e.g. Bourkes Crossing ford) need to be identified and remediated so that fish movement is not impeded.

5. Monitoring techniques for Macquarie perch that are able to be utilised by the general community need to be investigated and developed. The interest and involvement of the local community has a much higher chance of being maintained if they can be actively involved in the data collection process.

6. There is increasing pressure from rural subdivision in the Mongarlowe valley, and the issue of allocation of water resources between consumptive and environmental uses and how these might impact on the Macquarie perch population needs to be considered by local and state authorities.

Alien fish

7. The upstream distributional limit in the river of the alien species Carp and Eastern Gambusia should be determined and any barriers or impediments to upstream expansion of these species should be identified and where possible maintained or augmented.

8. The presence of Carp and Eastern Gambusia in farm dams in the middle and upper catchment (above Bentleys Point) should be investigated, and control measures considered for any populations located

Introduction

Macquarie perch *Macquaria australasica* is a nationally threatened fish species. It is listed or recommended to be listed as endangered nationally, and in all the States and Territories in which it occurs (ACT, NSW, Vic and SA (Lintermans 2007). The species does not occur in Queensland. Populations still exist in NSW, Vic and ACT, but it is no longer known from SA, where it is known only from two specimens in the South Australian Museum, collected in 1917 and 1918 (Hammer *et a*l. 2007).

It has long been known that there is a population of Macquarie perch in the Mongarlowe River. Hungerford (1971) reported on the presence of Macquarie perch in a "….stream somewhere between Canberra and the coast." These fish were the result of a 1969 fishing expedition by Bryan Pratt and Keith Shields and the stream was the Mongarlowe River (Bryan Pratt pers. Comm. 25 July 2008). Bishop and Tilzey (1978) reported on aspects of the ecology of Mongarlowe Macquarie perch in a baseline study for the proposed Welcome Reef Dam and Bishop (1979) conducted several years of research into the distribution and ecology of the species in this river. Pratt (1979) also records the presence of the species in the Mongarlowe River. Bishop (1979) records that Macquarie perch was actively sought by anglers in the Mongarlowe from the early 1900s, and that some local families subsisted almost entirely on Macquarie perch in the Great Depression. The records of the Braidwood Fishermans Club (reported in Bishop 1979) provide valuable information on the catch of this species from 1970 to 1974.

As Macquarie perch continue to decline in distribution and abundance, and in the face of increasing development pressure on Macquarie perch habitats, an investigation of the current status of the species in the Mongarlowe was initiated.

Current knowledge of Macquarie perch

There has been considerable debate about whether there is more than one taxon within Macquarie perch. It is considered that there are at least two taxa contained within Macquarie perch, one of which occurs in the western or inland rivers (the Murray-Darling form) and one in the eastern or coastal rivers (the coastal form). The coastal form is considerably smaller than the Murray-Darling form, growing to about 180 mm total length, and is only found in two catchments in NSW: the Hawkesbury-Nepean and the Shoalhaven (Harris and Rowland 1996). Dufty (1986) considered that these two coastal populations might be distinct from each other, as well as being distinct from the Murray-Darling form. Genetic studies are currently underway to determine how many taxa are included within Macquarie perch.

Description

Macquarie perch is a moderately-sized, deep-bodied, laterally-compressed fish with large white eyes. The predominant body colour is bluish-grey to black on the dorsal and lateral surfaces with a whitish ventral surface. Colouration is variable between populations, with some coastal populations being quite mottled (Harris & Rowland 1996; Merrick and Schmida 1984). The lateral line is obvious and there are conspicuous open pores on the lower jaw. Adult specimens possess a distinct "humped back" and the tail is rounded. In the Murray-Darling form the maximum length is 460 mm and maximum weight is 3.5 kg, but individuals larger than 350 mm

or one kilogram are uncommon (Harris & Rowland 1996). The mouth is large with jaws equal in length.

Distribution

The preferred habitat is cool, shaded, upland streams with deep rocky pools and substantial cover (Cadwallader 1979). The species will also survive well in impoundments with suitable feeder streams in which to breed. The species now seems to be confined to the upper reaches of catchments which are more pristine and less impacted by agriculture and sedimentation.

The Murray-Darling form is typically found in the cooler, upper reaches of the Murray-Darling River system in Victoria, New South Wales and the Australian Capital Territory. The species was introduced into some coastal drainages in Victoria and NSW in the late 1800s and early 1900s (Stead 1913). Populations of the Murray-Darling form are currently known from the upper reaches of the Murrumbidgee, Lachlan and Murray catchments in New South Wales; the Goulburn, Broken, Ovens and Mitta Mitta catchments in Victoria; and the Paddys, Cotter and Murumbidgee rivers in the Australian Capital Territory. They have been stocked or translocated into a number of reservoirs including Talbingo, Cataract, Khancoban and Coliban reservoirs, and translocated into streams including the Yarra, Mongarlowe and Wannon rivers, and Sevens Creek. In The Canberra region they have been translocated past a natural barrier on the Queanbeyan River (Lintermans 2006a) and the Molonglo and upper Cotter Rivers (Lintermans 2006b). The coastal form is only known from the Shoalhaven and Hawkesbury-Nepean systems in NSW (Harris & Rowland 1996; Morris *et al*. 2001).

Behaviour and biology

Macquaria australasica are reported to live for up to 17 years (Douglas *et al*. 2002). Males generally reach sexual maturity at two years of age and 210 mm total length, and females at three years and 300 mm total length (Lake 1967; Harris and Rowland 1996).However, in the Cotter River, ACT, males mature at about 140–150 mm TL (Ebner and Lintermans 2007; Lintermans 2007) and in Lake Dartmouth ripe males have been recorded down to lengths of 117 mm (Douglas *et al*. 2002). Fish in reservoirs undertake a spawning migration into inflowing rivers. Fish gather in schools before spawning which can last several weeks (Battaglene 1988). Spawning occurs in late spring/summer when water temperatures reach approximately 16.5°C (Cadwallader and Rogan 1977) with fish depositing eggs above riffles or fast-flowing sections of river. The eggs are then washed downstream where they lodge in gravel or rocky areas until hatching. (Cadwallader and Rogan 1977).

Fecundity is approximately 31,000 eggs per kilogram of fish weight (Cadwallader and Rogan 1977), with females carrying up to 110,000 eggs (Battaglene 1988). Mature eggs are 1 to 2 mm in diameter and cream coloured. After fertilisation the eggs swell to approximately 4 mm diameter and are amber coloured (Battaglene 1988). Larvae hatch in 10-11 days at water temperatures of 15-17°C (Gooley 1986) with the larvae being about 7 mm long upon hatching (Battaglene 1988).

The diet of *M. australasica* consists predominantly of small benthic aquatic insect larvae, particularly mayflies, caddisflies and midges. Shrimps, yabbies, dragonfly larvae and molluscs are also eaten (McKeown 1934; Cadwallader and Eden 1979; Butcher 1945, 1947; Bishop 1979; Battaglene 1988; Lintermans 2006a).

Conservation status

The species is listed as endangered nationally as well as in the ACT, Vic and SA (ACT Government 1999, 2007; DSE 2003; DEH 2003). The species is currently listed as vulnerable in NSW, but has been recommended for upgrading to endangered (Fisheries Scientific Committee 2006). Concern over the decline in distribution and abundance of the species was first raised by Lake (1971) who rated it as one of the top four most seriously threatened species. Bishop (1979) considered Macquarie perch endangered and the Council of Nature Conservation Ministers (CONCOM) list of endangered Australian vertebrates, adopted in 1980, included Macquarie perch (Burbidge & Jenkins 1984). Michaelis (1985) in her review of nationally threatened inland fish species, classified Macquarie perch as 'vulnerable'.

In 1985 the Australian Society for Fish Biology (ASFB) listed Macquarie perch as a nationally 'restricted' species (Harris 1987). The definition of 'restricted' was "Taxa which are not presently in danger but which occur in restricted areas, or which have suffered a long term reduction in distribution and/or abundance and are now uncommon". The reason for the lowering of the threatened species category for Macquarie perch was that whilst the Murray-Darling populations had declined quite dramatically in both distribution and abundance, the New South Wales coastal populations appeared to be doing quite well.

The ASFB reviewed the national threatened fishes listing in 1988 and annually thereafter and in 1992 the status of Macquarie perch was raised to 'Indeterminate' (ASFB 1992). The definition of indeterminate is "Taxa which are likely to fall into the Endangered, Vulnerable or Potentially Threatened category but for which insufficient data are available to make an assessment. (Require investigation)". The indeterminate categorisation occurred because of the taxonomic confusion as to whether the coastal populations were in fact a separate species. It had also become apparent that the New South Wales coastal populations were declining as well. The Action Plan for Australian Freshwater Fishes (Wager and Jackson 1993) classified Macquarie perch as 'Poorly Known'. The species was listed as endangered by the ASFB in 1998 (ASFB 1998) and nationally in 1999 (ANZECC 1999).

The breeding biology of the species makes it highly susceptible to sediment addition to streams, which smothers spawning sites and eggs. The spread of the virus, EHN by the alien species Redfin perch and trout and is also considered to have played a part in the widespread decline of Macquarie perch.

Conservation Status

National	ACT	NSW	VIC	SA
ASFB Endangered *EPBC* Endangered	Endangered (angling prohibited)	Endangered* (angling prohibited)	Endangered (DSE 2003) (Angling restricted)	Endangered (DEH 2003) (angling prohibited)

* In Nov 2006 the NSW Fisheries Scientific Committee recommended that the status be changed from vulnerable to endangered, but this change has not been enacted yet.

Evidence for decline

Macquarie perch were formerly found in lowland rivers such as the Murray (in NSW and SA), Murrumbidgee near Wagga Wagga. and lower Ovens River. J.O. Langtry's survey of fish in the Murray river in 1949-50 recorded Macquarie perch as comprising 16% of the total fish catch in the Murray River at Barmah (Cadwallader 1977), but they are now absent from the Murray. Similarly, records of fish passing through the Euston fishway indicate that the numbers of Macquarie perch declined from a mean of 373 fish per annum between 1940-45 to zero fish between 1987-92 (Mallen-Cooper and Brand 2007). The NSW inland commercial fishery records indicate a similar result with Macquarie perch returns from the lower Murray dropping from 488 kg in 1959-60 to zero by 1962-63 (Reid et al 1997) although the reliability of this data for this species is open to question. There have been no recent records of Macquarie perch from the Murrumbidgee River near Wagga Wagga, despite considerable sampling in the last 10 years.

Populations of Macquarie perch that were formerly common in the lower Mitta Mitta River, have also disappeared following the construction of Dartmouth Dam and subsequent cold-water discharges (Koehn *et al*. 1995). The population of Macquarie perch in Dartmouth dam itself initially supported a significant recreational fishery (Hume 1991), but recent surveys have shown that the Macquarie perch fishery in the dam has been declining dramatically, with the results from 2000 indicating a 30-fold decline since 1984-85 (Douglas *et al*. 2002). In Victoria, in the decade commencing 1970, Macquarie perch were only recorded at 20 of the 52 localities where they had been recorded prior to 1970 (Cadwallader 1981) and since 1980 the number of sites where they are known to occur has declined even further.

Prior to the 1960s Macquarie perch were abundant in Lake Eildon, Victoria with large numbers of fish observed during the annual spawning run. In 1959 and 1960 the spawning run coincided with the opening of the angling season it as estimated that 2-3 tonne of fish were removed by anglers from 2 of the 5 major spawning streams in the first week of the season alone (Cadwallader & Rogan 1977). Macquarie perch are now rarely recorded from Lake Eildon although a restocking program has commenced in recent years.

In the ACT, the catch rate of Macquarie perch from a long-term monitoring program in the Murrumbidgee River has declined almost 50-fold since 1979 (Lintermans 2002). When it is considered that the base rate for this reduction came from the late 1970s, when the abundance of Macquarie perch in the upper Murrumbidgee River had already declined from being 'Common' in the 1940s to 'rare' in the 1970s (Greenham 1981), the overall decline has been dramatic. Similarly, Macquarie perch have declined from being considered moderately common in the Molonglo, Paddys and Queanbeyan rivers in the 1940s to now being absent or rare (Lintermans 2002).

Macquarie perch were a popular and commonly targeted species in Lake Burrinjuck and its tributary the Goodradigbee River up until the 1980s (McKeown 1934; Battaglene 1988, Burchmore *et al*. 1988) but recent surveys of the Goodradigbee River have caught very few individuals (Harris & Gehrke 1997; Lintermans unpubl. data) and it is now below detectable limits and considered effectively extinct in this location (Lintermans 2006b).

Threats
There are a variety of threats still operating on Macquarie perch populations. They include:

- Habitat modification: Sedimentation of streams can smother spawning sites and reduce food availability. Clearing of riparian vegetation removes shade from streams, as well as limiting inputs of fallen branches, logs and leaf litter which form the basis for food webs for fish, including Macquarie perch. Barriers such as dams, weirs and road crossings fragment populations and prevent fish gaining access to important spawning sites or recolonising areas after drought or local catastrophes. Discharge of cold water from large dams can prevent Macquarie perch breeding.
- Flow regulation and water harvesting: Regulation of rivers and harvesting of water has altered the natural flow patterns in many rivers. In some valleys, the seasonal flow patterns have been reversed, particularly below dams. Peak flows in such valleys may now occur in summer (irrigation flows) rather than winter, or may be significantly reduced as water is stored and diverted for agricultural production or domestic water supply.
- Alien species: Alien fish species can compete with Macquarie perch for food and living space. Trout are known to prey upon Macquarie perch. Alien species can carry diseases and parasites harmful to native fish, with Redfin perch known to carry a virus (EHN virus) which is lethal to Macquarie perch.
- Illegal fishing: When populations are small and fragmented, they can easily be further depleted by overfishing.

Origin of the Mongarlowe River population
The origin of the Macquarie perch population in the Mongarlowe River has been debated for many years. Lake (1971) noted that Macquarie perch were present in some coastal rivers of NSW, but stated that they were almost certainly introduced to these areas. Whether he was referring to the populations in Cataract Reservoir or the Mongarlowe, or both, is unknown. He later stated that they were present in the "Shoalhaven and Kangaroo rivers and tributaries" and that they were "probably introduced to these eastern waters" (Lake 1978). Llewellyn and MacDonald (1980) noted that some populations of Macquarie perch had been possibly introduced in some coastal streams of New South Wales, but did not specifically mention the Mongarlowe River. Harris and Rowland (1996) considered the Mongarlowe population the result of a translocation from the Murray-Darling Basin, and DEWHA (2008) reports that preliminary genetic analysis indicates that Macquarie perch from the Mongarlowe originated from Murrumbidgee River stock.

Aims of the Current sampling

Collection of adult Macquarie perch can be difficult. Gill nets have been used successfully in the past (Bishop 1979; Cadwallader and Rogan 1977; Lintermans 2006) buts can cause to stress to fish when enmeshed for prolonged periods or in high summer water temperatures (Bishop 1979). As Macquarie perch is a nationally endangered species, the wellbeing of fish after capture is a significant consideration. As coastal streams host populations of Longfinned eel *Anguilla reinhardtii* and Shortfinned eel *Anguilla australis*, which are known to prey in fish captured in

gill nets, the use of this technique to sample an endangered species in coastal streams is not desirable. Gill nets are also known to capture and drown non-target species such as Platypus *Ornithorhynchus anatinus* (Grant & Carrick 1974), and so their use is less desirable where Platypus is abundant (as in the Mongarlowe River). Methods which do not enmesh fish but which collect an adequate sample size are limited. Sampling for rare fauna is particularly problematic, and so sampling methods which target abundant life phases or return higher catch per unit effort are preferred. Boat electrofishing has been used but has returned small sample sizes in rivers (Harris and Gehrke 1997; Lintermans unpubl. data). Backpack electrofishing has been successfully used to sample Macquarie perch in smaller streams (ARI 2007; Saddlier *et al*. 2002; Bruce *et al.* 2007) but cannot adequately sample pools greater than ~1.5 m depth and has not been a particularly successful sampling technique for Macquarie perch in the Canberra region (Lintermans 2001, 2005). Fyke nets have been successfully deployed to capture large numbers of juvenile Macquarie perch in the Canberra region (Lintermans 2001, 2005, 2006, unpubl data) and elsewhere (Morison and Anderson 1987) but do not always collect a representative sample of adult fish. However, if the objective of sampling is to investigate whether the Macquarie perch population is 'healthy', then a sampling technique that provides robust information on the breeding status of the population is suitable.

The aims of the current program were to:

- Investigate levels of recruitment in the Mongarlowe Macquarie perch population
- Investigate geographical and inter-annual variation in recruitment success

Methods

Site selection

The sites surveyed by Bishop (1979) were reviewed, and relevant landholders contacted for permission to access the river through their property. Sampling sites selected based upon landholder permission, the relative abundance of Macquarie perch at sites recorded by Bishop (1979), good vehicle access, and a desire to encompass the main geographical range of the species in the Mongarlowe River. Six sites were selected for sampling in 2007, with the intention of re-sampling two of these sites in 2008 in order to provide information on inter-annual variation in recruitment. However, upon review of the 2007 results, a single site was re-sampled and an additional site included in 2008 (Table 1, Figure 1).

Table 1. Sampling sites used in the 2007 and 2008 Macquarie perch monitoring of the Mongarlowe River.

Site No.	Site Name	Grid Reference	Date sampled 2007	Date sampled 2008	Approx. Altitude (m)
1	Junction Pool	6095400 765500	2/3/07	14/3/08	550
2	Riverside	6093400 764500	9/3/07	-	550
3	Bentleys Point	6088100 770500	10/3/07	-	560
4	Shepherds Farm	6083700 769600	3/3/07	-	590
5	Chinamans Hole	6077700 766400	30/3/07	-	610
6	Mongarlowe Bridge	6076200 766600	31/3/07	-	620
7	Bourkes Crossing	6073300 766600	-	15/3/08	630

Two sampling techniques were utilized: fyke nets and collapsible bait traps

Fyke nets: Ten single-winged fyke nets (9 mm stretch-mesh) were set at each site. Fyke nets (Figure 2) were attached to the bank at the cod-end and then set at an angle to the bank facing downstream, with a weight attached to the wing to hold the net securely. The single wing attached to the centre of the front 'D' of the fyke net. Each fyke net had a 150 mm diameter polystyrene float inserted in the cod end to provide an airspace to prevent mortality of non-target animals such as Platypus. Nets were set between 15:30 and 16:30 hrs and left overnight. Nets were retrieved between 07:30 and 08:30 hrs the following morning, giving a 16 hour soak time. All fish were removed from the net, identified, measured (Caudal Fork Length or Total Length, as appropriate) and released at the point of capture.

Bait traps: Five small collapsible bait traps were attached to the banks with a short length of cord. Bait traps (Figure 3) were set at 18:00 hrs and retrieved at 08:30 hrs the following morning. Captured fish were identified and measured (Caudal Fork Length or Total Length, as appropriate) before release at the capture site.

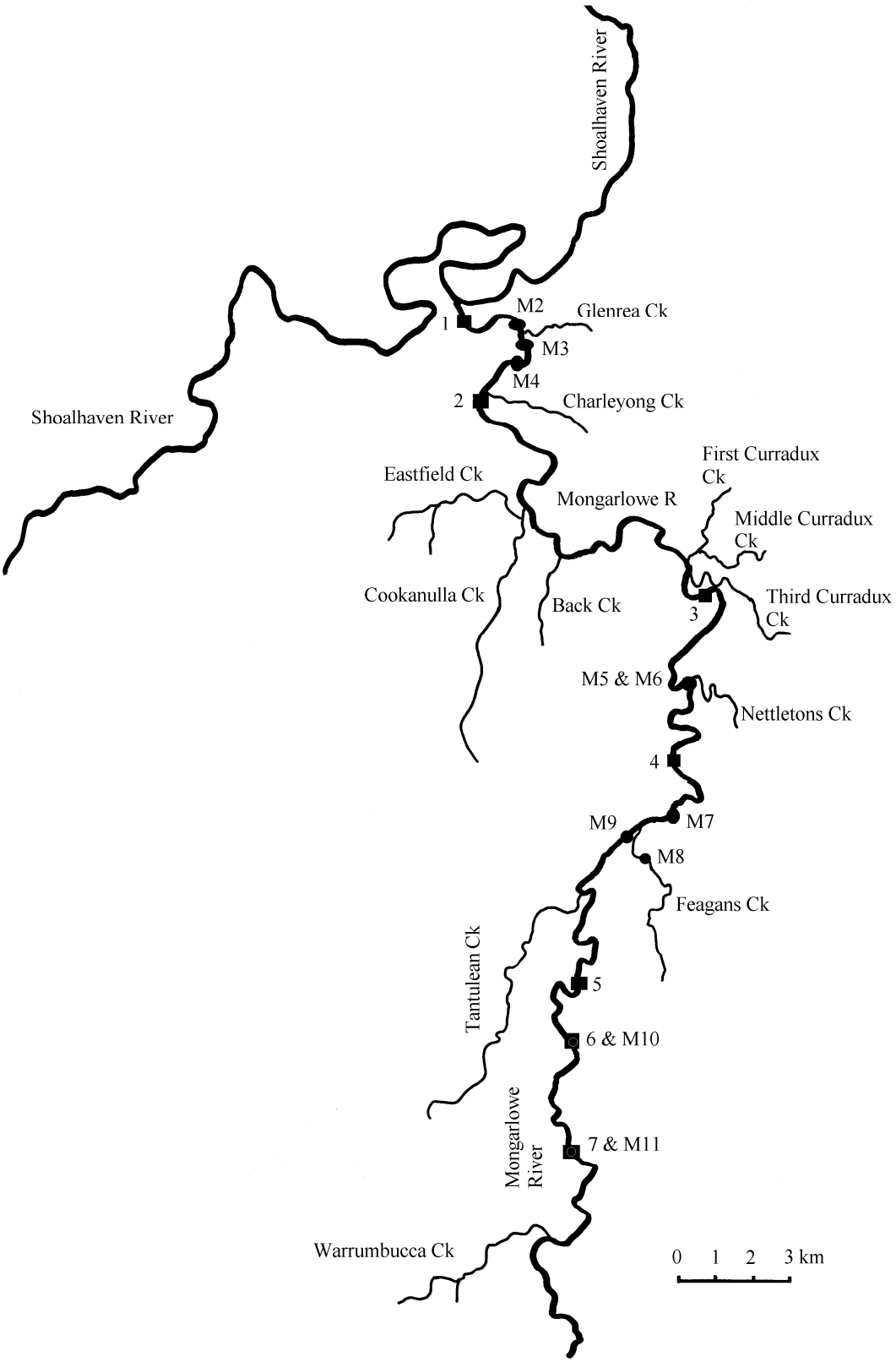

Figure 1. Location of sampling sites surveyed in the current project (square symbols) and sites sampled by Bishop (1979) (circles labeled with an 'M'prefix).

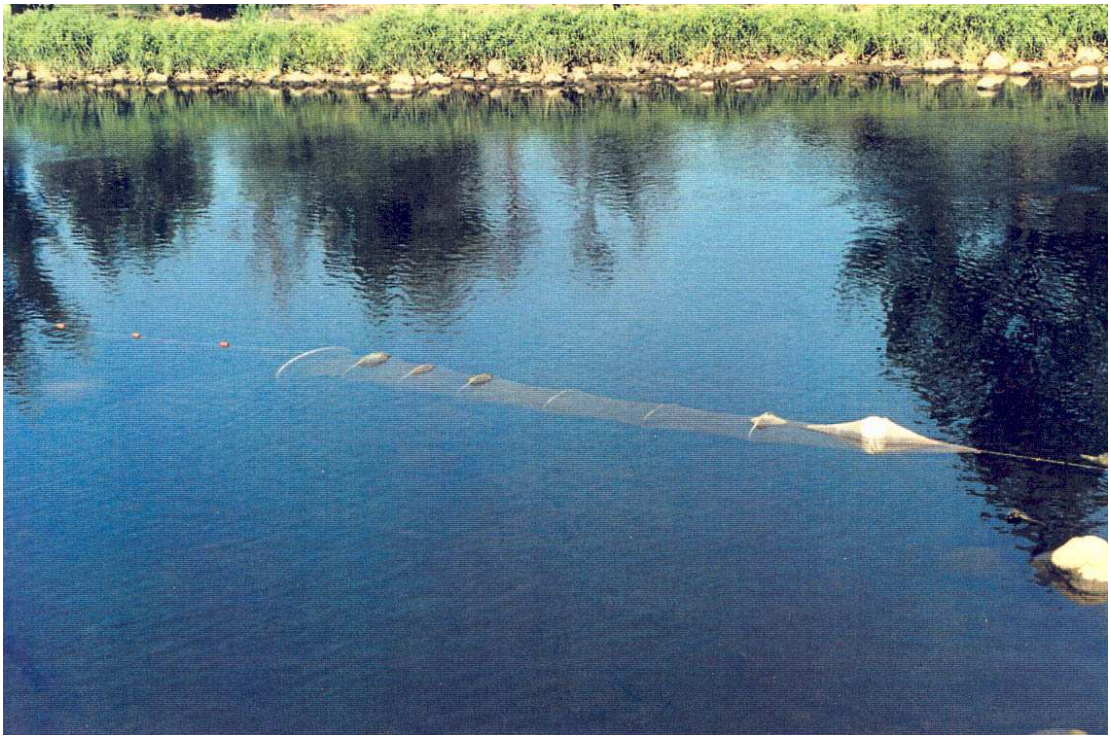

Figure 2. A single-winged fyke net.

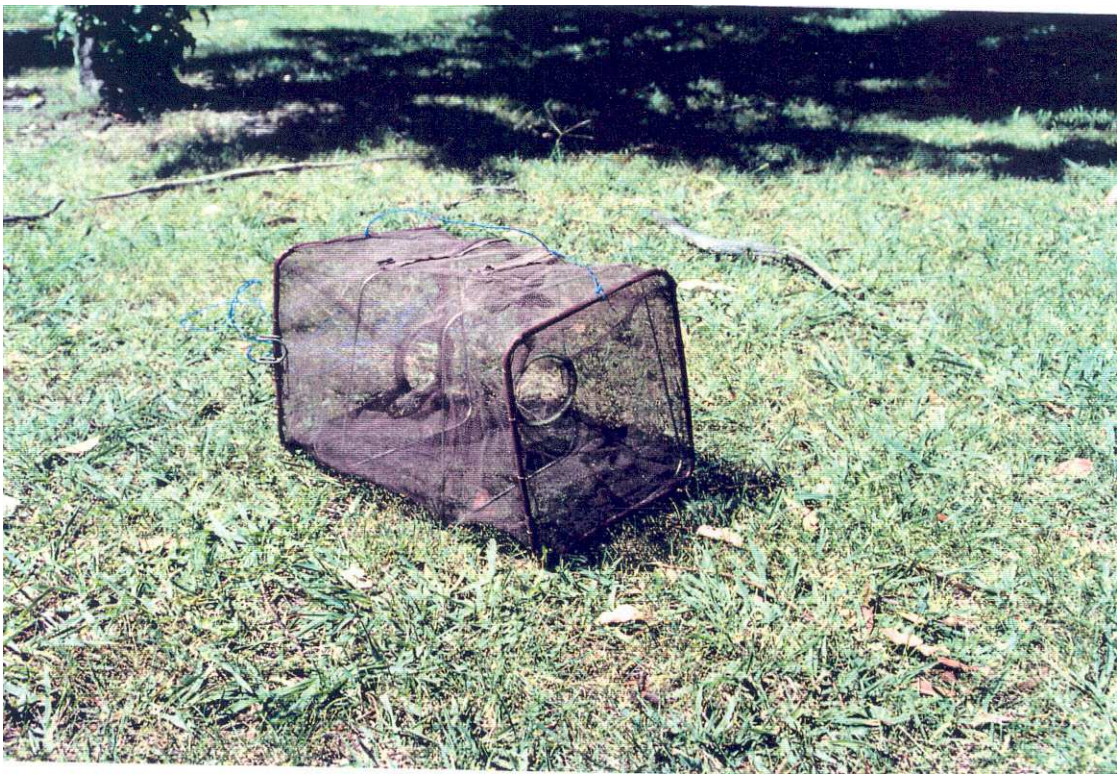

Figure 3. A collapsible bait trap.

Results

A Total of 158 fish from six species (five native and one alien) were captured and another species (alien) was observed (Table 2). The species captured were:

Native:

Macquarie perch	*Macquaria australasica*
Longfinned eel	*Anguilla reinhardtii*
Mountain galaxias	*Galaxias olidus*
Firetailed gudgeon	*Hypseleotris galii*
Carp gudgeon	*Hypseleotris spp*

Alien

Eastern Gambusia	*Gambusia holbrooki*
Carp	*Cyprinus carpio*

Non-target species captured were Platypus (Figure 4) and Eastern snake-necked tortoise *Chelodina longicollis* with Platypus captured at 6 sites and tortoises at 3 sites (Table 3). All non-target individuals were released alive at the point of capture.

Table 2. Number and species of fish recorded in the Mongarlowe River.

Species	**Junction Pool**		**Riverside**	**Bentleys Point**	**Shepherds Farm**	**Chinamans Hole**	**Mongarlowe Bridge**	**Bourkes Crossing**
	2007	*2008*						
Macquarie perch	1	1	-	-	-	-	-	1
Longfinned eel	1		3	1	1	-	1	
Mountain galaxias	-		9	1	7	9	1	16
Firetailed gudgeon	5	5	19	4	1	-	-	
Carp gudgeon	9	4	18	27	-	-	-	
Carp	Obs	Obs	-	-	-	-	-	
Eastern gambusia	Obs	3	Obs	10	-	-	-	
Total	**16**	**13**	**49**	**43**	**9**	**9**	**2**	**17**

Table 3. Number and species of non-target species captured in the Mongarlowe River.

Site	**Platypus**	**Eastern snake-necked tortoise**
Junction Pool	1	1
Riverside	1*	
Bentleys Point	1	4
Shepherds Farm		2
Chinamans Hole	1	
Mongarlowe Bridge	2	
Bourkes Crossing	1	

*plus 2 observed

Figure 4. A female Platypus captured at Bourkes Crossing.

The size of fish captured is shown in Table 4, with all Macquarie perch captured being young-of-year, indicating that some recruitment occurred in each of 2007 and 2008 (albeit at extremely low levels).

Table 4. Minimum, maximum and mean length of fish sampled from the Mongarlowe River.

Species	**Min. length (mm)**	**Max length (mm)**	**Mean length (mm)**
Macquarie perch	51	73	58.7
Longfinned eel	500	800	654.3
Mountain galaxias	29	68	41.2
Firetailed gudgeon	22	51	31.7
Carp gudgeon	14	51	24.8
Eastern gambusia	25	42	33.7

The length frequency of Macquarie perch captured is shown in Figure 5, with all fish being young of the year. A photograph of one of the Macquarie perch captured in 2007 is at Figure 6.

Bait traps recorded the majority of individuals (131 of 158 fish) and captured fish at all of the 7 sites. Fyke nets captured fish at 6 of the 7 sites, but notably captured all individuals of the target species (Macquarie perch) (Table 5).

The abundance of fish recorded was surprisingly low, with an average of only 19.75 fish captured per sampling night. The majority of fish sampled (148 of 158 fish) were from small-bodied species, with an extremely low number of large-bodied or angling species recorded.

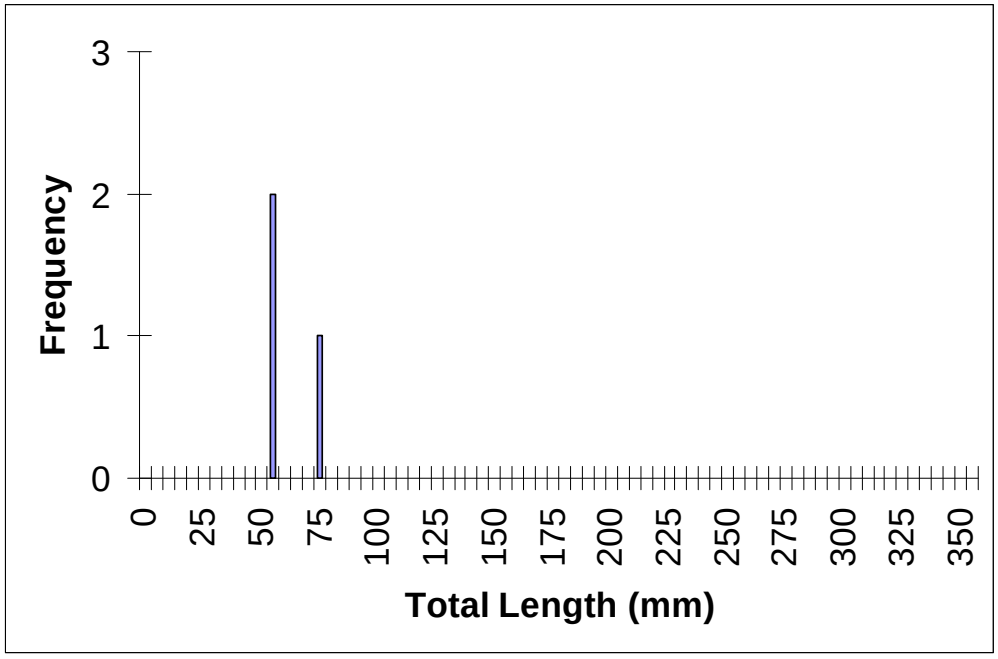

Figure 5. Length frequency of Macquarie perch captured from the Mongarlowe River in 2007 and 2008.

Figure 6. A Macquarie perch (73 mm total length) from the Junction Pool, 14 March 2008.

Table 5. Number of fish by species and gear type from the Mongarlowe River.

Species	**Junction Pool**		**Riverside**		**Bentleys Point**		**Shepherds Farm**		**Chinamans Hole**		**Mongarlowe Bridge**		**Bourkes Crossing**	
	bait	*fyke*	*bait*	*fyke*	*bait*	*fyke*	*bait*	*fyke*	*bait*	*fyke*	*bait*	*fyke*	*bait*	*fyke*
Macquarie perch	-	2	-	-	-	-	-	-	-	-	-	-	-	1
Lonfinned eel	-	1	-	3	-	1	-	1	-	-	-	1	-	-
Mountain galaxias	-	-	9	-	1	-	6	1	9	-	1	-	15	1
Firetailed gudgeon	5	5	16	3	4	-4	1	-	-	-	-	-	-	-
Carp gudgeon	10	3	16	2	27-	-			-	-	-	-	-	-
Eastern gambusia	1	2	-	-	10	-	-	-	-	-	-	-	-	-
Total	**16**	**13**	**41**	**8**	**42**	**1**	**7**	**2**	**9**	**-**	**1**	**1**	**15**	**2**

Discussion

Macquarie perch

The total number of Macquarie perch captured was extremely low, indicating poor recruitment by this species on both years of the survey. That the major survey technique itself (fyke nets) is effective for this species is demonstrated by results at other sites in the Canberra region in previous years and at one site during both years of the current survey (Table 6).

Table 6. Examples of catches from fyke nets set for a single night at other sites in the Canberra region (Lintermans unpublished data).

Site and Water body	No. of fyke nets set	Year	No. of Macquarie perch captured
Kissops Flat	10	2003	36
Murrumbidgee River above Cooma	10	2006	95
Killarney	10	1998	49
Murrumbidgee River above Adaminaby	10	1999	59
Cotter Reservoir	10	2006	120
Cotter River	10	2007	236
	12	2008	361

At any of the sites in Table 6, the catch of Macquarie perch in fyke nets from a single nights sampling outweighs by at least tenfold the total catch from 8 nights in the Mongarlowe River. That fyke nets are most suited to capturing young-of-year (age 0+) or yearling (age 1+) fish is shown by Figure 7, with relatively few adult fish (> 175 mm length) captured.

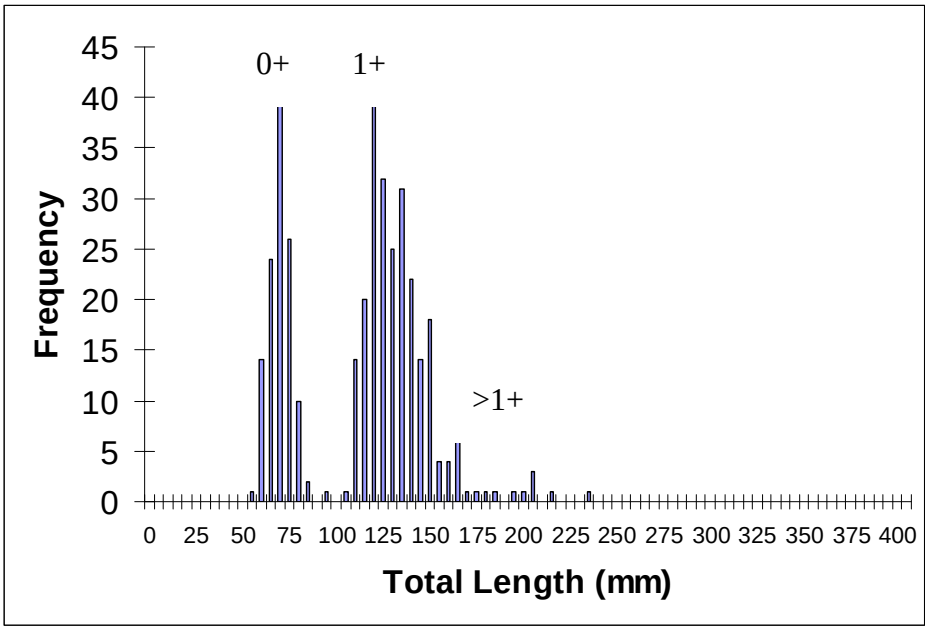

Figure 7. Length frequency of Macquarie perch captured in fyke nets in Cotter Reservoir in June 2008 (Lintermans unpubl. Data). Age 0+ fish are fish less than 1 year old (i.e. spawned in late 2007); age 1+ fish are fish less than 2 years old (i.e. spawned in late 2006).

However, Figure 7 also demonstrates the high efficiency with which fyke nets capture 0+ and 1+ Macquarie perch, (approximately 93 percent of the catch) making these nets an extremely effective technique for detecting recent recruitment in this species. Other sampling techniques such as gill nets or boat electrofishing may be more efficient at capturing larger, adult Macquarie perch, but such techniques are relatively inefficient for determining the recruitment status of population due to their low efficiency in capturing small fish.

The geographical spread of young-of-year fish detected in the current survey encompasses the full range o sites from Bourkes Crossing to Junction Pool, indicating that recruitment occurs over the full range of the species in the Mongarlowe River.

That adult Macquarie perch are still present in the Mongarlowe River is beyond question. If young-of-year fish are present, there must be adults present to produce them. There are also a number of recent records of adult Macquarie perch from the Mongarlowe River (Table 7).

However, the lack of recruitment detected during the current project raises some concerns about the future of the population in the Mongarlowe River. Macquarie perch are a relatively long-lived species, with fish aged greater than 10 years and up to 17 years having been captured in other studies in southeastern Australia (Cadwallader and Rogan 1977; Battaglene 1988, Douglas *et al.* 2002; Lintermans unpubl. data). Therefore a lack of recruitment in any particular year is no great cause for concern, but a prolonged failure to recruit or prolonged low levels of recruitment is a cause for concern. It is unknown whether the low recruitment detected in the current study represents the normal recruitment level for this population (i.e. a small population just ticking over). It may be that recruitment levels have been suppressed by the extended drought, which has affected Macquarie perch populations in some rivers in the Murray-Darling Basin (e.g. the Queanbeyan River, Lintermans unpublished data).

Table 7. Records since 1998 of adult (> 140 mm total length) Macquarie perch from the Mongarlowe River.

Month and year	source	location	Data source
12/2005	Dead specimen recovered	Mongarlowe bridge	Di Bott pers. comm.
4/1998	Scientific survey	Upstream of Charleyong Bridge	NSW DPI unpubl. data
2/1999	Scientific survey	Upstream of Charleyong Bridge	NSW DPI unpubl. data
~ 2003	Angler capture	Immediately below Kings Hwy bridge	K. Ramm pers comm..
10/2006	Scientific survey	Shepherds Farm	NSW DPI unpubl. data
4/2007	Angler capture	Upstream of Bourkes Crossing	Su Wild-River pers. comm.
1/2008	Angler Capture	Tombarra	Su Wild-River pers. comm.

Flow levels in the Mongarlowe River at Monga, upstream of the study area are presented in Figure 8. In June 2007 there was a significant flow event exceeding 7000 Ml/day but flows have generally been less than 100 Ml/day. Where these flows lie in relation to the long-term average flows in the Mongarlowe River is unknown, as long-term flow data was not able to be sourced at the time of writing this report.

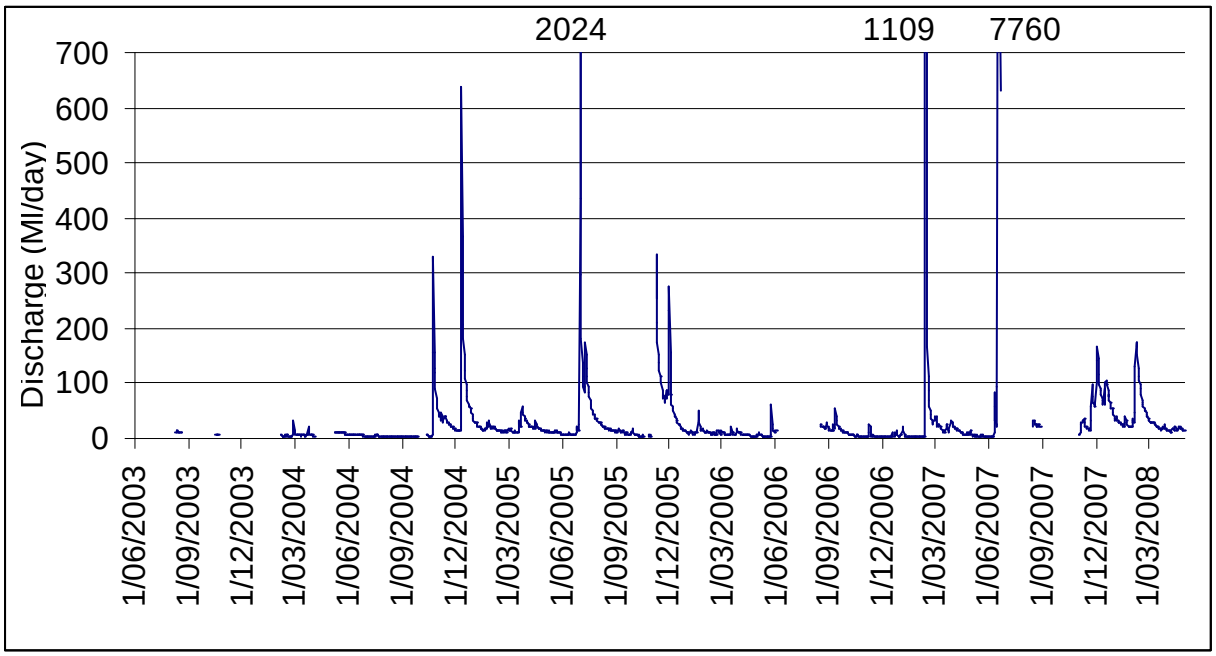

Figure 8. Flow levels in the Mongarlowe River at Monga since 2004 (source: http://waterinfo.nsw.gov.au)

Only further monitoring of recruitment over coming years will reveal what the average recruitment level is and whether or how it is related to stream discharge. Both Bishop (1979) and Bishop and Tilzey (1978) noted that according to local anglers the Macquarie perch recreational fishery had apparently deteriorated in the fifty years prior to the mid 1970s. However, the records of the Braidwood Fishing Club from 1970-74 (reported in Bishop 1979) showed that Macquarie perch still supported a recreational fishery at that time with 207 fish caught with a total gutted weight of 204 Kg. This was second only (in weight) behind Brown trout *Salmu trutta* (490 fish, 252 Kg) with Rainbow trout *Oncorhynchus mykiss* third (328 fish, 90 Kg). The effort used to catch these numbers of fish (number of anglers and hours fished) is not available. Bishop and Tilzey (1978) suggested that the Mongarlowe River was “probably the largest lotic [flowing water] Macquarie perch population in Australia”. Whilst the abundance of adult Macquarie perch cannot be assessed by the current survey, it seems likely that the population has declined further since the study of Bishop (1979) and Bishop and Tilzey (1978), and unless recruitment levels improve in the near future, its future looks grim.

Bishop (1979) recorded Macquarie perch from the junction of the Mongarlowe River with the Shoalhaven River up to site M11 (Bourkes Crossing)(Table 8). At three sites between these two extremities he failed to record the species, but at five of the seven sites where he recorded Macquarie perch, he considered them common. Although he sampled three sites upstream of M11, he did not record any Macquarie perch at these sites.

Table 8. Abundance of Macquarie perch in the Mongarlowe River recorded by Bishop (1979)

Site Number	Macquarie perch abundance
M2	rare
M3	common
M4	common
M5	-
M6	common
M7	common
M8	-
M9	-
M10	common
M11	rare

The results of Bishop (1979) cannot be directly compared to those of the current survey because Bishop was using methods (gill nets) that largely targeted adult fish, whilst the current survey targeted young of year or juvenile fish. The mesh sizes that Bishop used were large (76, 110 and 150 mm stretch mesh), compared to the 9 mm stretch mesh used in the fyke nets in the current survey, and resulted in the capture of Macquarie perch ranging from 185 to 450 mm length. There would be some benefit in re-sampling some of Bishop's sites utilizing the same sampling technique (gill nets) that he used. This would allow direct comparison with his results.

Members of the Friends of Mongarlowe, the Braidwood Fishing Club and local landholders all showed a keen interest in the project, and were keen to assist with the sampling. Monitoring techniques that are 'community-friendly' need to be investigated and developed. The interest and involvement of the local community has a much higher chance of being maintained if they can be actively involved in the data collection process. There are a number of potential monitoring techniques that could be used by community members following some initial guidance and training. Spotlighting has been previously used with success for Macquarie perch and represents a non-invasive technique that can be used by community members without a NSW DPI fish sampling permit. Similarly, snorkeling is a technique that can also be employed by community members, and is successful in detecting both adult and larval fish. The use of rigorously controlled targeted angling events might also be of use, as occurs for Bass and Murray cod in selected NSW waters (see Park 2005). The use of targeted angling would need to be discussed and approved y NSW DPI, due the threatened status of Macquarie perch. Incidental catches of Macquarie perch by anglers should also be recorded, and the threatened species sighting forms of NSW DPI (http://www.dpi.nsw.gov.au/fisheries/species-protection/report-it)should be promoted to local anglers.

Distribution of alien fish

The current survey indicates that two alien fish species are not distributed throughout the entire length of the Mongarlowe River. Both Carp and Eastern gambusia were not recorded at sites upstream of Bentleys Point. There are anecdotal records of carp as far upstream as the Mongarlowe village, and fieldwork during this project recorded them at the junction of Bobs Creek (S. Wild-River pers. comm.) between site M7 and M9 (Figure 1). However, the distribution of Eastern gambusia is largely unknown. Bishop (1979) and Bishop and Tilzey (1978) did not record either Carp or Eastern gambusia in the Mongarlowe catchment.

Confirmation of the geographical extent of these species distribution in the catchment should be sought. If they are confined to the lower Mongarlowe, or are only present occasionally in the upper reaches, it is possible that there might be some physical barrier that prevents or limits these species accessing the upper portion of the river. If this is so, then the location and nature of the barrier should be identified. The presence of these species in other water bodies in the upper catchment (e.g. farm dams) should also be investigated, as there may be an opportunity to prevent the establishment or spread of these pests into the upper catchment. If these species are identified in other water bodies, but are not widespread, there may be opportunities to eradicate these local populations. Gambusia are the most widely distributed freshwater fish in the world (Pyke 2005), and Eastern gambusia have been implicated in the decline of at least nine fish species in Australia (Arthington *et al.* 1986; Lloyd and Walker 1986;Lintermans 2007;Howe *et al.* 1997), and at least 35 species worldwide (Lloyd 1990). Gambusia aggressively chase and fin-nip fish much larger than themselves which can lead to bacterial and fungal infections (Meffe 1983). They also prey on the eggs of fish, frogs and larval fish (Lintermans 2007; Aarn and Ivantsoff 2001; Ivantsoff and Aarn 1999) and have been listed as a threatening process for frogs in New South Wales (NSW NPWS 2003), and if they can be prevented from establishing in the middle and upper Mongarlowe it would benefit these aquatic ecosystems.

Recommendations

Macquarie perch

1. The genetic identity of the Mongarlowe River Macquarie perch population needs to be confirmed. It is considered likely that the Mongarlowe River population is the result of a translocation from the Murray-Darling Basin, but this needs confirmation. The genetic identity (source) of the population will influence how the population is managed.

2. Monitoring of recruitment levels should be conducted annually to determine the long-term recruitment patterns in the population. Monitoring should be conducted across the full known range of the species in the Mongarlowe. The relationship between rainfall and flow patterns should also be investigated to determine if they are correlated with recruitment success.

3. The upstream limit of the Macquarie perch population in the Mongarlowe River needs to be determined. Does the species extend into the headwaters of the Monga National Park?

4. Barriers to Macquarie perch movement in the Mongarlowe (e.g. Bourkes Crossing ford) need to be identified and remediated so that fish movement is not impeded.

5. Monitoring techniques for Macquarie perch that are able to be utilised by the general community need to be investigated and developed. The interest and involvement of the local community has a much higher chance of being maintained if they can be actively involved in the data collection process.

6. There is increasing pressure from rural subdivision in the Mongarlowe valley, and the issue of allocation of water resources between consumptive and environmental uses and how these might impact on the Macquarie perch population needs to be considered by local and state authorities.

Alien fish

7. The upstream distributional limit in the river of the alien species Carp and Eastern Gambusia should be determined and any barriers or impediments to upstream expansion of these species should be identified and where possible maintained or augmented.

8. The presence of Carp and Eastern Gambusia in farm dams in the middle and upper catchment (above Bentleys Point) should be investigated, and control measures considered for any populations located

References

Aarn and Ivantsoff, W. 2001. Predation on native fishes by *Gambusia holbrooki* in the Orara River, New South Wales. *Fishes of Sahul* 15 (1): 726–732.

ACT Government 1999. *Macquarie Perch* (Macquaria australasica) *An endangered species.* Action Plan No. 13. Environment ACT, Canberra.

ANZECC 1999. *Threatened Australian Fauna.* Environment Australia, Canberra.

ARI 2007. *An assessment of the status of Macquarie perch, Macquaria australasica, in Hughes Creek, Victoria 2006/2007*. Report prepared for the Goulburn Broken Catchment Management Authority. Arthur Rylah Institute for Environmental Research, Victoria.

Arthington, A.H., Mckay, R.J. and Milton, D.H. 1986. The ecology and management of exotic and endemic freshwater fishes in Queensland. Pp 224–225 in Hundloe, T. (ed.) *Fisheries Management – theory and practice in Queensland*. Griffith University/University of Queensland.

ASFB 1992. Australian threatened fishes – 1992 supplement. Australian Society for Fish Biology Newsletter 22(2): 18-21.

ASFB 1998. Australian threatened fishes – 1998 supplement. Australian Society for Fish Biology Newsletter 28(2): 30-37.

Battaglene, S., 1988. *Macquarie Perch.* Agfact F3.2.5, NSW Agriculture and Fisheries.

Bishop, K.A. 1979. *Fish and aquatic macroinvertebrate communities of a coastal river (Shoalhaven River, New South Wales) during the development of a water diversion scheme.* M Sc thesis, Macquarie University

Bishop, K.A. and Tilzey, R.D.J. 1978. *Welcome Reef Project Environmental Study - Aquatic Life.* Consultancy report to Metropolitan Water, Sewerage and Drainage Board, Sydney.

Bruce, A., Knight, J. and Creese, B. 2007. *Survey of aquatic threatened species Macquarie perch (Macquaria australasica) and Adams' emerald dragonfly (Archaeophya adamsi) within the Hawkesbury-Nepean catchment*. Interim project report for the Hawkesbury-Nepean Catchment Management Authority. NSW Department of Primary Industries, Port Stephens Fisheries Centre. 28p.

Burchmore, J.J., Battaglene, S.C. and Roach, A.C. 1988. *Lake Burrinjuck Fish Management Study: Interim Report*. Unpublished report, NSW Fisheries.

Butcher, A.D. 1945. *The food of indigenous and non-indigenous freshwater fish of Victoria with special reference to trout*. Pamphlet No. 2, Fish and Game Dept., Victoria.

Butcher, A.D. 1947. *The freshwater fish of Victoria and their food*. Government Printer, Melbourne.

Cadwallader, P.L. 1977. *J.O. Langtry's 1949-50 Murray River investigations*. Fisheries and Wildlife Paper No. 13.Fisheries and Wildlife Division, Victoria.

Cadwallader, P.L. 1979. Distribution of native and introduced fish in Seven Creeks River system. *Australian Journal of Ecology* 4: 361–385.

Cadwallader, P.L. 1981. Past and present distributions and translocations of Macquarie perch *Macquaria australasica* (Pisces: Percichthyidae), with particular reference to Victoria. *Proceedings of the Royal Society of Victoria* 93: 23–30.

Cadwallader, P.L. and Eden, A.K., 1979. Observations on the food of Macquarie perch, *Macquaria australasica* (Pisces: Percichthyidae) in Victoria. *Australian Journal of Marine and Freshwater Research* 30: 401-409.

Cadwallader, P.L. and Rogan, P.L. 1977. The Macquarie perch *Macquaria australasica* (Pisces: Percichthyidae), of Lake Eildon, Victoria.. *Australian Journal of Ecology* 2: 409-418.

DEH 2003. *2003 review of the status of threatened species in South Australia: Proposed Schedules under the South Australian National Parks and Wildlife Act 1972, a discussion paper*. South Australia Department for Environment and Heritage.

Douglas, J.W., Giles, A. and Strongman, R.J. 2002. Lake Dartmouth Multi-species Fishery assessment. *Marine and Freshwater Resources Institute Freshwater Fisheries Report No 02/2*. Marine and Freshwater Resources Institute: Snobs Creek.

DSE 2003. Advisory list of threatened vertebrate fauna in Victoria – 2003. Department of sustainability and Environment, Victoria, East Melbourne, Victoria.

Dufty, S., 1986. *Genetic and morphological divergence between populations of Macquarie Perch* (Macquaria australasica) *east and west of the Great Dividing Range*. Unpublished BSc. (Hons) thesis, University of New South Wales, Kensington.

Ebner, B and Lintermans (eds) 2007. Fish passage, movement requirements and habitat use for Macquarie Perch. Final Report to the Department of Agriculture, Fisheries and Forestry Australia,. Parks, Conservation & Lands, Territory & Municipal Services, Canberra

Fisheries Scientific Committee 2006. Proposed determination: *Macquaria australasica* – Macquarie perch. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/208218/PD-Macquarie-Perch.pdf (accessed 8/8/2008)

Gooley, G.J., 1986. Culture methods for Macquarie Perch at Dartmouth, Victoria. *Australian Fisheries* 45(9): 18-20.

Grant, T.R. and Carrick, F.N. 1974. Capture and marking of the Platypus *Ornithorhynchus anatinus*, in the wild. *Australian Zoologist* 18 (2): 133-135.

Greenham, P. 1981. *Murrumbidgee River aquatic ecology study*. Report to the National Capital Development Commission and the Department of the Capital Territory, Canberra.

Hammer, M., Wedderburn, S. and Van Weenen, J. 2007. Draft Action Plan for South Australian Freshwater Fishes : 2007-2012. Native Fish Australia (SA) Inc, Adelaide.

Harris, J.H. and Gehrke, P.C. (eds.) 1997. *Fish and Rivers in Stress*: *The NSW Rivers Survey*. New South Wales Fisheries and the Cooperative Research Centre for Freshwater Ecology.

Harris, J.H. and Rowland, S.J. 1996. Family Percichthyidae: Australian freshwater cods and basses. Pp 150–163 *in* McDowall, R. M. (Ed.) *Freshwater Fishes of South-eastern Australia*. Second edition. Reed Books, Australia.

Howe, E.H., Howe, C., Lim, R. and Burchett, M. 1997. Impact of the introduced poeciliid *Gambusia holbrooki* (Girard, 1859) on the growth and reproduction of *Pseudomugil signifer* (Kner, 1865) in Australia. *Marine and Freshwater Research* 48: 425–434.

Hume, D. 1991. Report on three years of creel surveys: 1984-1987. *Arthur Rylah Institute for Environmental Research Technical Report Series No. 122.*

Hungerford, R. 1971. The Macquarie perch. Pp 370-374 in Hungerford R. *Guide to Trout Angling with expert advice on all Freshwater Species.* Pollard Publishing, Wollstonecraft, NSW.

Ingram, B.A., Douglas, J.W. and Lintermans, M. 2000. Threatened fishes of the world: *Macquaria australasica* Cuvier, 1830 (Percichthyidae). *Environmental Biology of Fishes* 59: 68.

Ivantsoff, W. and Aarn 1999. Detection of predation on Australian native fishes by *Gambusia holbrooki. Australian Journal of Marine and Freshwater Research* 50: 467–468.

Koehn, J.D., Doeg, T.J., Harrington, D.J. & Milledge, G.A., 1995. *The effects of Dartmouth Dam on the aquatic fauna of the Mitta Mitta River*. Unpublished report to the Murray-Darling Basin Commission. Department of Conservation and Natural Resources, Melbourne.

Lake, J.S. 1971. *Freshwater Fishes and Rivers of Australia*. Thomas Nelson (Australia) LTD.

Lake, J.S. 1978. *Australian Freshwater Fishes.* Thomas Nelson Australia, West Melbourne.

Langdon, J.S. 1989. Experimental transmission and pathogenicity of epizootic haematopoietic necrosis virus (EHNV) in redfin perch *Perca fluviatilis* L., and 11 other teleosts. *Journal of Fish Diseases* 12: 295–310.

Lintermans, M. 2000a. *The Status of Fish in the Australian Capital Territory: A Review of Current Knowledge and Management Requirements*. Technical Report 15, Environment ACT, Canberra.

Lintermans, M. 2001. *Fish Monitoring Program to Assess the Effectiveness of Environmental Flows in the Cotter and Queanbeyan rivers.* Consultancy report to Ecowise Environmental Ltd, Canberra. Environment ACT, Canberra. 39 p.

Lintermans, M. 2002. *Fish in the Upper Murrumbidgee Catchment: A Review of Current Knowledge***.** Environment ACT, Canberra.

Lintermans, M. 2005. Environmental Flows in the Cotter River ACT and the response of the Threatened Fish Species Macquaria australasica and Gadopsis bispinosus in 2003 and 2004. Consultancy report to ACTEW Corporation andActewAGL. Environment ACT, Canberra. 33 p.

Lintermans, M. 2006a. *The Re-establishment of the Endangered Macquarie Perch, Macquaria australasica, in the Queanbeyan River, New South Wales, with an examination of dietary overlap with alien trout.* CRC Freshwater Ecology Technical Report.

Lintermans, M. 2006b. Threatened Fish in Mountain streams: out of sight, out of mind. Pp 41-54 in NPA 2006, *Caring for Namadgi – Science and People*. National Parks Association of the ACT, Canberra.

Lintermans, M. 2007. *Fishes of the Murray-Darling Basin: an introductory guide*. Murray-

Darling Basin Commission, Canberra. 166 p.

Llewellyn, L.C. and MacDonald, M.C. 1980. Family Percichthyidae: Australian Freshwater Basses and Cods. Pp. 142–149 in: McDowall, R.M. (ed.) *Freshwater Fishes of South-eastern Australia*. First edition. Reed Books. Sydney.

Lloyd, L.N. 1990. Biological interactions of *Gambusia holbrooki* with Australian native fishes. In Pollard, D A. (ed.), *Australian Society for Fish Biology Workshop: Introduced and Translocated Fishes and Their Ecological Effects*. Bureau of Rural Resources Proceedings No. 8, Australian Government Publishing Service, Canberra.

Lloyd, L.N. and Walker, K.F. 1986. Distribution and conservation status of small freshwater fishes in the River Murray, South Australia. *Transactions of the Royal Society of South Australia* 110: 40–57.

Mallen-Cooper, M. and Brand, D.A. 2007. Non-salmonids in a salmonid fishway: what do 50 years of data tell us about past and future fish passage? *Fisheries Management and Ecology* 14: 319-332

McKeown, K.C. 1934. Notes on the food of trout and Macquarie perch in Australia. *Records of the Australian Museum* 19: 141–152.

Meffe, G.K. 1983. Attempted chemical renovation of an Arizona springbrook for management of the endangered Sonoran topminnow. North American Journal of Fisheries Management 3: 315-321.

Merrick, J.R. and Schmida, G.E. 1984. *Australian Freshwater Fishes: Biology and Management*. Published by J. Merrick, North Ryde, New South Wales.

Morison, A.K. and Anderson, J.R. 1987. *Status of Trout cod Maccullochella macquariensis, Macquarie perch Macquaria australasica, and other fish populations in the upper reaches of Seven Creeks, based on surveys between 1981 and 1987.* Arthur Rylah Institute for Environmental Research Technical Report Series No. 59. Department of Conservation, Forests and Lands, Shepparton, Victoria.

Morris, S.A., Pollard, D.A., Gehrke, P.C. and Pogonoski, J.J. 2001. *Threatened and potentially threatened freshwater fishes of coastal New South Wales and the Murray-Darling Basin.* Report to Fisheries Action Program and World Wide Fund for Nature. NSW Fisheries Final Report Series No. 33.

NSW NPWS 2003. NSW Threat Abatement Plan. Predation by Gambusia holbrooki – the Plague Minnow. National Parks and Wildlife Service, Hurstville, NSW.

Park, T. 2005A role for recreational fisherman in the management of Murray cod: the Angler catch database. Pp 88-92 *In* Lintermans, M. and Phillips, B. (eds) 2005. *Management of Murray Cod in the Murray-Darling Basin: Statement, Recommendations and Supporting Papers. Proceedings of a workshop held in Canberra, ACT 3-4 June 2004*. Murray-Darling Basin Commission, Canberra. 128 p.

Pratt, B.H. 1979. *The Canberra Fisherman*, ANU Press, Canberra.

Pyke, G.H. 2005. A review of the biology of *Gambusia affinis* and *G. holbrooki*. *Reviews in Fish Biology and Fisheries* !5: 339-365.

Reid, D.D.; Harris, J.H.; Chapman, D.J. 1997. NSW Inland Commercial Fishery Data Analysis. Fisheries Research and Development Corporation, NSW Fisheries, Cronulla and CRC Freshwater Ecology, Canberra.

Saddlier, S.R., Crowther, D. and Papas, P. (2002). *Aquatic Fauna and Habitat structure of Seven Creeks: Status of Pre and Post-Rehabilitation Works Condition*. A Consultants Report for the Goulburn-Broken Catchment Management Authority and the Natural Heritage Trust. Freshwater Ecology Section, Department of Natural Resources and Environment, Victoria

Stead, D.G. 1913. An account of some experiments in the acclimatisation of two species of Australian freshwater fish. *Australian Association for the Advancement of Science* 14: 279–288.

Wager, R. and Jackson, P.D. 1993. *The Action Plan for Australian Freshwater Fishes*. Australian Nature Conservation Agency, Canberra.