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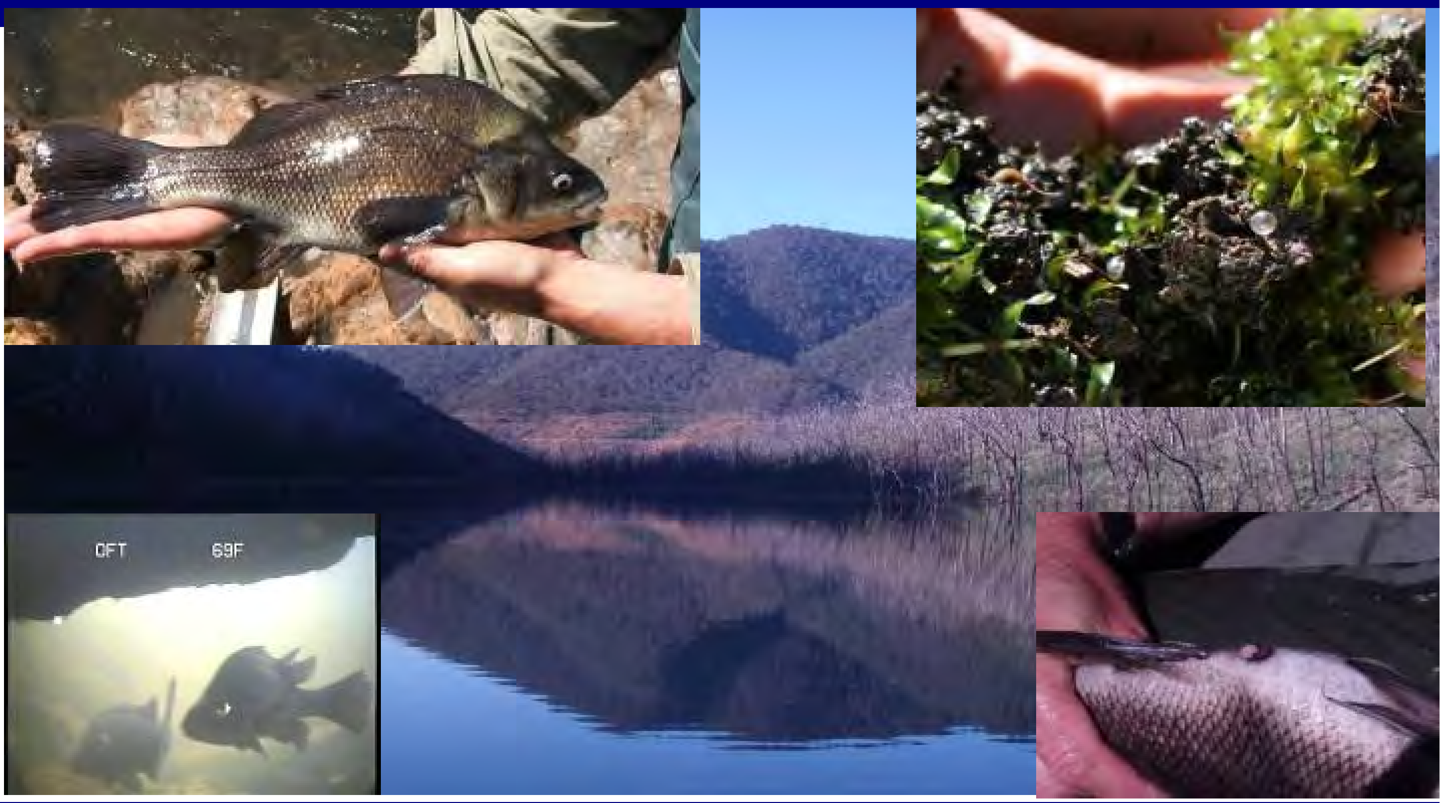
# An assessment of spawning stocks, reproductive behaviour and habitat use of Macquarie Perch *Macquaria australasica* in Lake Dartmouth, Victoria

Z. Tonkin, J. Lyon and A. Pickworth

**2009**



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# An assessment of spawning stocks, reproductive behaviour and habitat use of Macquarie Perch *Macquaria australasica* in Lake Dartmouth, Victoria


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123 Brown Street, Heidelberg, Victoria 3084


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**Front cover photo:** left to right: Adult Macquarie Perch, drift sample containing Macquarie Perch eggs, underwater image of spawning aggregations, running ripe female Macquarie Perch and Lake Dartmouth (Zeb Tonkin and Andrew Pickworth).

# Contents

# List of tables and figures

## List of tables



## List of figures

## Acknowledgements

We thank Peter Liepkalns of Goulburn–Murray Water who provided inflow data and information on the general status of the dam and river inflows; Graham Hackett for help with otolith preparation and; John Douglas from the Department of Primary Industries, Victoria, for advice on netting techniques and provision of data from previous studies. This work was funded by the Department of Sustainability and Environment's Fire and Drought Contingency Program, The National Heritage Trust, Goulburn Broken Catchment Management Authority and North East Catchment Management Authority. All work was carried out under animal ethics permit number 07/10.

# Summary

The Macquarie Perch *Macquaria australasica* has undergone a dramatic reduction in range and abundance throughout the Murray–Darling Basin. The Mitta Mitta River population, primarily located in Dartmouth Dam, has long been considered one of the strongest remaining populations, although the species was abundant throughout the river until the construction of the dam. Work undertaken in the late 1990s, however, suggested the population was in decline, and because of the recent prolonged drought and post-bushfire sedimentation events an assessment of the status of the Lake Dartmouth Macquarie Perch population was urgently required. The primary objective of this project was to undertake an assessment of current spawning stocks and behaviour of Macquarie Perch in Lake Dartmouth for comparison with surveys undertaken from 1994 to 1998 (Douglas 2002), subsequently providing information which will contribute to an assessment of the current status of the Lake Dartmouth Macquarie Perch population.

Results indicated that the average sizes, age structure and condition of the spawning population are below the levels recorded during the initial filling stage of the lake, but they have not dropped since the last surveys more than ten years ago, and perhaps even have improved slightly since the 1990s. This suggests that resources available for Macquarie Perch in the lake have stabilised since the 1990s and are adequate to sustain healthy growth rates of fish there. Inundation of terrestrial vegetation that has regrown around the lake margins after prolonged low lake levels may explain the sustained or improved growth in the Macquarie Perch population. The abundance of spawning fish compared to previous studies could not be assessed. However, observations of numbers of fish in the reach and data from tag recaptures suggest a small spawning population.

The habitat use and behaviour of spawning fish was also documented from observations, angling, underwater videography and the collection of eggs and larvae. Habitat use and behaviour of Macquarie Perch were consistent with those of the Lake Eildon population, most notably the major spawning habitat being located just upstream of the first set of rapids above the lake.

The result of the study suggest that the apparent reduced population size reported in previous studies is most likely the result of a lack of recruitment success, possibly as a result of limited spawning habitat availability and other factors that reduce the survival of eggs, larvae and juveniles. The effect of sedimentation from post-bushfire runoff on spawning habitat availability and egg survival, and interactions with exotic species (particularly carp) are likely to limit recruitment. With the ongoing extreme drought and the presence of post-fire sedimentation throughout the population's major spawning area, the continuation of spawning stock monitoring, and large-scale tagging programs, as well as an assessment of exotic species impacts, are recommended in order to assess the overall status of the Macquarie Perch population. It is also recommended that key threats to this population are identified to adequately improve management and assist rehabilitation programs for the species, not only in Lake Dartmouth but also in other populations within the Murray–Darling Basin.

# 1 Introduction

The Macquarie Perch *Macquaria australasica* is a medium sized perchichthyid fish endemic to the south-eastern reaches of the Murray–Darling Basin (Lintermans 2007). Individuals up to 465 mm in length and 3.5 kg in weight have been recorded, but they are more commonly less than 350 mm long and weight less than 1 kg (Table 1). Macquarie Perch occupies a range of habitats, such as small rocky upland streams, large deep rivers with sand or clay substrates, woody debris and impounded waters, and they feed primarily on aquatic insects and crustaceans (Cadwallader and Douglas 1986; Ingram et al. 2000). It is a potadromous species, undertaking upstream spawning migrations during spring or early summer (October–December) when water temperatures reach 16 °C. Eggs are deposited above riffle areas (Cadwallader and Douglas 1986; Broadhurst et al. in prep.), where they lodge among gravel and boulders and hatch in 13–18 days (Lintermans 2007).

The Macquarie Perch was once widespread and abundant, supporting a popular recreational fishery. By the 1970s however, the species had undergone major declines in distribution and abundance, to the extent that it is now listed as nationally endangered under the *Environmental Protection and Biodiversity Conservation Act 1999* (Cwlth) and threatened in Victoria under the *Flora and Fauna Guarantee Act 1988* (Vic.). The reasons for the decline include catchment erosion, clearing of streamside vegetation, desnagging, competition and predation by introduced species such as trout and redfin, and the construction of dams that act as barriers to movement and modify river flows and temperatures downstream (Cadwallader 1981; Gray, De Silva et al. 2000; Macdonald 2008).

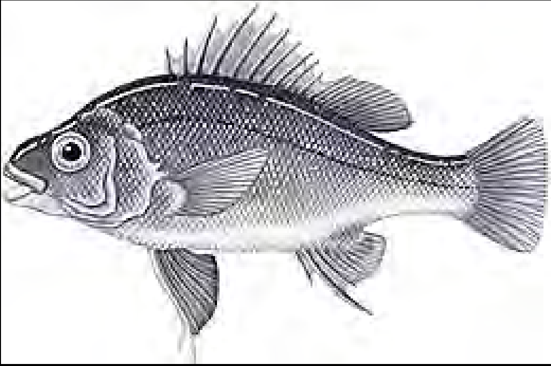
In Victoria only a few populations remain in the Goulburn, Mitta Mitta, Ovens, Campaspe, Upper Murray and Yarra (translocated) catchments, with many of these being small isolated remnant populations occurring in suboptimal habitats (Macdonald 2008). The construction of the Dartmouth Dam on the Mitta Mitta River in 1979 is believed to have caused the disappearance of two major populations of Macquarie Perch in the lower Mitta Mitta River (Koehn et al. 1995). However, a population established in the dam has, over the last two decades, been recognised as being the largest remaining population of the species. Furthermore, Dartmouth Dam was still supporting an important recreational fishery up until the early 1990s (Douglas et al. 2002). During the late 1990s however, research indicated a decline in Macquarie Perch growth and possible recruitment success (Douglas et al. 2002).

This research, coupled with population crashes of Macquarie Perch reported earlier in other large impoundments such as Lake Eildon (Cadwallader and Rogan 1977), led many to believe that this population was also on the verge of collapse. A major decline in lake productivity, leading to reduced fecundity, increased alien species interaction and severe loss or restricted access to adequate spawning areas due to prolonged drought and sedimentation from bushfire runoff, were thought to be the key drivers of this inevitable collapse. Subsequently, it has recently been suggested that the translocated population in the Yarra River is the most stable population remaining in Victoria (Pitman et al. 2007), despite no assessment of the Dartmouth Dam population having been made for around a decade.

In the light of the prolonged drought and a general view that the population is facing collapse, the major aim of this study was to provide information that could contribute to an assessment of the current status of the Lake Dartmouth Macquarie Perch population. Because of the limited time and resources available for the study, the primary objective was to undertake a rapid assessment of spawning stocks and spawning behaviour of the population for comparison with surveys undertaken from 1994 to 1998 (Douglas 2002; Douglas et al. 2002). Specifically, the project investigated:

- size class, age structure and general condition of spawning stocks
- spawning locations, behaviour and habitat use during a time of prolonged drought
- potential threatening processes key knowledge gaps and future recommendations for the population.

**Table 1 Biology and conservation status summary for Macquarie Perch (from Macdonald 2008).**

| | |
|---|---|
|  | • ***Macquaria australasica***<br>• Common name – **Macquarie Perch**<br>• Other names – **Silvereye, White-eye, Mountain Perch, Bream, Black Bream, Maccas** |
| Biology | • Naturally a riverine species once found commonly in upper reaches of the Murray–Darling Basin<br>• Size up to 465 mm long and weight up to 3.5 kg, but more commonly less than 350 mm long and 1 kg in weight<br>• Diet of aquatic insects and crustaceans<br>• Spawns on rocky substrates mid-October to mid-December when day length increases and water temperatures rise (above 16 °C)<br>• May migrate during spawning to access suitable habitat<br>• Lays demersal eggs in running water over gravel beds and amongst stones (up to 32 000)<br>• Eggs hatch in 13–18 days |
| Conservation status | • Victoria: endangered (listed under the *Flora and Fauna Guarantee Act 1988*)<br>• Australia: endangered (listed under the *Environment Protection and Biodseviersity Conservation Act 1999*)<br>• May not be taken from the wild in Victoria, except from Lake Dartmouth, the Upper Coliban River, and the Yarra River (Victorian Fishing Regulations 2006). |

Picture: (FishVictoria 2007) biological information (Harris and Rowland 1996)

# 2 Methodology

## 2.1 Study site

Because of the focus on spawning stocks, the study site was based at the Mitta Mitta River inflow of the lake (Figure 1), which has been recognised as the primary spawning tributary for the Lake Dartmouth Macquarie Perch population (Douglas 2002). Other major tributaries of the lake, including Toke Creek, Dart River and Shady Creek (Figure 1B, C, and D respectively) were also examined during the time of sampling. Water quality at the lake–river junction was collected daily during all trips.

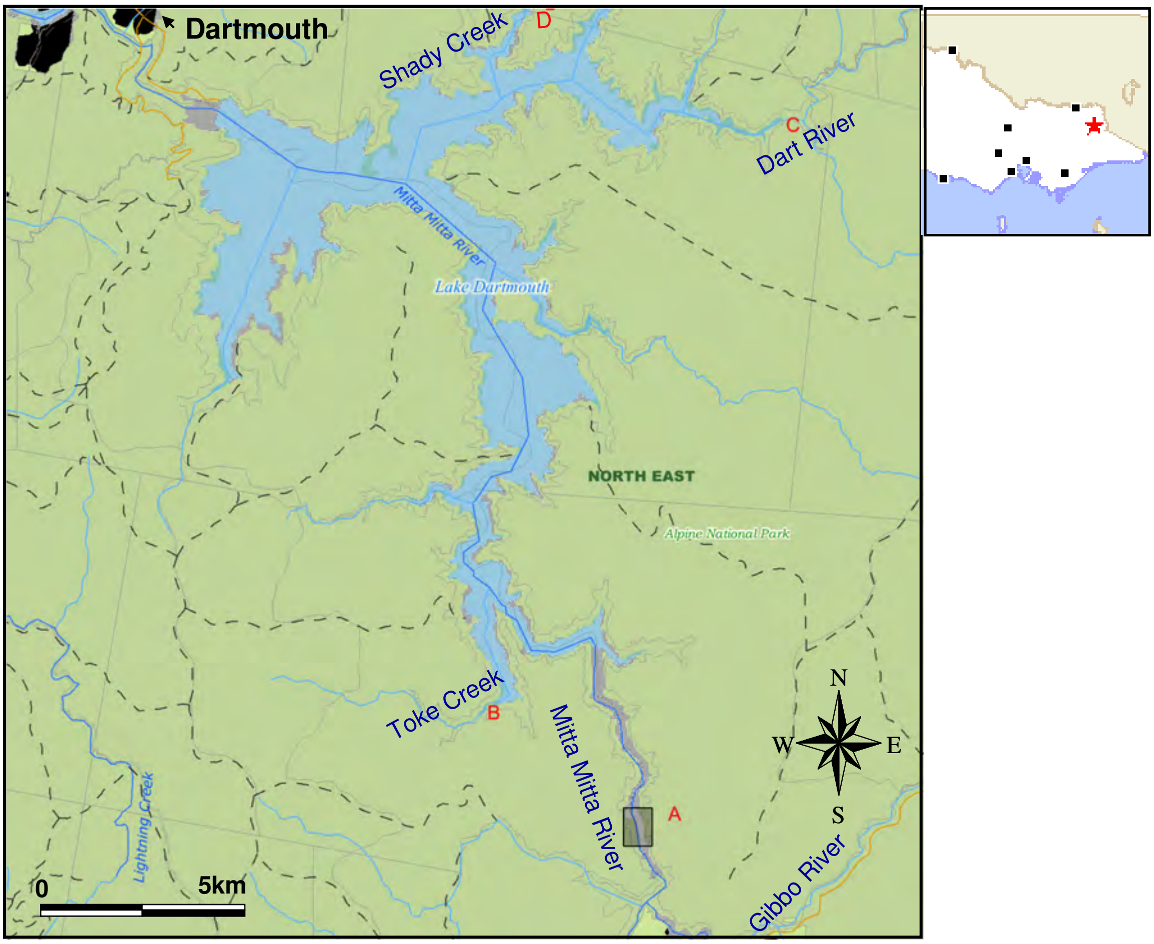



**Figure 1. Lake Dartmouth and major tributaries investigated during the study. Shaded box represents the main study area for fish collection and Mitta Mitta River inflows at current lake levels.**

## 2.2 Fish collection and processing

In an effort to target pre-spawning fish, and specifically the movement of fish from the lake into the lower reaches of the river, collections were made using six frog-mouth drum nets (2 m diameter opening) and seven single-wing fyke nets over three one-week periods, at the end of October, November and December 2008. All nets were set with mouths facing downstream in a 500 m reach of the lake–river junction to target fish moving from the lake into the river. All nets were checked at 0800 hours (night set) and again at 1800 hours (day set). In each of the three sampling periods, sampling consisted of three day sets and three night sets.

In addition to the standardised netting, angling with the use of artificial lures in the river upstream of the lake was also used as a method of fish collection. This proved a valuable method of collection to assess condition of fish in spawning areas upstream of the lake due to minimising fish handling and area disturbance as well as being useful in areas that were difficult to access.

Fish collected during the standardised netting regime were weighed (nearest g), and measured for total length (TL, nearest mm). They were then sexed by applying light pressure to the abdomen (see Figure 3). Fish longer than200 mm were tagged with an externally unique T-bar tag (Figure 2). Fish collected by angling in the river upstream of the lake were also measured for length and weight and assessed for sex, but only those caught during the October sampling period were externally tagged.

Nineteen individuals, representing the entire size range of fish collected, were humanely euthanased by immersion in overdosed anesthetic (Alfaxalone 40 mg/L) to assess the age structure of the population's spawning stocks and compare it with previous studies. Sagittal otoliths removed from euthanased fish were used to prepare transverse sections for annuli counts. Fin clips for genetic analysis were also taken from the first 50 fish collected in October as part of a state-wide recovery program for the species.

**Figure 2. Drum netting the Mitta Mitta River inflow into Lake Dartmouth.**

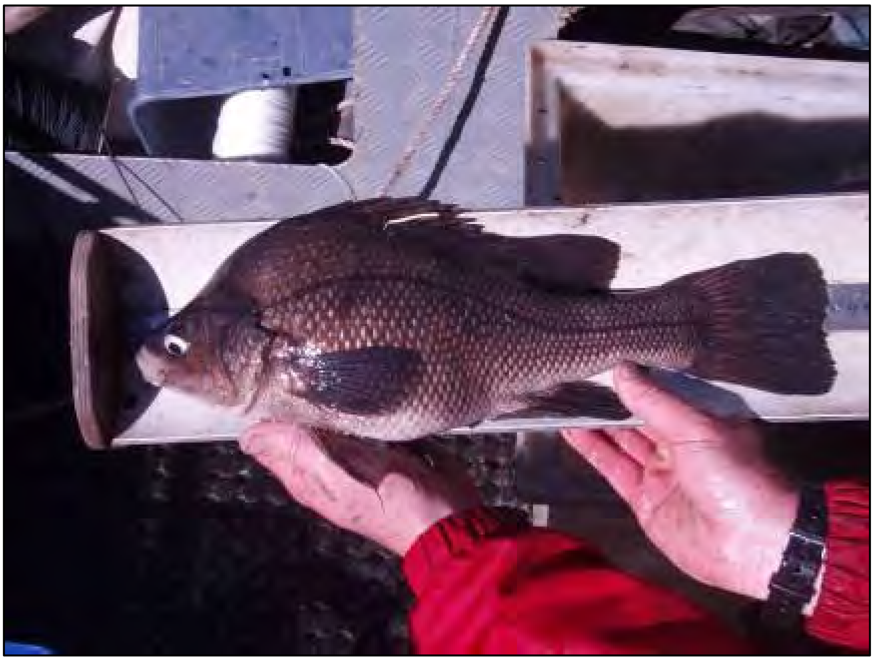


**Figure 3. Firm pressure to the abdomen, indicating running ripe female Macquarie Perch (top); same fish prior to release, showing external tag (bottom).**

## 2.3 General observation of spawning behaviour and habitat use

Low flows in previous years have generally been thought to be detrimental to Lake Dartmouth’s Macquarie Perch population, particularly migrating fish. However, the low inflows and low turbidity in October and November 2008 (which followed the lowest September rainfall on record) provided a rare opportunity to observe aspects of the species’ spawning behaviour and habitat use after the migration from the lake.

During the October and November sampling (the time of peak fish abundance in the river), approximately 3 km of river was assessed for the presence and behaviour of Macquarie Perch using a combination of visual observations (using polarised sunglasses), underwater video equipment and angling. Although such data is not quantitative, it provided much needed information on spawning aggregations, barriers preventing upstream passage, exotic species interactions and general habitat use by the species. These activities were limited during the December sampling because heavy rainfalls increased water levels and turbidity.

**(a)**

**(b)**

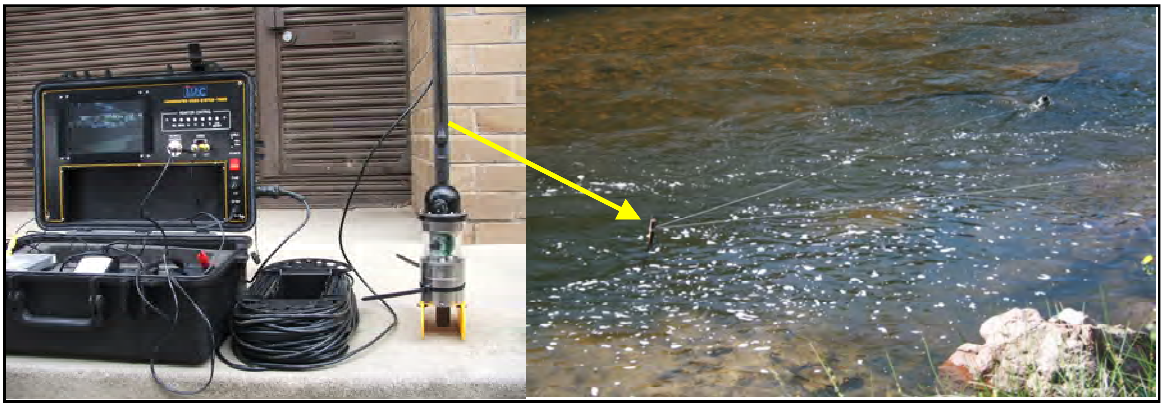


**Figure 4. Observations of adult Macquarie Perch (top); the underwater video equipment used during the study and how it was positioned in the river (bottom).**

## 2.4 Spawning assessment

To confirm the occurrence of spawning, during the November sampling a single Elton glass eel net (two 5 m, 1 m deep wings with 1 mm mesh size, 800 mm diameter hoop leading to a 500 µm cod end) was set facing upstream to collect drifting eggs and/or larvae (Figure 5). The net was positioned at the top of the first set of major riffles upstream of the lake approximately 30 m downstream of the major aggregation of adult Macquarie Perch (located using the methods described in section 2.3). The contents of the net were collected twice: once after a day set from 0900 to 1500 h on 18 November, and then after a night set from 1600 to 0800 h on 29 November. Each sample was preserved in 95% ethanol and sorted and identified in the laboratory.

**Figure 5. Elton glass eel net set just upstream of first set of rapids to collect drifting Macquarie Perch eggs and larvae.**

## 2.5 Data analysis

Length (TL) and weight (W) data of Macquarie Perch were used as an assessment of general body form of spawning mature Macquarie Perch, expressed by the equation

$$W = aL^b$$

Where $W$ is the weight in grams; $L$ is the TL in mm, and $a$ and $b$ are constants (see Gray et al. 2000). Length and weight data from spent fish were excluded from the analysis. Length–weight relationships could then be used to compare changes in body condition using Fulton's mean condition factor $K$ (see Froese 2006):

$$K_{mean} = 100aL^{b-3}$$

This enabled the calculation of a mean condition factor for mature fish at 250, 300, 350 and 400 mm TL, thus providing data on the current condition of the population's spawning stock and enabling a direct comparison with fish collected in the late 1990s (Douglas et al. 2002). Frequency histograms were constructed from length data using all fish collected, as well as fish collected using standardised netting only (both total and fish collected in each sampling period). This could also be directly compared with previous survey data (see Douglas et al. 2002).

Standardised netting data was also used to assess the timing of upstream fish movement by a two-way analysis of variance (ANOVA) using total numbers of fish (for each species) collected per set as the dependent variable and trip and day/night set as the factors. All analyses were performed using the statistical package GenStat for Windows 10.1.

# 3 Results

## 3.1 Site parameters and water quality

During the time of the study, Lake Dartmouth was around 27% capacity. Furthermore, spring rainfall for the state was one of the lowest on record, so that inflows into the lake were well below average (Figure 6), and only slightly higher than those reported during the 1996 drought (Douglas et al. 2002). The Mitta Mitta River – Lake Dartmouth junction is well downstream of the Gibbo River inflow, which is another major tributary of the lake (Figure 1). The lower 3 km of river still contained large amounts of sediment from the 2003 postfire ash slug washed down the Mitta Mitta and Gibbo Rivers. Although some areas had been washed free of the sediment slug, vast areas were still buried. There was large variation in water temperatures throughout the day but very little between sampling periods. In all three sampling periods water temperatures at the lake–river junction were around 17 °C during the morning and above 20 °C in the afternoon. Turbidity was below 3 NTU during the October and November sampling and around 12 NTU during the December sampling.

The Dart River, Toke Creek and Shady creek were also assessed but had insufficient inflows (in some cases, no inflow) for Macquarie Perch migration during October and November. No fish were detected in any of these tributaries during this time.

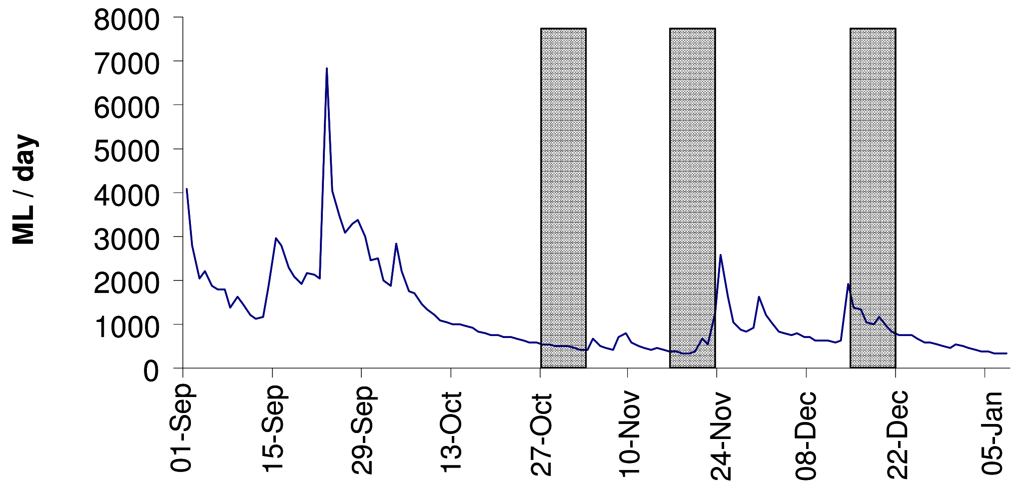



**Figure 6. Daily inflows of the Mitta Mitta River into Lake Dartmouth from September – December 2008. Grey bars indicate times of fish sampling.**

## 3.2 Macquarie Perch spawning stock assessment

A total of 157 fish, comprising of 75 males, 71 females and 11 fish of indeterminate sex were collected during the study (Table 1). Mature male fish ranged in TL and weight from 150 to 440 mm and 60 to 1150 g, with a mean of 352 mm and 695 g respectively. Mature female fish ranged in TL and weight from 235 mm to 432 mm and 184 to 1310 g, with a mean of 389 mm and 931 g respectively (Table 2). The length frequency of both mature male and female fish was dominated by fish around 390 mm TL (Figure 7).

The length–weight relationship of Macquarie Perch using the formula $W = aL^b$ was calculated for all mature fish collected (Figure 8a) and, as presented by Gray et al. (2000), for all fish greater than 230 mm TL (Figure 8b). This data was used to calculate a mean condition factor across numerous sizes of fish, resulting in $K_{mean}$ = 5.29 for all size classes tested. A total of 19 fish spanning the entire size range were euthanased for aging. The oldest fish was a 14-year-old spent female of 400 mm TL. The youngest mature female fish was a 4-year-old ripe female. The youngest fish collected was a 1-year-old, 105 mm TL immature male fish. The youngest mature male fish was two years of age (180 mm). Although only 19 fish were collected for aging, 10-year-classes of fish were shown (Figure 7).

**Table 2. Length and weight data for mature male and female Macquarie Perch (*n* = 157) collected using all methods for all trips in 2008. Maturation status of fish of unknown sex is not known.**

| | **Males (*n* = 75)** | **Females (*n* = 71)** | **unknown sex (*n* = 11)** |
|---|---|---|---|
| **Total length (mm)** | | | |
| Mean ± SE | 352.2 ± 8.6 | 389.8 ± 3.7 | 297.5 ± 39.9 |
| Range | 150 – 440 | 235 – 432 | 105 – 395 |
| **Weight (g)** | | | |
| Mean ± SE | 695.1 ± 45.2 | 931.4 ± 29.1 | 463.2 ± 129.9 |
| Range | 60 – 1150 | 184 – 1310 | 16 – 906 |

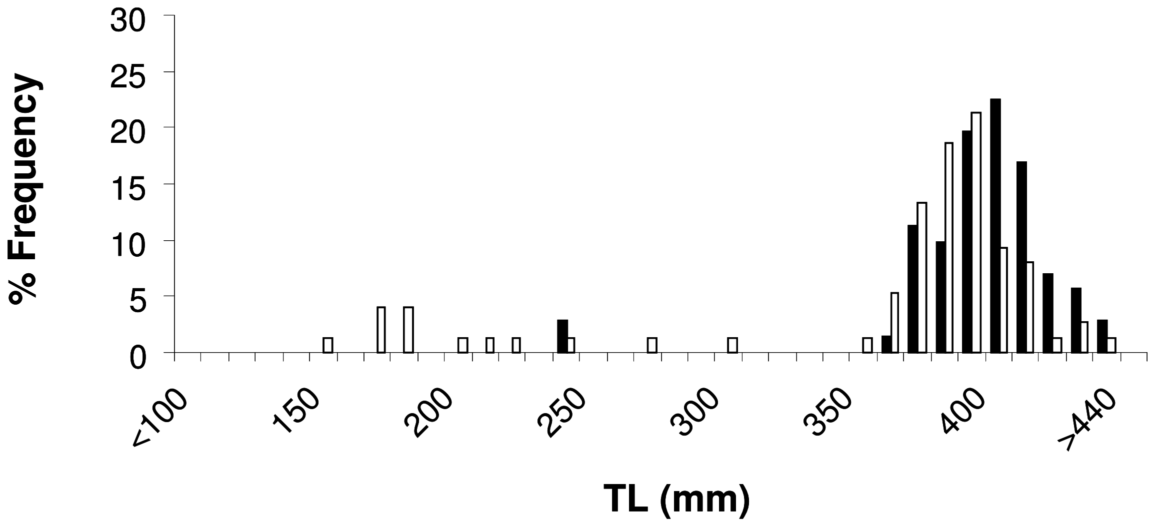



**Figure 7. Total length (TL) frequency of mature male (white bars) and female (black bars) Macquarie Perch collected using all methods (*n* = 146).**

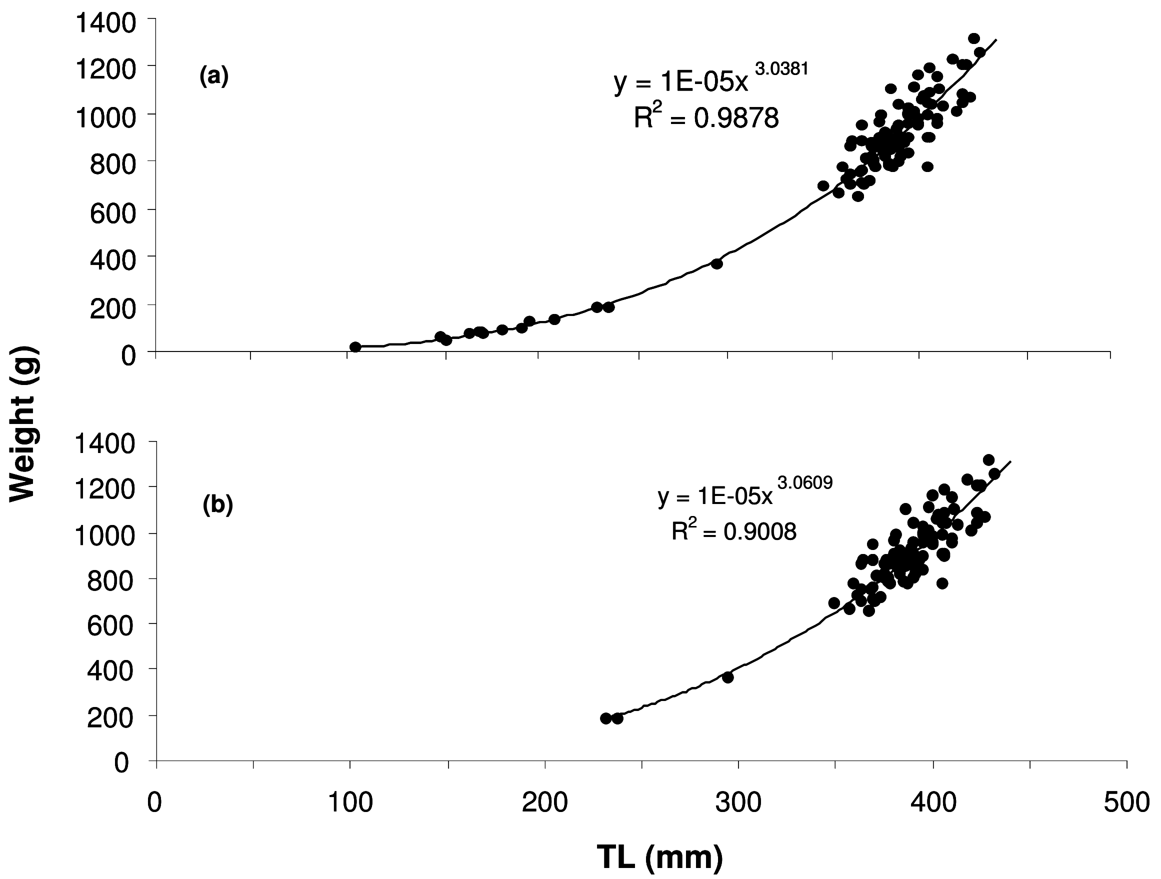



**Figure 8. Total length (TL) – weight relationship of (a) all mature Macquarie Perch collected in the study (*n* = 105), and (b) fish > 230 mm TL as assessed by Gray et al. (2000) (*n* = 95). Spent fish excluded.**

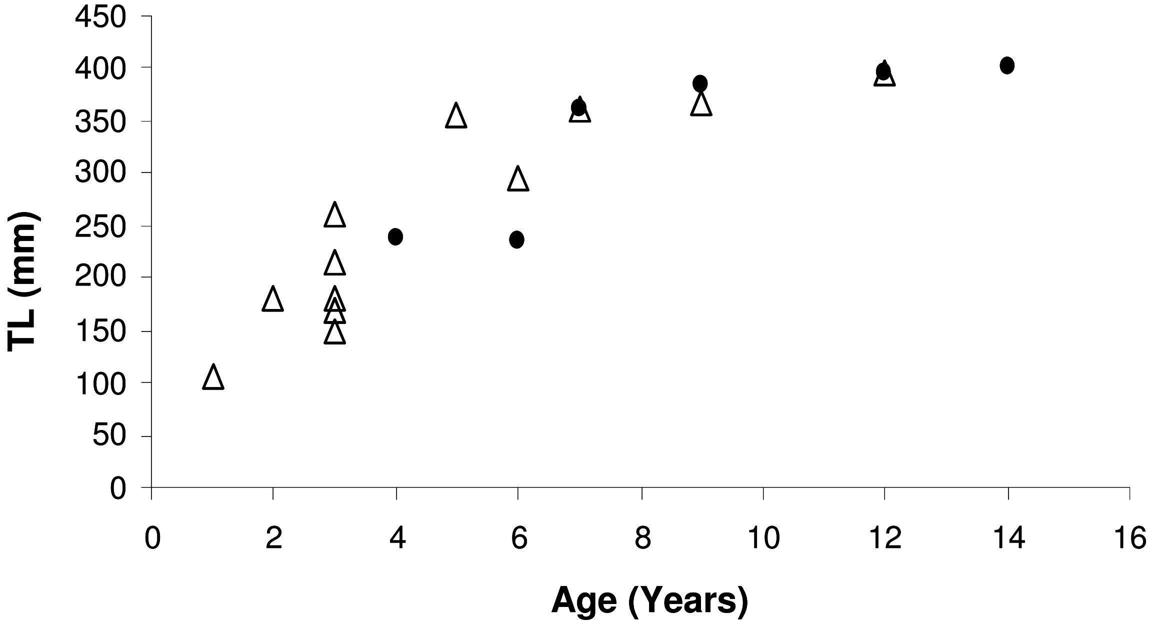



**Figure 9. Total length (TL) at age relationship of male (white triangles) and female (black dots) Macquarie Perch collected in 2008 (*n* = 19).**

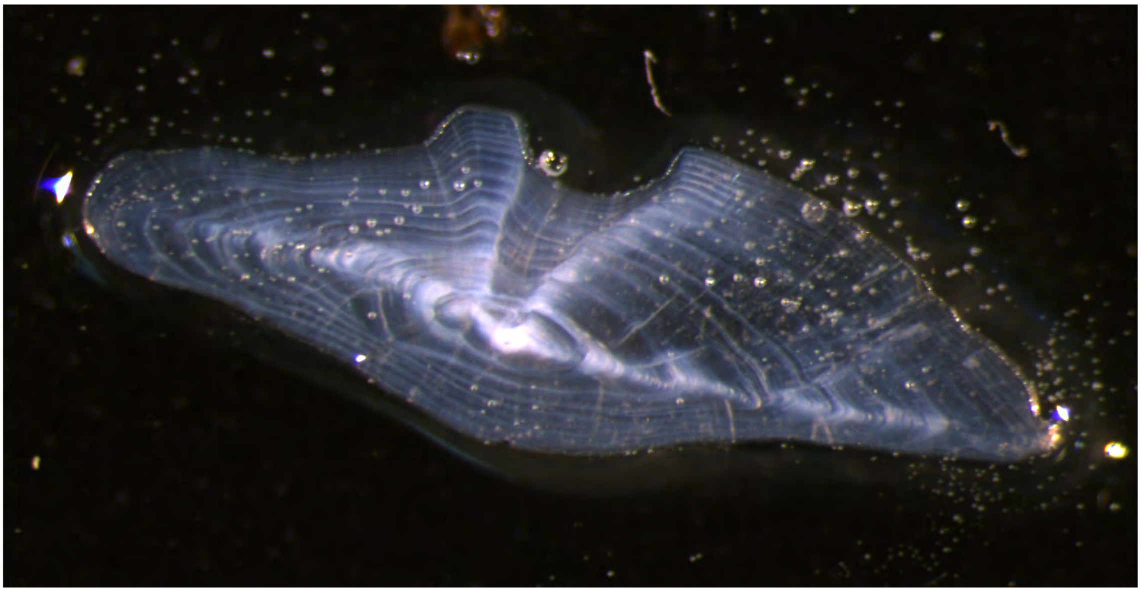


**Figure 10. Transverse section of a sagittal otolith from a 14-year-old female Macquarie Perch 400 mm TL.**

## 3.3 Standardised netting data

A total of 58 Macquarie Perch were collected using the standardised netting regime. There were significantly more Macquarie Perch collected in October than in November and December ($p < 0.05$). Catches in November were also significantly higher in November than December ($p < 0.05$; Figure 11). There was no significant difference in numbers of fish collected in nets between day and night sets.

The length-frequency of fish collected by standardised netting is presented in Figure 12. As with the combined data set, the highest length-frequency values of both male and female fish were around 400 mm TL. When each sampling period is analysed separately, October and November fish follow the trend of length frequencies around 390 mm TL. However, December sampling is dominated by small male fish, although this must be treated with caution given the low numbers of fish collected (Figure 13c).

Three exotic species, Common Carp *Cyprinus carpio*, Goldfish *Carasius auratus* and Brown Trout *Salmo trutta* were also collected in the standardised netting, and both Goldfish and Common Carp collected in similar numbers as Macquarie Perch (Table 3). Goldfish was the most abundant fish species collected during the netting, despite no fish being collected in the December trip (significant; $p < 0.01$). Numbers of carp collected were not significantly different between trips ($p > 0.05$). Significantly greater numbers of exotic species were collected from night sets than nets set during the day (all $p < 0.01$).

**Table 3. Total numbers of fish collected in October, November and December sampling periods by the standardised netting regime.**

| | | Sampling period | | | |
|---|---|---|---|---|---|
| **Common Name** | **Scientific Name** | **Oct** | **Nov** | **Dec** | **Total** |
| Macquarie Perch | *Macquaria australasica* | 33 | 16 | 9 | 58 |
| Common Carp | *Cyprinus carpio* | 20 | 11 | 15 | 46 |
| Goldfish | *Carasius auratus* | 11 | 53 | 0 | 64 |
| Brown Trout | *Salmo trutta* | 1 | 0 | 1 | 2 |

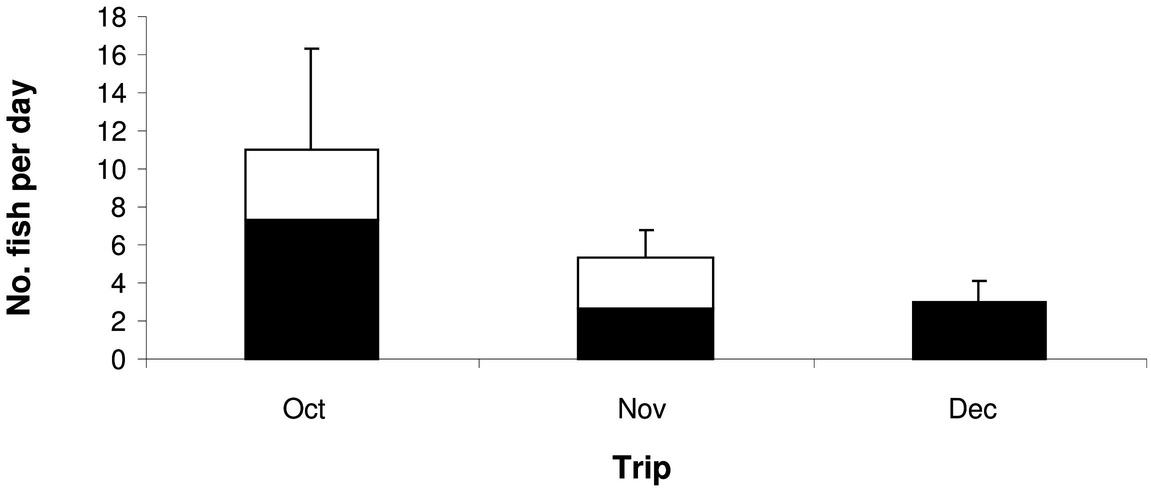



**Figure 11. Mean ± SE number of Macquarie Perch collected per day in the standardised netting regime for each sampling period. Proportions of fish collected from night (black) and day (white) sets are also presented.**

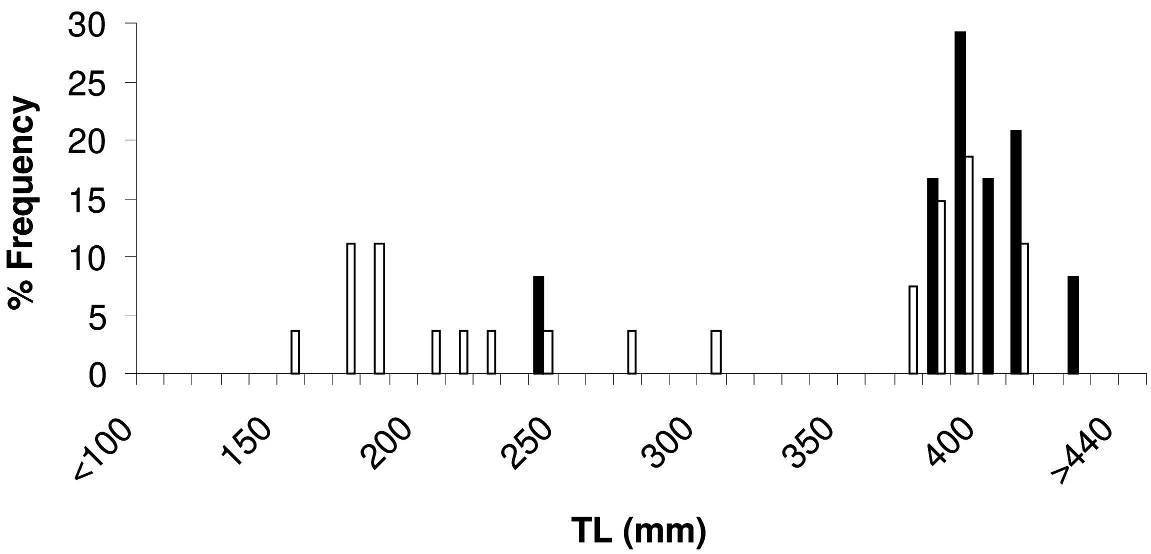



**Figure 12. Total length (TL) frequency of mature male (white bars *n* = 27) and female (black bars *n* = 24) Macquarie Perch collected using standardised netting for all sampling periods.**

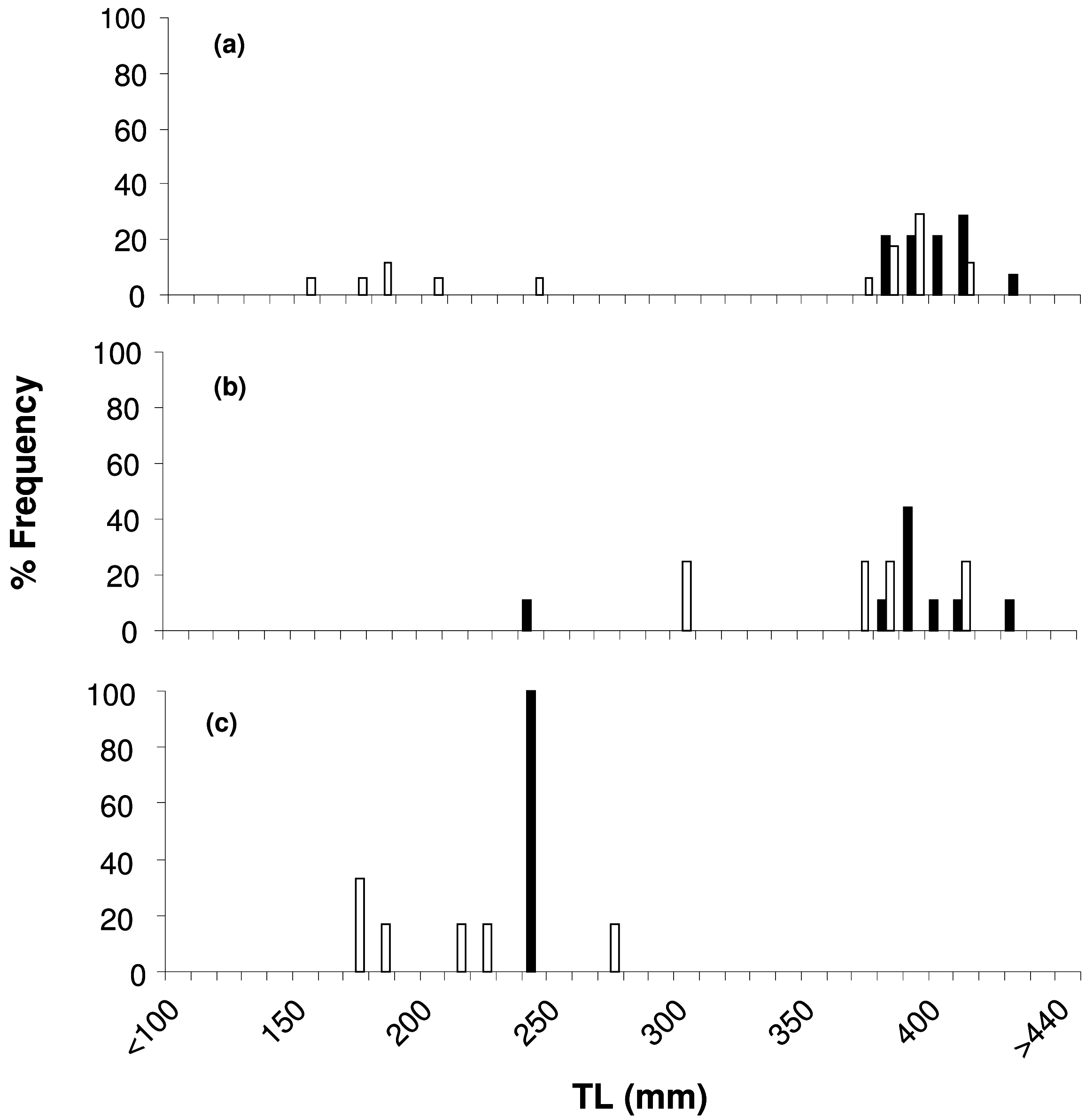



**Figure 13. Total length (TL) frequency of mature male (white bars) and female (black bars) Macquarie Perch collected using standardised netting for (a) (October (*n* = 17 and 14); (b) November (*n* = 4 and 9); and (c) December (*n* = 1 and 5).**

## 3.4 General observation of spawning behaviour and habitat use

### 3.4.1 Abundance and distribution of spawning fish

For several days during both October and November sampling periods, intensive exploration of the river provided important information on Macquarie Perch habitat use and spawning behaviour at an impoundment level of 27%. Initial exploration was undertaken from the lake inflow to approximately 4 km upstream using polarised sunglasses and angling. When fish were sighted, approximate numbers were recorded, several fish were angled (weighed, measured, assessed for condition and tagged). At the time of sampling, Macquarie Perch showed aggression towards artificial lures, which meant that angling was an effective detection method in deeper areas of the river where direct viewing was not possible. These areas were revisited in November.

Fish were observed from the Mitta Mitta River inflow into the lake to approximately 3 km upstream of the lake where a natural rock barrier exists (Figure 14d). After intensive searching (including observation and angling the three pools upstream of this point) failed to locate a single fish, it was concluded that migrating fish from the lake could not pass this section.

Although fish were observed from the river inflow up to the barrier on all occasions, by far the greatest concentration of fish was found in a pool upstream of the first set of rapids above the lake (Figure 14b). On occasions up to 40 individuals could be seen congregated in a small area, with many more fish in deeper water further out in the channel. Large numbers of fish were also located at two other sites upstream of this point, as well as at the lake–river junction (area of standardised netting) (Figure 14), but not at the densities seen in the pool. All other fish observed were generally in much lower numbers, usually in groups of 2–8. Observations of patterns in fish distribution were the same for each visit during both October and November using all methods described. On each occasion the 3 km reach was assessed, we estimated that no more than 500 Macquarie Perch were within the reach at any one time. The majority of fish observed, captured on video and collected by angling in these areas were large fish, supporting the dominant length-frequency data presented in section 2.3.

### 3.4.2 Spawning stock behaviour and habitat use

The main aggregation of fish was in two small areas upstream of the first major rapid above the lake (Figure 15). Furthermore, the highest aggregations of fish were found in the tail end of pools, just upstream of shallow, fast-flowing gravel or pebble substrate. During the morning, large numbers of fish were found congregating in slower-flowing areas containing structures such as large woody debris, undercut clay banks or boulders. In late afternoon, however, more fish were found in faster-flowing water towards the centre of the channel. On several occasions during the late afternoon, fish were observed in groups of two or three displaying what appeared to be courting behaviour such as rolling, chasing and nudging.

Interactions between Macquarie Perch and exotic species were also observed. Most notably, Common Carp were often found with aggregations of Macquarie Perch. Large individuals, often in groups, were frequently seen trailing groups of Macquarie Perch (Figure 16). Videos showed large carp feeding by filtering gravel at these times. Because this behaviour suggested these fish may be feeding on Macquarie Perch eggs, six carp were collected by angling, and the stomach contents were removed and preserved for investigation. Sorting of these samples did not reveal any eggs, but the samples have been kept for further investigation using genetics. High numbers of both Brown Trout and Rainbow Trout *Oncorhynchus mykiss* (generally less than 250 mm FL) were also found around Macquarie Perch aggregations. Also of note were large schools of Eastern Gambusia *Gambusia holbrooki* around the lake margins.

One hundred and one Macquarie Perch were externally tagged during the study. While the use of external tags was employed primarily to provide information during future surveys or from angler returns, a small number of fish were recaptured shortly after their release (Table 4). Several fish were first captured by netting as they moved out of the lake, and recaptured by angling in the major spawning pool above the first riffle zone. One female fish (fish no. 112768) was collected by netting as it moved from the lake, recaptured by angling the following day in the first pool, then captured a third time in November back in the lake–river junction, weighing 16 g less than its original capture weight.

Table 4. Macquarie Perch tag recapture data.

| Tag No. | Total length (mm) | Weight (g) | Sex | First capture | Recapture information |
|---|---|---|---|---|---|
| 111290 | 406 | 1085 | F | 28 Oct, in drum net, Mitta Mitta River – Lake junction | 30 Nov, by angling, 200 m upstream of 1st spawning pool |
| 111297 | 410 | 1150 | M | 28 Oct, in drum net, Mitta Mitta River – Lake junction | 18 Nov, by angling, in 1st spawning pool |
| 112751 | 389 | 930 | M | 28 Oct, in drum net, Mitta Mitta River – Lake junction | 18 Nov, by angling, in 1st spawning pool |
| 112768 | 378 | 770 | F | 28 Oct, in drum net, Mitta Mitta River – Lake junction | 29 Oct, by angling, in 1st spawning pool;<br>18 Nov, in drum net, in Mitta Mitta River inflow (weight 754 g) |
| 112784 | 423 | 1200 | F | 29 Oct, by angling, 1st spawning pool | 30 Nov, by angling, 200 m upstream of 1st spawning pool |
| 112711 | 377 | 855 | F | 30 Oct, by angling, 1st spawning pool | 19 Nov, by angling, in Mitta Mitta River – Lake junction |

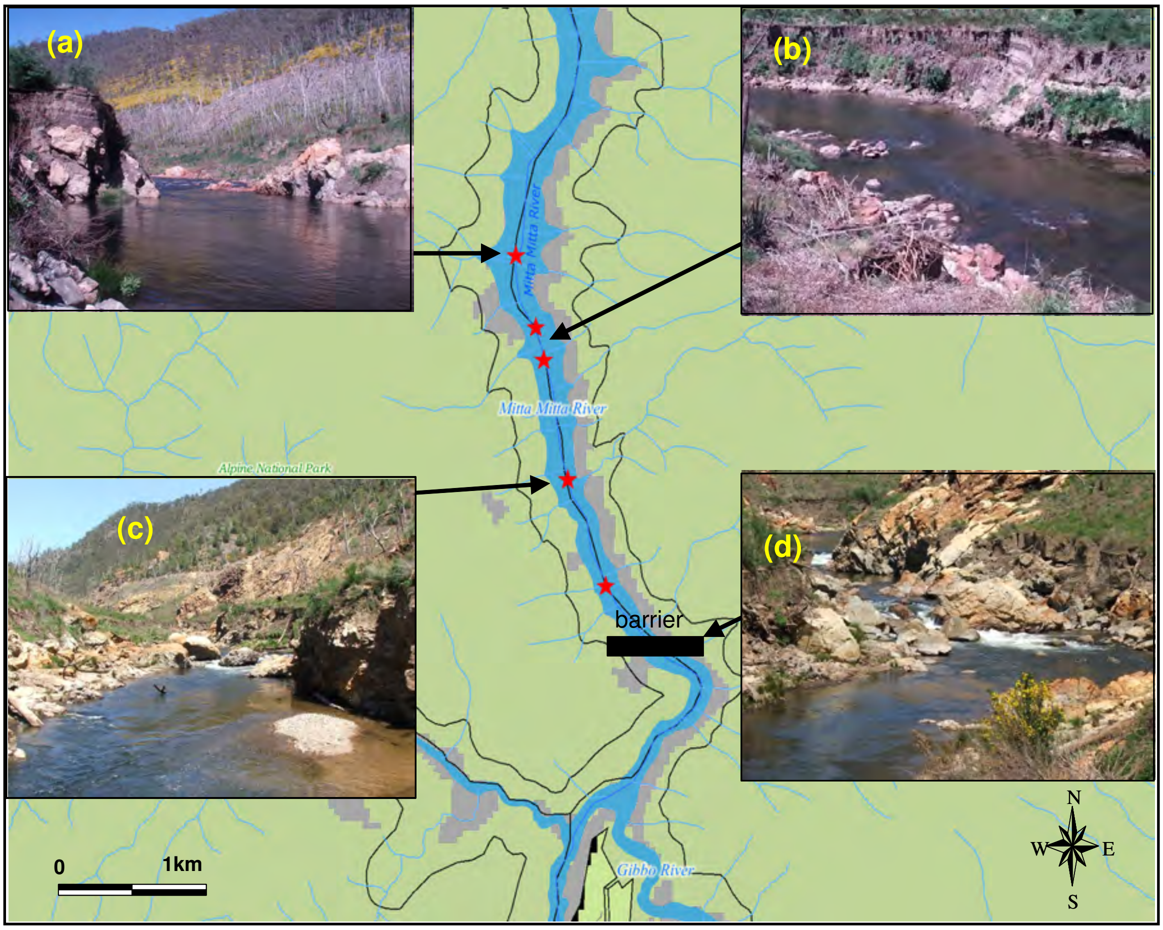



**Figure 14. Mitta Mitta River Study area, illustrating (a) Mitta Mitta River – Lake Dartmouth junction; (b) & (c) location of major aggregations of adult Macquarie Perch in the reach, and (d) natural instream barrier to Macquarie Perch movement. Red stars indicate areas of highest fish numbers.**

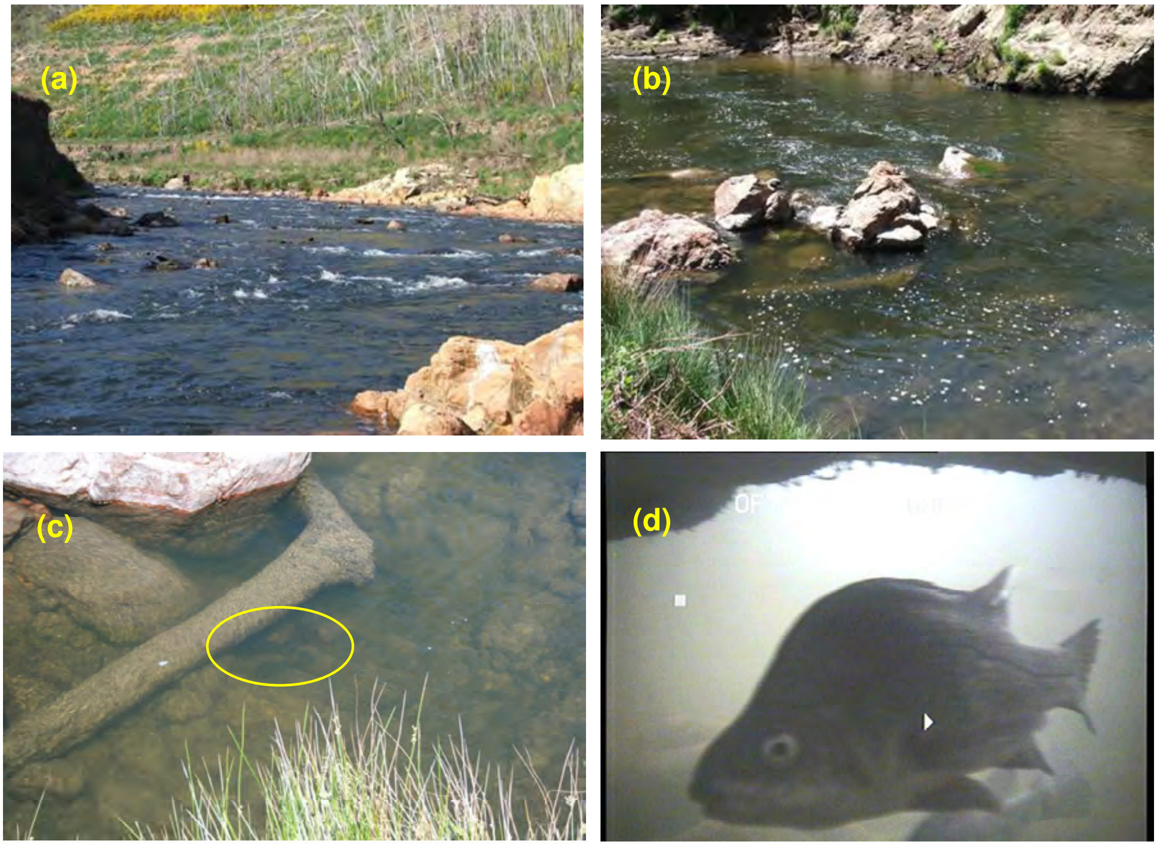



**Figure 15. (a) First set of rapids upstream of the lake; (b) Tail end of first pool above rapids classified as major spawning pool; (c) and (d) adult Macquarie Perch utilising low flow areas.**

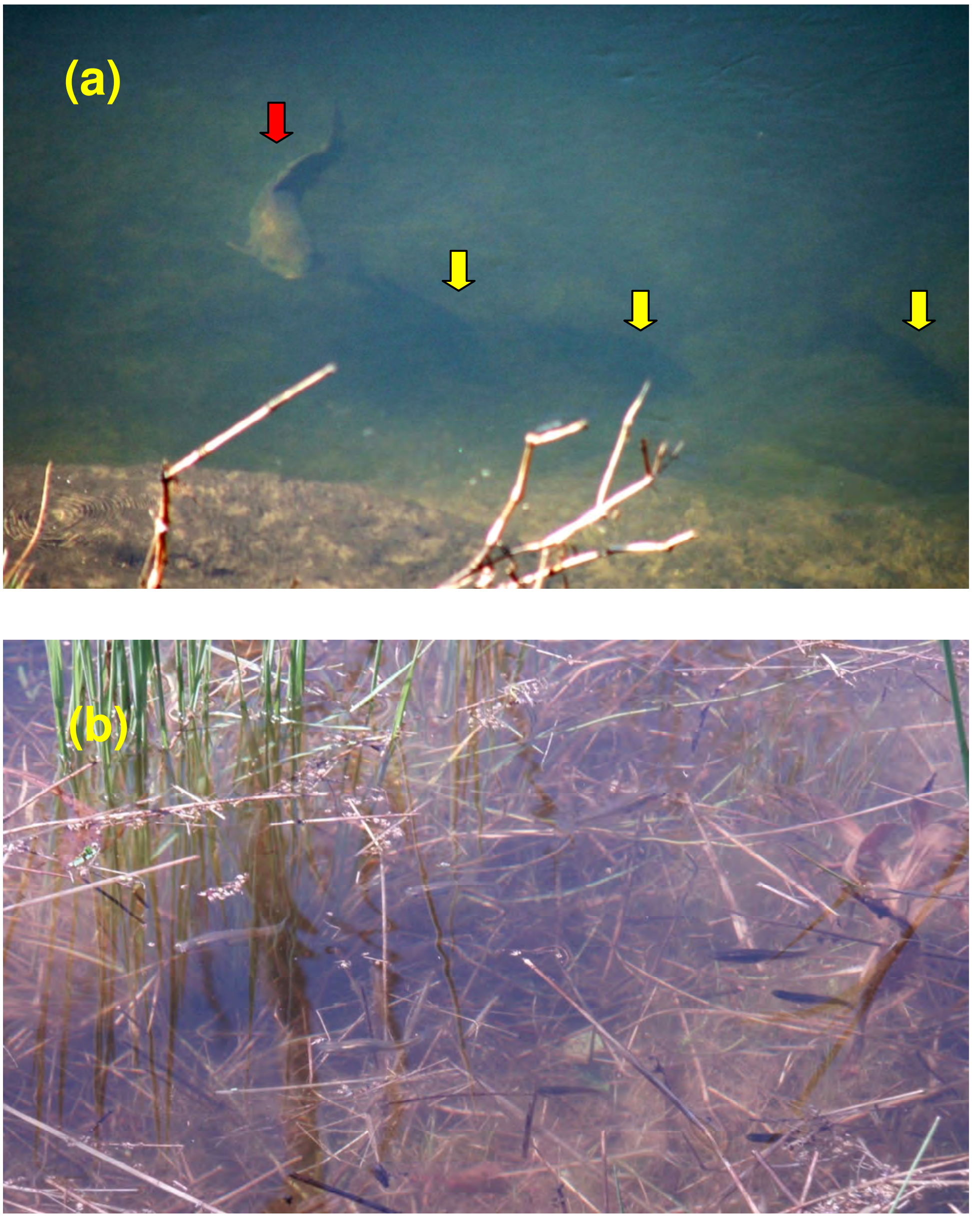



**Figure 16. (a) Large adult Common Carp (red arrow) trailing a group of three adult Macquarie Perch (yellow arrows); and (b) school of adult Eastern Gambusia around lake margin.**

## 3.5 Spawning assessment

A large amount of material was collected in the net after the day set. The sample was mixed and subsampled so that 50% of it was preserved for processing in the laboratory. The night sample was collected the following morning, when it was discovered that the net wing had dislodged and torn. The amount of material in the net was much less than that collected during the day sample, suggesting that the net malfunction had occurred shortly after setting on the previous evening. However, inspection of the contents revealed the presence of eggs (2–4 mm diameter) matching those of Macquarie Perch as described by Douglas (2002) (Figure 17). Further processing in the laboratory found two eggs in the day set (from a 50% subsample) and 108 eggs and two Macquarie Perch larvae in the night sample (despite an early net malfunction).

**Figure 17. Macquarie Perch eggs collected in drift sample.**

# 4 Discussion

## 4.1 Status of spawning stock

It is difficult to compare the abundance of spawning stock with that found in previous studies because of differences in sampling methods. However, Douglas (2002) reported that fish were collected in drum and fyke nets in relatively small numbers (up to 6 individuals per net) in the 1998 and 1999 spawning runs, which is similar to numbers collected in the present study. This may suggest that the spawning stock of the population has not changed substantially in almost a decade, but further assessment is required to confirm this. Observations of numbers of fish in the reach and numerous recaptures indicate that the spawning population is still small, as reported by Douglas et al. (2002).

The results of the present study do, however, enable a direct comparison of spawning stock condition and length-frequencies with earlier work by Douglas et al. (2002) and Appleford et al. (1998). The mean condition of spawning fish collected in the present study (derived from the length–weight relationship) had a mean condition value of 0.0015 for four size classes of fish (250, 300, 350 and 400 TL respectively). Fish collected between 1980 and 1982 (Appleford et al. (1998) during the initial filling phase, and in the late 1990s (Douglas et al. 2002) had a mean condition factor of 0.0023 and 0.0013 respectively (calculated using the parameters of the length–weight relationship reported by the authors), although the latter was a value for the entire Macquarie Perch population, not just the spawning stock. This suggests that, although the condition of current fish stocks is less than the condition at the time initial lake inundation (because of the trophic upsurge that occurred in the first few years after impoundment), it has not deteriorated since the late 1990s and perhaps has even improved slightly. The length-frequencies reported in the present study indicate that the highest proportions of fish collected using all methods as well as netting only were large fish around 390 mm TL. This was true for both male and females. Douglas (2002) reported that fish collected in drum and fyke nets from 1994 to 1996 had highest frequencies between 200 and 260 mm TL, with much lower proportions of fish between 380 and 410 mm TL. While that study did not report on female fish, a similar size frequency of running ripe male fish was also reported in 1995.

In the 1998 and 1999 spawning seasons the average size of spawning fish was 367 mm and 300 mm TL and 826 g and 515 g in weight respectively (Douglas 2002). The present study recorded the average size of male and female spawning as 352 mm and 390 mm TL and 695 g and 931 g respectively. There are also no major differences in age structure or size at maturity between the data recorded in the present study and that recorded in the late 1990s (Douglas 2002). Aging also indicated that successful recruitment has occurred over 10 of the last 14 years, although the strength of each of these recruitment years is unknown. Therefore it appears that although the condition, average sizes and age structure of the spawning population are not at the levels recorded during the initial filling stage of the lake, they have not dropped since the last surveys over a decade ago and perhaps have even improved slightly since the 1990s. However, the large size classes of fish representing the spawning stock and the limited number of smaller fish collected (and observed) may indicate that recruitment has been severely limited in the past decade. An overall population assessment and future young-of-year surveys are required to assess this.

## 4.2 Spawning behaviour and habitat use

Douglas et al. (2002) suggested that detection and description of Macquarie Perch spawning habitat for Lake Dartmouth was urgently required in order to determine if the population was restricted by the availability of spawning habitat, and so that management measures could be made to protect or enhance spawning areas. The present study detected a major aggregation of fish upstream of the first major rapids on the Mitta Mitta River above the lake. This finding is in agreement with Cadwallader and Rogan (1977), who reported that fish in Lake Eildon during the 1960s spawned in the first few rapids upstream of the lake, the majority being less than 2 km upstream. Observations in the present study may, however, have been biased by the instream barrier approximately 3 km upstream of the lake. Douglas (2002) reported that Macquarie Perch were spawning more than 2 km upstream of the river–lake junction, and that during 1996 no large aggregations of fish were found in the 2.5 km stretch upstream of the lake, a likely result of the drought during this season. Inflows during 1996 were between 550 and 1000 ML/day, which is similar to the range experienced during the present study. Nevertheless, habitat use and behaviour of Macquarie Perch was consistent with numerous other studies, such as:

- fish taking up position just upstream of the head of a riffle (Cadwallader and Rogan 1977)
- an apparent lack of fish in other tributaries such as the Dart River (Douglas et al. 2002; Cadwallader 1981)
- spawning over a prolonged period of several weeks (Cadwallader and Backhouse 1983), and may have been several months in the present study.

The spawning period of fish during the present study can not be accurately assessed, but was likely to be over an extended period of time. Fish were already present and displaying spawning behaviour during the first trip in mid October, when at this time afternoon water temperatures of the river were already around 20 °C. Previous studies reporting fish moved into tributaries when water temperatures were around 16 °C (Cadwallader and Rogan 1977), therefore fish may have initiated spawning several weeks before the first trip. As spawning fish were still present in the river in mid December (albeit very few), Macquarie Perch appear to be capable of a more prolonged spawning period than first reported. The fact that several individuals were recaptured in spawning areas more than three weeks after their initial capture also supports this view. Indeed the closely related perchichthyd Golden Perch *Macquaria ambigua* have a flexible spawning period, capable of spawning over a prolonged period (Lake 1967). The aggregations of large numbers of adult fish over such an extended period do expose the species to exploitation by legal and illegal fishing. Cadwallader and Rogan (1977) reported an estimated catch of 2–3 tons of Macquarie Perch from the Goulburn and Jamison Rivers during the opening of the fishing season in the 1960s.

Numerous fish were recaptured during the study, despite limited effort. Douglas et al. (2002) also recaptured a high proportion of fish, predominantly in the Mitta Mitta River area. This may indicate either the lake has a small spawning population that migrate from across the lake to spawn, or that these are fish that reside in this area of the lake (Mitta Mitta River area). Future surveys and a more extensive tagging study are required to assess this.

The collection of far great numbers of eggs and larvae during the night sample compared to the day also suggests that the species spawning activity and larval drift is greatest between evening and early morning. These observations are only based on single samples and need to be replicated to be confirmed, although given this observation has been confirmed for both Golden Perch (King et al. 2007) and Silver Perch *Bidyanus bidyanus* (Tonkin et al. 2006) it does seem likely for Macquarie Perch.

Another observation of behaviour and habitat use by the species was the use of slow-flow regions around spawning areas. In particular, the use of complex habitats such as boulders, undercut banks and large woody debris. This is relevant for habitat restoration efforts for the species.

## 4.3 Potential threats

The results of the spawning stock assessment suggest that resources in the lake available for Macquarie Perch have stabilised since the 1990s and may not be the sole cause of a population decline. Therefore, if indeed the population size of Macquarie Perch in Dartmouth Dam has dropped, it would appear that recruitment is the limiting factor of the population. Douglas et al. (2002) suggested that the reduced growth and reproductive potential may have reduced the population size through variable spawning success, but Gray et al. (2000) reported that mean percentage fertilisation and mean relative fecundity were all related to relative condition factor, so these factors are not likely have limited recruitment recently. Of course these observations of condition and size structure may reflect a short-term state, given the current regrowth around the edges of the lake (due to an extended period at low capacity) and subsequent spring inundation. Indeed, if lake levels continue to rise over the coming season, conditions may be similar to or less than the initial filling stages of the impoundment. Future surveys, not only of Macquarie Perch populations but the fish community in general are required to monitor the productivity of the impoundment.

The results of the present study suggest that recruitment is likely to be most limited by spawning habitat availability, and by factors limiting survival of eggs, larvae and juveniles. Furthermore, the large size classes of fish representing the spawning stock, and the limited number of smaller fish, may also indicate recruitment has been severely limited in the past decade. It appears that, at least under current impoundment levels, the Mitta Mitta River is the exclusive spawning area for the current population. Douglas et al. (2002) indicated that siltation, varying water levels and degradation of the physical environment from flooding in this area may all adversely affect Macquarie Perch recruitment. At the current lake level, spawning habitat appeared to be limited to a 3 km reach. This habitat availability is likely to depend on the lake level and inflows. At present, any rise in the lake is likely to reduce the amount of spawning habitat to a point, but further increases would allow fish to ascend the large rapid which is acting as a barrier to fish movement. If fish could ascend this barrier, the Gibbo River would then be available as a potential spawning tributary, although the degree of use will also depend on inflows and suitable habitat (given that post-fire sedimentation also influenced the Gibbo River).

The sediment slug that came down the Mitta Mitta and Gibbo Rivers following the 2003 bushfires has also influenced the available spawning habitat (Lyon and O'Connor 2007). Although some areas have been flushed of this sediment, many riffle areas are still completely buried, leading to a lack of complex habitats. The low lake levels and sediment slug also left the channel upstream of the lake devoid of any riparian vegetation, and is probably the reason for the large daily temperature variations observed during the present study. Aside from a reduction in spawning habitat, the large amount of sediment still in the lower river channel is also likely to have influenced egg survival, particularly after local rainfall events. Increased water temperatures and large daily variation may also adversely impact egg survival.

Exotic species may also be influencing the survival of Macquarie Perch eggs, larvae or juveniles. Of particular concern is the presence of large Common Carp feeding around groups of adult Macquarie Perch, and in the riffle areas downstream of these groups. Further evidence is needed to confirm whether carp are ingesting Macquarie Perch eggs and early larvae. However, given the high numbers of carp observed throughout the confined river reach, and the vast quantities of sediment that carp filter daily, one would suspect they are at least disturbing areas of egg and larval settlement. Both Brown and Rainbow Trout may also be influencing recruitment strength, most likely by preying on larval and juvenile stages. Eastern Gambusia were also abundant around the lake margins, and may influence juvenile Macquarie Perch through aggression or competition for food resources when the latter migrate back into the lake (Macdonald and Tonkin 2008).

Although Macquarie Perch have been found in large numbers in the presence of exotic species such as trout (e.g. Koehn et al. 1995) and cyprinids (e.g. Pitman et al. 2007), the influence of exotic species may become significant when a species is already under stress from other factors.

## 4.4 Future research and management recommendations

Because the findings of this project were based on a single season, many of the areas addressed in the study require further investigation, as do areas that were identified as major knowledge gaps. The main recommendations from this study are as follows:

- Repeat the study in future seasons to monitor spawning stocks and confirm the habitat requirements of Macquarie Perch spawning. Additional assessments of spawning habitat availability during different impoundment levels are also recommended. This will inform habitat restoration of both the Dartmouth population and others in the basin.
- Undertake a tagging program (both external and acoustic) to determine whether fish from the entire lake spawn in the Mitta Mitta, or whether only fish that are resident in the river spawn there.
- Assess the impact of exotic species, particularly Common Carp, on Macquarie Perch spawning and recruitment.
- Conduct an overall fish survey of the lake over coming seasons using both sampling and a creel survey, to assess lake productivity and overall abundance and size structure.

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