Assessment of a Stocking Program: Findings and recommendations for the Snowy Lakes Trout Strategy

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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This project was jointly funded by the Recreational Freshwater Fishing Trust and New South Wales Department of Primary Industries.

The data in this report were collected with the co-operation of hundreds of recreational fishers who filled in and returned catch survey forms and presented their fish for weighing, measuring and otolith removal. Thanks to many Snowy Mountains businesses (e.g. accommodation centres) who encouraged anglers to fill in the forms and acted as weigh-in stations for weighing and measuring fish.

Trapping and electrofishing the spawning runs would have been impossible without the dedicated work of Gaden Trout Hatchery staff (particularly Sam Crocker, Garry Green, Garry Caldwell and Mark Jefcoate) and Fisheries Compliance staff (particularly staff from the Monaro Office), more often than not in challenging climatic conditions. Roy Winstanley assisted with field sampling and data collection and analysis between 2000 and 2003. Mark James (Cronulla Fisheries Centre) assisted with data collection, particularly during the 2000 – 2001 Easter and Snowy Mountains Surveys and 2005 Easter survey.

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Research was conducted under the authority of the NSW Animal Care and Ethics Committee (permit ACEC 00/06).

NON-TECHNICAL SUMMARY

Assessment of Stocking Program:
Findings and recommendations for the Snowy Lakes Trout Strategy

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OBJECTIVES:

- To assess whether trout stockings within Lake Eucumbene and Lake Jindabyne have had any impacts on the fishery.
- To determine the extent of any impacts.
- To suggest biological and economic recommendations for the Snowy Lakes Trout Strategy.

NON-TECHNICAL SUMMARY:

Stocking is used worldwide as a management tool to rehabilitate fish populations either following a decline or to prevent declines. Various species of trout and salmon have been stocked into Australian systems since the late 1800s to establish recreational fisheries. Such stocking practices have been increasingly regulated in recent years but a total of 63,700,000 brown, rainbow and brook trout have been stocked into NSW since 1980. There has been relatively little monitoring of stocking success over that time, so the relative efficiency of these practices is poorly understood.

In December 2000, the Snowy Lakes Trout Strategy was drafted to guide fish stocking practices in the region. The group comprises representatives from the tackle, tourism and guiding industries, the Monaro Acclimatisation Society, angling media, the Jindabyne Chamber of Commerce, and the Snowy Mountains Hydro Electric Authority. Fisheries managers, researchers and Gaden Trout Hatchery staff represent the NSW Department of Primary Industries (previously NSW Fisheries). The main recommendation was that rainbow trout be stocked into Lake Eucumbene (150,000 fingerlings) and Lake Jindabyne (50,000 fingerlings) on an annual basis. No brown trout were to be stocked. A monitoring program was subsequently established to determine the relative success of these stockings. The program sought to monitor various aspects of the trout population to determine if the stocking practices were adequate. This report summarises the findings of the monitoring program (between 2000 and 2005) and provides future stocking recommendations, to ensure that the economic importance of trout fishing to the Snowy Mountains region is maintained.

Annual spawning migrations of trout into the tributaries of both Lake Jindabyne and Eucumbene were assessed between 2000 and 2005 to identify any changes in the biology and structure of the trout populations. The primary aim of these surveys was to identify if there were any changes to the trout populations that might require management intervention to prevent a collapse. To achieve this, a number of metrics were monitored annually for five years.

In addition to assessments of the spawning fish, annual spawning runs were monitored by direct trapping and electrofishing to ascertain whether spawning fish were of appropriate condition. Secondly, the ratio of wild fish to stocked fish in the spawning run (determined by the previous fin-clipping of stocked fish) was annually monitored to ensure natural recruitment was contributing to the fishery within each lake. Thirdly, age information was collected from migrating fish to determine the spawning age of adult fish, which may provide information on the frequency of future stockings within the lakes. Finally, angler catch data were also collected and assessed from

two major tournaments, the annual Snowy Mountains Trout Festival and the Easter long-weekend tournament, to establish whether catches were adequate, and did not vary among years.

Lake Eucumbene

Data demonstrated that both rainbow and brown trout populations were performing well in the lake and its associated tributaries. Monitoring of angler catch data showed no significant changes in catch rates between 2000 – 2005. Although the catch of rainbow trout spiked in 2001, catches in all other years was similar for both species.

Rainbow trout were sampled in substantial numbers. Over the five year period, the greatest percentage of stocked to wild fish was 8% in 2005. This low recapture rate of stocked fish demonstrates that wild fish are greatly contributing to recruitment within the lake and its associated tributaries.

The age structure of migrating rainbow trout was consistent among years. Each year, over 75% of migrating fish were three years old with at least 8% of the catch present as two year olds. Four year old fish migrated in 2004, but were present in extremely small numbers. The condition of spawning fish (both brown and rainbow trout) also varied little among years, although female fish generally returned higher condition values than males. Overall, males and females consistently returned condition values of over 1.1, which is classified as 'fair to good' for spawning fish.

Lake Jindabyne

Data again demonstrated that both rainbow and brown trout populations were performing well in the lake and its major tributary, the Thredbo River. Angler catch data showed few differences in the catch rate of brown and rainbow trout. However, in 2002 and 2004, the catch rate of brown trout was marginally greater than rainbow trout. Statistically, there were no significant differences between species or among years. The proportion of stocked fish in the spawning migration peaked at 19% in 2004. This observation suggests that the rainbow trout population in Lake Jindabyne is more dependent on stocking than the one in Lake Eucumbene. However, the relatively low percentage of recaptures suggests that wild fish are still providing a large contribution to recruitment within the lake.

The age structure of migrating rainbow trout was consistent with results from Lake Eucumbene except during 2004. In this year, a large proportion of spawning fish (>80%) were two years old. In all other years, the greatest proportions were three year old fish (at least 60%). In 2004 and 2005, small numbers of four year old fish were sampled but these contributed less than 5% to the total spawning run. All fish (both species) returned condition factor values of greater than 1.1 in all seasons sampled. In general, females returned slightly higher values than males but this result was not statistically significant.

Recommendations

The results from this five year study suggest that both rainbow and brown trout populations of Lake Jindabyne and Eucumbene are in excellent condition. Spawning fish all displayed high condition factors and migrated in good numbers during each year of sampling. Information from angler catch returns demonstrates that the recreational fishery is healthy and that annual catch rates are consistent and vary little among years. These results suggest that stocking should continue at the present rates as there are no signs of population distress in either waterbody. In Lake Jindabyne, current stockings of 50,000 rainbow trout per annum appear adequate to maintain the population. In Lake Eucumbene, the current rate of 150,000 should also continue. No brown trout have been stocked into either waterbody for almost 20 years and the species has maintained self-sustaining populations over that time. Therefore, there is no immediate requirement to stock brown trout into either lake.

1. INTRODUCTION

Globally, stocking is referred to as the repeated injection of fish into an ecosystem in which a population of that species already exists (Cowx 1998; Aprahamian *et al* 2003). The existing population may be either already native to the recipient water body, or exotic, its presence arising from previous introductions. More recently, stocking is used worldwide as a management tool to rehabilitate fish populations either following, or to prevent, population declines.

Salmonids were first introduced to Australia from England in 1864 from eggs transported to Tasmania. The first introduction within NSW was between 1873 and 1888 (Faragher 1986) and stockings have continued since to maintain and enhance a profitable recreational fishery. Stocking of salmonids now occurs to reduce the requirement for natural recruitment to support recreational fisheries. The practice was initially unregulated, and could be undertaken by any individual seeking to introduce fish into a given waterway. More recently, however, government and private hatcheries have adopted a more controlled approach to stocking practices to prevent the unwanted introduction of fish into conservation areas, or to prevent overstocking, both of which can have unwanted ecological effects.

Over the past 20 years, a total of 63,700,000 brown, rainbow and brook trout have been stocked into NSW waterways (NSW DPI, Unpublished Data). However, a large proportion of these stockings were not monitored. Without any regular assessment or monitoring of stocked fish populations, management interventions regarding the frequency and numbers of future stocking events cannot be accurately determined. If factors such as the age structure, recruitment success, assessment of reliable angler data and an overall understanding of the fish population are regularly assessed, stocking activities can be managed in the best interest of the fishery and target species.

1.1. Lake Eucumbene

Lake Eucumbene was constructed in 1958 (approximate centre 36°04’ S, 148°42’ E). It is a major recreational trout fishery on the mainland of Australia. The Lake is a highland impoundment in the Snowy Mountains of NSW at an altitude of 1164 m (full supply level) and has a capacity of 4,796,494 megalitres (Diplock & van der Walt 2005) (Figure 1).

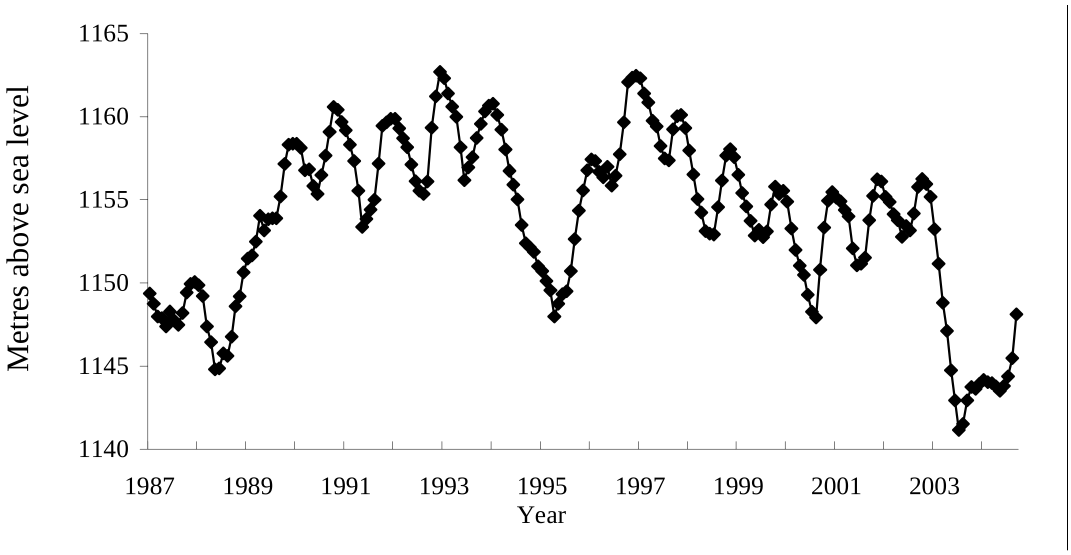

Figure 1. Lake Eucumbene water levels 1987 – 2004. Note that full supply level is 1164m above sea level. Data reproduced with the permission of Snowy Hydro.

The lake covers an area of 14,500 hectares at full supply level and was formed in 1957 by the construction of a dam on the Eucumbene River as part of the Snowy Mountains Hydroelectric Scheme. Water level fluctuations vary with electricity demand and precipitation. Fluctuations can be up to 19 m annually (Faragher 1983, Figure 1). The maximum depth of Lake Eucumbene is 107 m and the mean depth is 33 m (Faragher 1992). Scribner (1987) classed Lake Eucumbene as oligotrophic (low in nutrients and biological production).

The fishery in the lake is based on two species, brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) and has been the subject of a number of studies since the dam was completed. Aspects of earlier research on the biology of the trout in Lake Eucumbene were published in the scientific literature (Tilzey 1976, 1977) and other findings were produced in fishing magazines, fishing books and as public information brochures (Tuma 1963, Bucknell 1965, Greenham 1967; Tilzey 1968, 1970, 1972, 1979, 1986).

A study in the period 1985 – 89 (Faragher 1992, Faragher and Gordon 1992, Faragher 1993) included tagging, catch data collection and age validation (by finclipping hatchery-bred young of the year (yoy) rainbow trout prior to release). The tagging study in this same period (Faragher and Gordon 1992) monitored the recaptures of the two species over an 1157-day period. The results showed that the annual rate of exploitation of rainbow trout by anglers was around three times higher than that for brown trout (26.7% for rainbow trout and 8.8% for brown trout). Another measure of the level of exploitation – the instantaneous rate of fishing mortality (F) – for rainbow trout was significantly greater than for brown trout (50.3% compared to 12.1%). The overall annual mortality rate (A) for rainbow trout was found to be 76.3% whereas for brown trout the figure was lower at 47.9% (Faragher and Gordon 1992, (Table 1).

Table 1. Mortality and exploitation estimates from the tagging study (Faragher & Gordon, 1992). *Z* = Instantaneous rate of total mortality (corrected for tag loss), *F* = instantaneous rate of fishing mortality, *U* = annual rate of exploitation and *A* = annual mortality rate. Bracketed figures denote asymptotic 95% confidence intervals. SE = standard error.

Parameter	Brown trout	Approx. SE	Rainbow trout	Approx. SE
Z	0.658 (0, 1.648)	0.230	1.437 (1.133, 1.741)	0.071
F	0.121 (0.028, 0.215)	0.218	0.503 (0.455, 0.552)	0.011
U	0.088 (0.042, 0.135)	0.011	0.267 (0.242, 0.292)	0.0059
A	0.479		0.763	

From first impoundment in 1957 until 1981 the number of rainbow trout in the angler catch decreased steadily from 80% of the catch in the 1960s to less than 40% of the catch in the early 1980’s (Tilzey 1986, Figure 3). The decline in the total number of rainbow trout in the lake from soon after impoundment until 1981, described by Tilzey (1986), caused the angler catch rates to fall. Initial high catches and growth rates are typical of trout fisheries in new or enlarged impoundments and are often followed by declines in catches and average weight of fish (Tuma 1963; Bucknell 1965; Greenham 1967; Tilzey 1968; Tilzey 1979; Davies and Sloane 1988, Stables *et al* 1990).

In Lake Eucumbene, this is attributed to an increase in brown trout numbers, a low exploitation rate of brown trout and a high exploitation rate of rainbow trout. A decline in mean length and weight of rainbow trout also occurred during this period (Faragher 1983). The lake was stocked with 300,000 yearling rainbow trout in December 1981. In the following year (1982), the rainbow trout proportion in the catch rose to 82.5% (Tilzey 1986). Except for some reported stocking of rainbow trout fingerlings in the late 1950s inundation phase (Tilzey 2000a), this was the first major stocking of trout since first impoundment.

Prior to 1980, the stocks of fish in the lake were largely descendants of the existing river populations. A subsequent smaller stocking of 84,000 rainbow trout fry occurred in November 1982. These two stockings kept the proportion of rainbow trout in the catch high for the next ten years (Figure 3; Faragher 1993), reaching levels not recorded since the 1960s.

Between 1986 and 1988, nearly 106,000 finclipped hatchery-bred, rainbow trout fingerlings were released for research purposes (Faragher 1992). Captures of some of these finclipped fish during the spawning migrations (herein spawning 'runs') showed that at least some of the fish survived until three years of age and were in spawning condition. Captures of fish of known ages also enabled age validation. These findings, together with the data indicating high exploitation rates for rainbow trout, found from the tagging study, led NSW Fisheries to the decision to supplement the stocks of rainbow trout by 300,000 at three year intervals (Faragher 1993).

1.2. Lake Jindabyne

Lake Jindabyne was constructed in 1967. It is approximately 930m above sea level (at full supply level) and has a storage volume of 389, 000 megalitres at full capacity (Diplock & van der Walt 2005). Lake Jindabyne is a major trout fishery on mainland Australia. It is one of four dams which form part of the Snowy Mountains Hydroelectric Scheme within the Snowy River Basin (Turner & Erskine 2005). Water levels rise from early spring when snow melts and usually peak between October and December. There is then a steady decrease in lake level which is lowest in the winter months before the subsequent snow melt (Williamson 1999; Snowy Hydro data). The fishery in the Lake is based on four species, brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*) and Atlantic salmon (*salmo salar*). There has been limited fisheries research done at Lake Jindabyne compared to Lake Eucumbene.

Figure 2. Trout technicians, Justin Stanger and Nathan Reynoldson performing annual electrofishing of migrating trout in Swamp Creek, a tributary of Lake Eucumbene (Photo: NSW DPI).

In December 2000, a working Group was established to develop a strategy to manage the trout fisheries of three important fisheries in Lake Eucumbene, Lake Jindabyne and Tantangara Reservoir. The group comprises representatives from the tackle, tourism and guiding industries, the Monaro Acclimatisation Society, angling media, the Jindabyne Chamber of Commerce, and the Snowy Mountains Hydro Electric Authority. Fisheries managers, researchers and Gaden Trout Hatchery staff represent the NSW Department of Primary Industries (previously NSW Fisheries).

A Snowy Lakes Trout Strategy was subsequently drafted to guide fish stocking practices in the region. The main recommendation was that rainbow trout be stocked into Lake Eucumbene (150,000 fingerlings) and Lake Jindabyne (50,000 fingerlings) on an annual basis. No brown trout stocking was to take place. A monitoring program was subsequently established to determine the relative success of these stockings. The program sought to monitor various aspects of the trout population to determine if the stocking practices were adequate. This report summarises the findings of the monitoring program and provides future stocking recommendations.

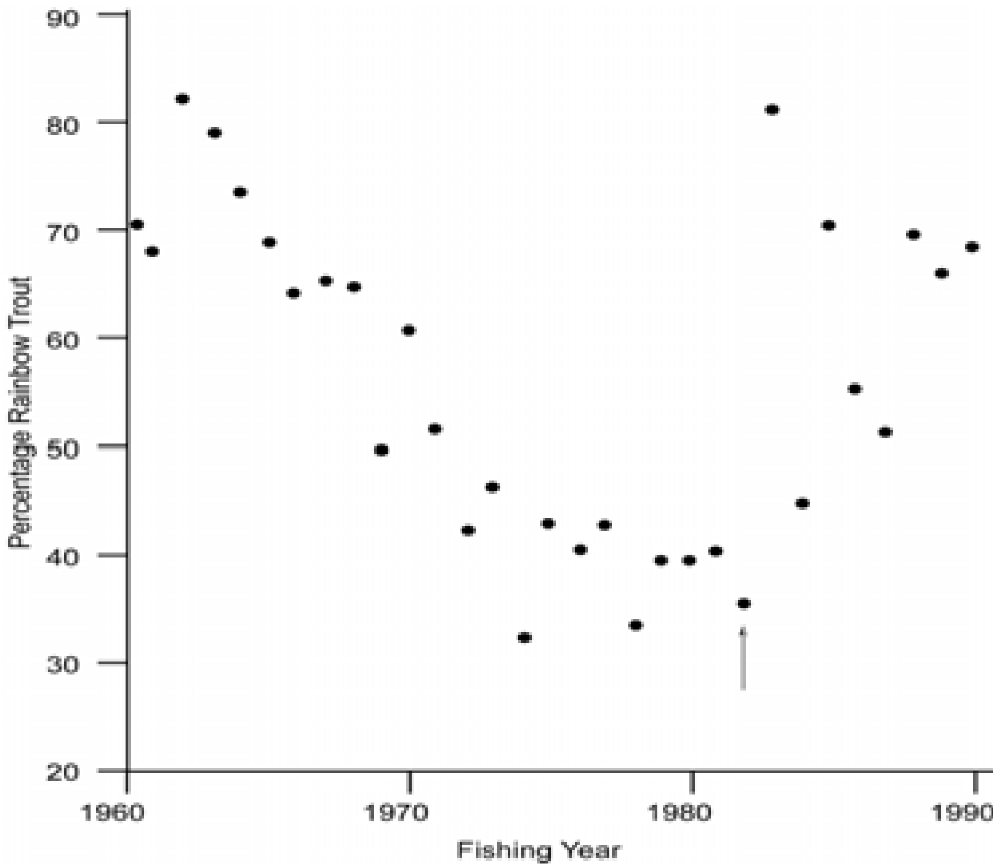

Figure 3. Percentage rainbow trout in recreational catch samples from Lake Eucumbene 1959 – 1960 to 1989 – 1990. The data from 1959 – 1960 to 1983 – 1984 are from Bucknell 1965; Greenham, 1967; Tilzey, 1970; Tilzey, 1986; and R. Tilzey, personal communication. The data from 1984 – 1985 to 1989 – 1990 are from Faragher, 1993. The arrow marks the date (December 1981) of the release of 300,000 yearling rainbow trout (84,000 rainbow trout fry were also released in November 1982).

Monitoring comprised an assessment of three specific population parameters to determine any interannual changes that might suggest a change in population structure, and hence, whether a management intervention was required to improve fish populations. First, angler catch data were collected and assessed from the annual Snowy Mountains Trout Festival and over the Easter long-weekend, to monitor the consistency of catches among years. Secondly, annual spawning runs were monitored by direct trapping and electrofishing to ascertain whether spawning fish were of appropriate condition. Thirdly, the ratio of wild fish to stocked fish in the spawning run was annually monitored to measure the proportion of natural recruits contributing to the spawning population within each lake. Finally, age information was collected on migrants to determine the spawning age of adult fish to inform the management of future stockings within the lakes.

All of this information was collated and analysed between 2000 and 2005 to determine the current state of fish within each system.

Figure 4. Fisheries Technician removes trout from a tank at the Gaden Trout Hatchery for fin clipping and processing as part of this study. Photo: Alistair McBurnie (NSW DPI).

2. METHODS

2.1. Angler data

Angler catch data were collected during the annual Snowy Mountains Trout Festival, held in the first week of November each year. Between 1997 and 2000, catch data were recorded as the total catch for the festival and hence comprised a large sample for each year. After NSW Fisheries implemented changes to bag and possession limits in October 2001, the Snowy Mountains Trout Festival committee changed the rules accordingly, and from 2001 angler catch was gauged by census of anglers at weigh-in centres. Recreational fishers were asked to record date, fishing locality, number of persons fishing, fishing method, hours spent fishing, species caught, length of fish and whether fish were retained or released. This enabled catch-per-unit-effort (CPUE) figures to be produced and compared with historical and recent data. In analysing the data, zero catch trips were excluded to make the data comparative with historical data. Although this inflates the catch per unit effort somewhat, it still allows comparisons of fishing success from year to year. Similarly, only fish greater than 300 mm were analysed in 1997 – 2000, as the Trout Festival rules excluded fish smaller than 300 mm in those years. From 2001 onwards, fish greater than 250 mm were analysed as the new regulations reduced the minimum size limit to 250 mm.

Catch data were also collected over the Easter long-weekend; a four day period each year. Data for the Easter long-weekend were collected between 2000 and 2005, although the data collected for the period 2000 – 2001 were more comprehensive than that for later years. This dataset relies on returns of angler catch forms and has generally been a smaller dataset than for the Snowy Mountains Trout Festival. Recreational fishers were requested to record similar information to that recorded for the Snowy Mountains Trout Festival.

2.2. Electrofishing and trapping

A permanently fixed trap located on the Thredbo River near Gaden Trout Hatchery traps both brown trout and rainbow trout during spawning runs between May and September (Figure 5). Fixed trapping (2001 – 2005) and electrofishing (2000 – 2001 and 2005) of rainbow trout was also conducted in a tributary of the Eucumbene River (Figure 6). At each site the trap is generally only actively deployed until the necessary eggs are sourced for hatchery production. The entire trap is then removed. The trapping period depended on the sizes of the spawning runs, the numbers of males and females trapped and environmental conditions that may influence the onset of spawning such as river height, water temperature and day length (Tilzey 2000b). Therefore the data collected during this period are often a small sample of the entire spawning run, which may last 10 – 11 weeks for each species (Davies & Sloane, 1987). Standard data collected include (but are not limited to) length, weight and sex of each fish. Although the majority of fish trapped during the spawning runs are ripe, those fish that were unripe or spent were not removed from the datasets, as this information was not always recorded. However, fish below 300 mm fork length were excluded from the analyses of mean length and weights, as fish below 300 mm were generally absent in the traps and rare in the electrofishing samples.

Both brown and rainbow trout were sampled with a backpack electrofishing unit (Smith Root Model 12) during daylight hours in the Eucumbene River catchment (usually at one of, or a combination of Swamp Ck, Gang Gang Ck and Alpine Ck) (Figure 8). These three creeks on the Providence Plain at the northern end of Lake Eucumbene are within about 3 km of each other and the location of the Eucumbene River trap site.

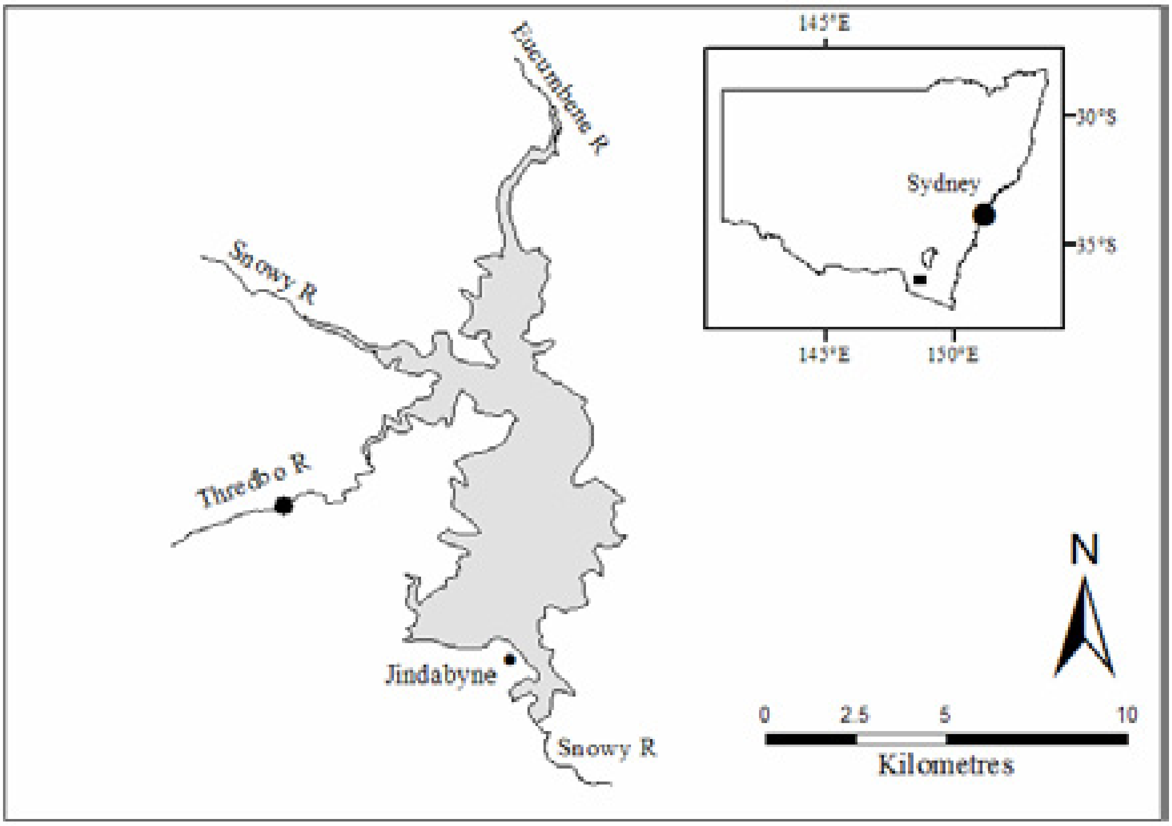

Figure 5. A map of the Lake Jindabyne catchment highlighting the sites sampled as part of this study.

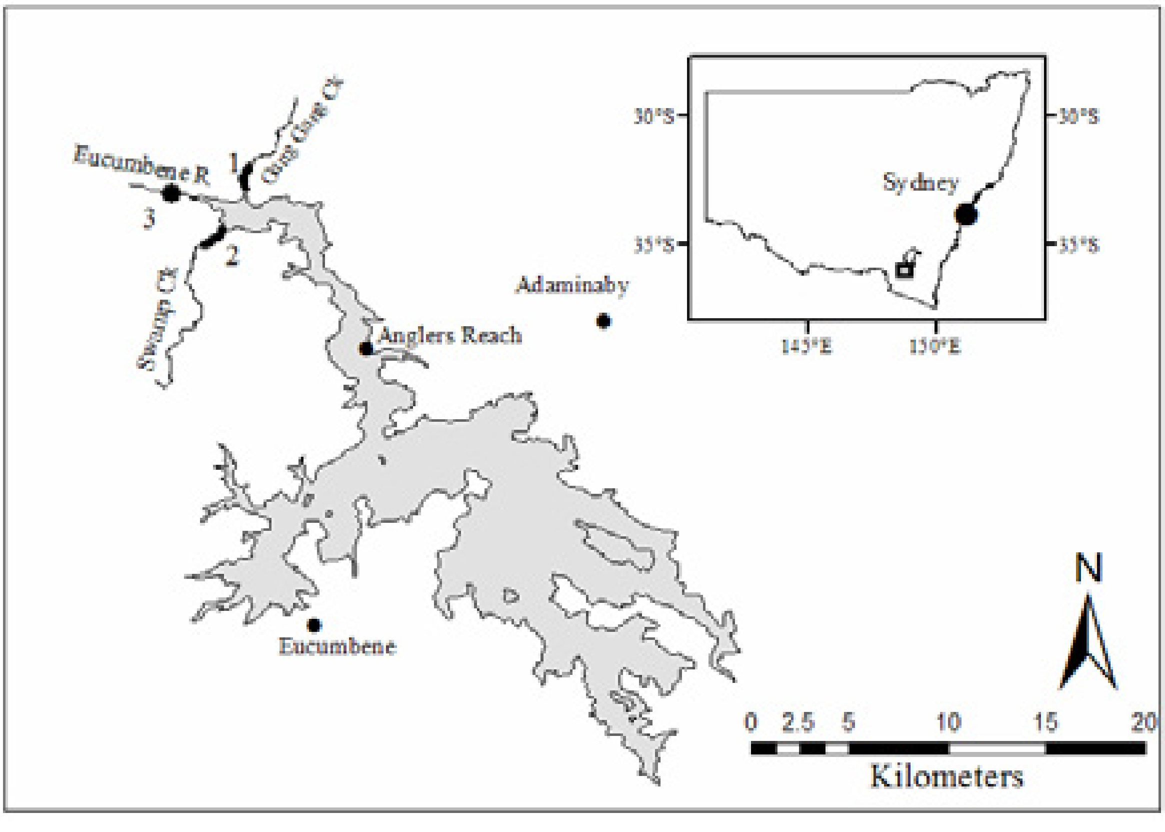

Figure 6. A map of the Lake Eucumbene catchment highlighting the sites sampled as part of this study.

Fork lengths (to nearest mm), weights (to nearest gram) and the sex of fish were recorded. Fish were subsequently released downstream of the capture site. Only fish above 300 mm fork length were used in the analysis of mean length, weight and condition factor. Most fish smaller than 300 mm are sexually immature (and therefore rarely enter traps designed to target spawning fish), so the length / weight data in this study was limited to fish over 300 mm fork length.

Lengths and weights of each fish were used to measure *Fulton's condition factor*, k, by application of the following formula:

$$k = \frac{10^5 \times w}{l^3}$$

Weight (w) was recorded in grams and length (l) was recorded in mm. According to Rader and Poff (1989), trout starve at condition factor values below 0.75. Values of 0.8 indicate extremely poor condition, 1.0 reflects a 'poor' fish, 1.2 is considered a fair fish, 1.4 represents a well proportioned 'good' fish and 1.6 reflects an excellent fish, considered as a trophy class fish (Barnham and Baxter, 1998).

'Condition' is essentially a measure of the available energy for allocation to life-history decisions, such as reproduction, growth or migration (Koops *et al*, 2004) and is based on the hypothesis that the heavier fish of a given length are in the best condition (Bagenal and Tesch, 1978). The average condition factor of fish in spawning condition is usually higher than that of fish outside the spawning season or post spawning, due to increased weight of gonads. However, calculating the condition factor of fish in the lakes outside of spawning times would require either the use of destructive sampling practices (e.g., using gillnets to capture trout) or the ability to obtain large samples of accurate data on whole (e.g., uncleaned) weights of recreationally caught trout. Both of these options are time consuming and/or destructive and have not been attempted during the course of this investigation. Condition factors for spawning trout in this study have been calculated using fork lengths. Although some studies use fork lengths and others use total lengths to calculate condition factor, the condition factor values can be compared between studies that use the same measurement method. Condition factor values from this study are compared to other Australian studies of landlocked trout populations (e.g., in Tasmania). Condition factor values from this study can be used for the following:

Comparing average condition factor values between males and females (the condition factor of spawning females is usually higher than that of spawning males – see Davies and Sloane, 1987).
Comparing average condition factor values between different years of sampling (temporal scale) and between different lakes (spatial scale); possible for brown trout and rainbow trout for both Snowy Mountains lakes using 2000 – 2005 data.
Comparing average condition factor values of different year classes (e.g., 2 year old vs 3 year old fish using finclipped fish as representatives of each year class) in the same sampling year (year class scale; possible for rainbow trout for 2003 to 2005 as these are the only datasets with large enough samples of known-age fish).

2.3. Fin clipping and recapture work

A percentage (25 to 50%) of hatchery-bred YOY rainbow trout were anaesthetised with the use of benzocaine (35mg/L)[1] and finclipped at Gaden Trout Hatchery. A different fin (left or right pectoral or left or right pelvic) was clipped each year (2001 to 2006) before release so that the year classes of fish could be identified (Table 2) (Figure 7). Finclipping enables identification of age and growth when fish are trapped in the spawning runs 2 to 4 years later. Rainbow trout were released between January and April each year (2001 – 2006). Two small samples of rainbow trout were measured in 2002 to obtain an average stocking size and evaluate the accuracy of the finclipping procedure prior to release. Average sizes of released fish in the two samples were between 64 mm (“small grade fish”, *n* = 102) and 71 mm fork length (“large grade fish”, *n* = 112). However, the average size of released fish tended to vary from year to year depending on the time of release (e.g. fingerlings released in January are generally smaller than fingerlings released in April). Fish with incorrectly-clipped fins made up less than 1% of each of the two samples in 2002. In 2006, subsamples of fingerlings were measured and checked for finclipping accuracy before release. The total numbers of rainbow trout released and the percentage of those that were finclipped are summarised in Table 2. Samples of fish trapped in the spawning runs were measured (usually rounded down to the nearest mm fork length, but occasionally rounded to the nearest 5 mm fork length) and weighed (to the nearest gram) each year (in conjunction with checking for finclips).

The collection of these data enables estimation of size ranges of individual year classes. The accuracy of such estimates is dependent on the numbers of finclipped fish (i.e., fish of known age) from each year class in the spawning runs. The first year that examination for finclips was carried out in conjunction with the usual task of trapping spawning rainbow trout for hatchery production was 2003. A maximum of three year-classes of rainbow trout (age 2+, 3+ and 4+) was present in the spawning runs as evidenced by the presence of finclipped (i.e., stocked) fish. No examination for finclips was undertaken until 2002 as the 3 year old rainbow trout had not been clipped and at the time it was suspected that the proportion of finclipped 2 year olds would be very small. Proportions of stocked fish in the spawning run of any one age class (age 2, 3 and 4) was calculated by determining the size range of each age class (from finclipped fish of known ages). There was usually some overlap in size ranges of consecutive age-classes. When estimating the percentage of finclipped fish in any one age-class, a range of possible proportions was included. The number of finclipped fish in an age class divided by the total number of fish in this age class was multiplied by a factor of 2 (in years where 50% of released fish were finclipped) or 4 (in years where 25% of released fish were finclipped).

Figure 7. Fin clipping an adult trout as part of this project. Photo: Alistair McBurnie (NSW DPI).

Table 2. Date, numbers and origin of rainbow trout stocked into Lake Eucumbene and Lake Jindabyne since 1980 with size stocked, percentage finclipped and finclip location (L = left; R = right).

Year eggs hatched	Release date	Hatchery of origin	Approximate numbers stocked		Size at stocking	% finclipped and fin location
			Eucumbene	Jindabyne		
1980	Jun 1981	Gaden	0	4,000	Yearling	0
1980	Dec 1981	Tumut	300,000	0	Yearling (c. 20cm)	0
1981	Dec 1981	Gaden	Nil	4,250	Fry	0
1982	Nov 1982	Gaden	84,000	60,000	Fry	0
1985	Apr 1986	Gaden	30,000	0	Fingerling	100% adipose
1986	Apr 1987	Gaden	50,000	0	Fingerling	100% adipose and L pectoral
1987	Dec 1987	Gaden	0	151,000	Fry	0
1987	Apr 1988	Gaden	25,300	19,400	Fingerling	100% of Eucumbene (adipose and R pectoral), 0% of Jindabyne
1989	Apr – May 1990	Gaden	160,000	20,000	Fingerling	0
1990	Dec 1990	Gaden	80,000	20,000	Fry	0
1992	May 1993	Gaden	Nil	10,000	Fingerling	0
1993	Aug 1994	Gaden	42,000	10,000	Fingerling	0
1994	Feb – Mar 1995	Gaden	100,000	50,000	Fingerling	0
1995	Sep 1995	Dutton	300,000	0	Fingerling	0
1993	Nov 1995	Gaden	0	2,000	Age 2+	0
1995	Feb – Apr 1996	Gaden	100,000	60,000	Fingerling	0
1996	Dec 1996	Gaden	0	200,000	Fry	0
1995	1996	Adaminaby[1]	200,000	0	*Fry*	0
1996	Sep 1996	Dutton	300,000	0	Fry	0
1996	Dec 1996	Gaden	300,000	200,000	Fry / Fingerling	0
1996	May 1997	Gaden	0	130,000	Fingerling	0
1997	Dec 1997	Gaden	300,000	200,000	Fry	0
1997	Feb 1998	Gaden	40,000	40,000	Fingerling	0
1999	2000	Gaden	50,000	66,000	Fingerling	0
2000	Mar – May 2001	Gaden	150,000	50,000	Fingerling	50% L pectoral
2001	Feb – Apr 2002	Gaden	150,000	50,000	Fingerling	25% R pelvic
2002	Jan – Feb 2003	Gaden	150,000	50,000	Fingerling	50% R pectoral
2003	Jan – Mar 2004	Gaden	150,000	50,000	Fingerling	25% L pelvic
2004	Jan – Feb 2005	Gaden	150,000	50,000	Fingerling	25% L pectoral

[1] Private trout farm at ”Dixieland”, Adaminaby

2.4. Ageing

Otoliths were removed from 185 brown trout and 161 rainbow trout in the Eucumbene spawning runs in 2000 – 2001. Additionally, otoliths were removed from fish captured during the Snowy Mountains Trout Festival in November 2000, from Lake Eucumbene. One sagittal otolith from each fish was embedded in clear resin and sectioned (approximately 0.25 – 0.30 mm) in a transverse plane using a low-speed saw fitted with a single diamond blade. The section was polished with 9 μm lapping film and mounted on a microscope slide under a coverslip. Otoliths were read using a binocular microscope using reflected light over a black background. Ages were estimated by counting the opaque zones, typically adjacent to the sulcus. Two staff read each otolith and age estimates were compared.

2.5. Data analysis

Data were analysed using the S-Plus and Microsoft Excel statistical packages. Analyses were done to determine the population structure of migrating brown and rainbow trout into the tributaries of Lake Eucumbene and Jindabyne. The total number of fish sampled among years was compared using one-way ANOVA. Catch data were standardised to electrofishing time to account for any variations in total effort among years.

Monitoring also involved the calculation of condition factors to determine if the relative condition of fish varied among years. Condition factors can also vary among sexes, therefore the variation in condition factor was also tested for any significant differences between male and female fish. Where these factors were compared between species (or sexes within each species) and then among years, a two-way ANOVA was used. Data were log x+1 transformed to stabilise variances and Quantile-quantile plots of the residuals (Insightful, 2001) confirmed that log x+1 transformed data were approximately normally distributed.

General linear regression techniques were used to explore the relationship between the age and length of migrating trout. This procedure involves regressing age (calculated from otolith sectioning) and length (of fish where otoliths were obtained) in the S-Plus statistical package. Data were log x+1 transformed to stabilise variances and Quantile-quantile plots of the residuals (Insightful, 2001) confirmed that log x+1 transformed data were approximately normally distributed.

Figure 8. Trout Technician, Cameron McGregor with a brown trout sampled as part of this study (Photo: NSW DPI).

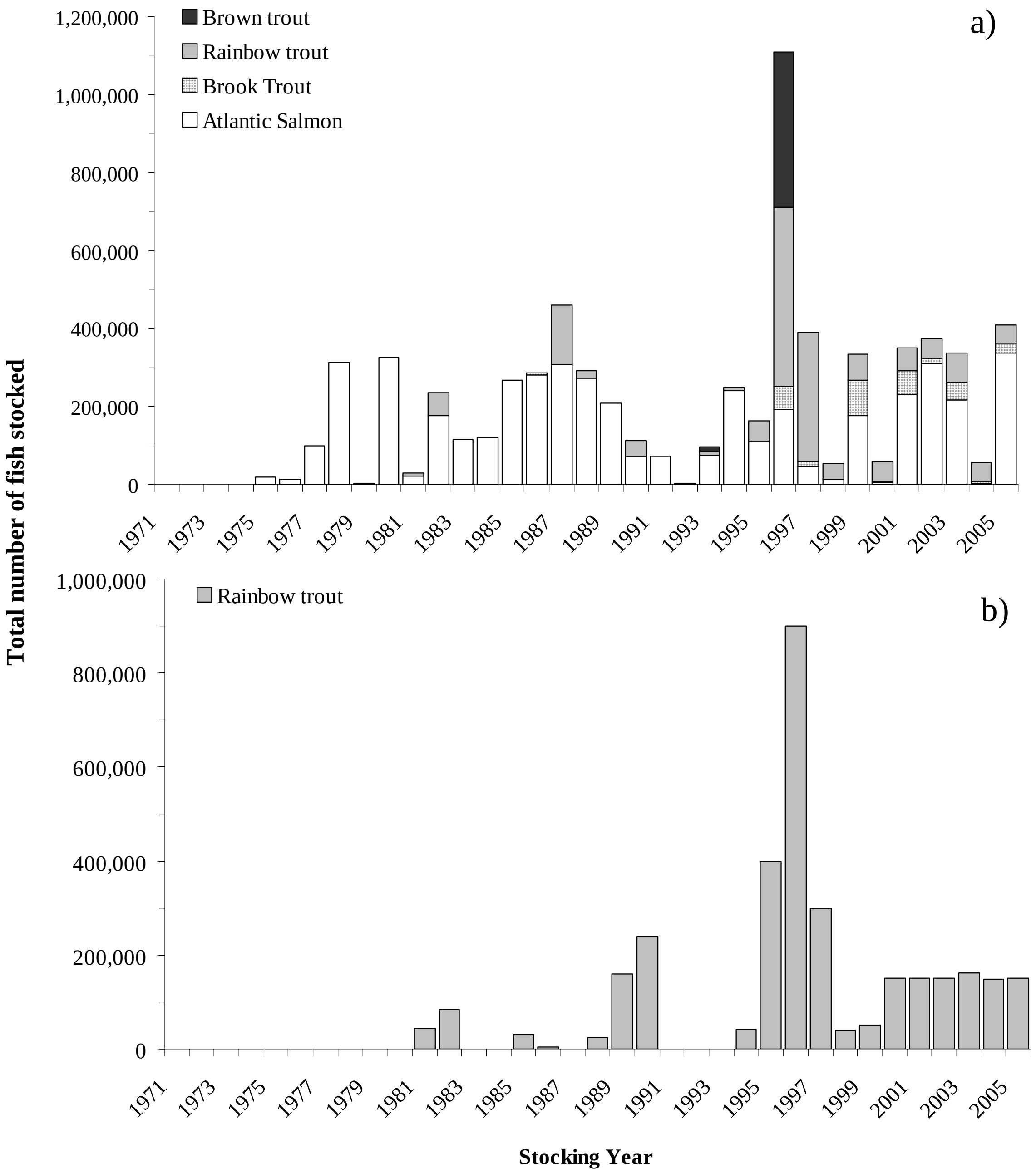

Figure 9. Total number of fish stocked into Lake Jindabyne (a) and Lake Eucumbene (b) between 1971 and 2005.

3. RESULTS

3.1. Lake Eucumbene

3.1.1. *Trapping and electrofishing*

A total of 3,809 fish were sampled from the Eucumbene spawning run between 2000 and 2005 comprising rainbow (n = 3,218) (Table 4) and brown (n = 591) (Table 5) trout.

The age structure of spawning fin-clipped rainbow trout varied greatly among years, and proportions were not consistent (Figure 10). In 2003, three-year old fish comprised greater than 75% of the total number of fin-clipped fish recaptured. However, this strong cohort was not subsequently re-sampled in similar proportions (as four-year olds) the following season. No three year olds were sampled at all in 2004 but formed 5% of the catch in 2005. Although no three-year old fish were sampled in 2004, four year old fish formed 20% of the 2005 catch. These variations in age structure suggest that there may be a number of factors influencing the age composition of the annual spawning run into Lake Eucumbene tributaries (Figure 11).

The length range of spawning fish was relatively consistent among years, generally ranging from 300 – 700 mm. The weight of fish varied, being relatively low in 2000 – 2002 and substantially greater in 2003 – 2005.

3.1.2. *Biological data*

Age data indicated that few rainbow trout survive after four years of age (Figure 12). This species grew rapidly until age 2, but there was considerable overlap between size and age for individuals 3 – 5 years old. The von Bertalanffy growth parameters ($L\infty$, K and t_o) estimated for the Lake Eucumbene rainbow trout population were 502, 0.61 and -0.404 respectively (r^2 = 0.851, $P < 0.05$, n = 161) (Figure 12).

Results showed that a significant proportion of the brown trout population live over 3 years with fish sampled in the 4 – 8 year range (Figure 13). Fish grew rapidly until three years old, but there was substantial overlap between size and age between four and nine years. The von Bertalanffy growth parameters ($L\infty$, K and t_o) estimated for the Lake Eucumbene brown trout population were 451.87, 0.695 and -0.061 respectively (r^2 = 0.639, $P < 0.05$, n = 185) (Figure 13).

Table 3. Lengths of fin-clipped hatchery-bred rainbow trout recaptured from the spawning run in the Lake Eucumbene catchment (Gang Gang Creek).

Release year	% fish clipped before release	Trapping year	Age at trapping (years)	No. of fin-clipped fish (% males)	Length range of fin-clipped fish	Mean FL of clipped fish
2001	50%	2003	3	14 (29)	395 – 480	414
2002	25%	2003	2	5 (60)	320 – 385	350
2002	25%	2004	3	9 (56)	375 – 455	421
2003	50%	2004	2	37 (76)	350 – 430	382
2003	50%	2005	3	53 (37)	371 – 472	425
2004	25%	2005	2	2 (100)	329 – 383	356

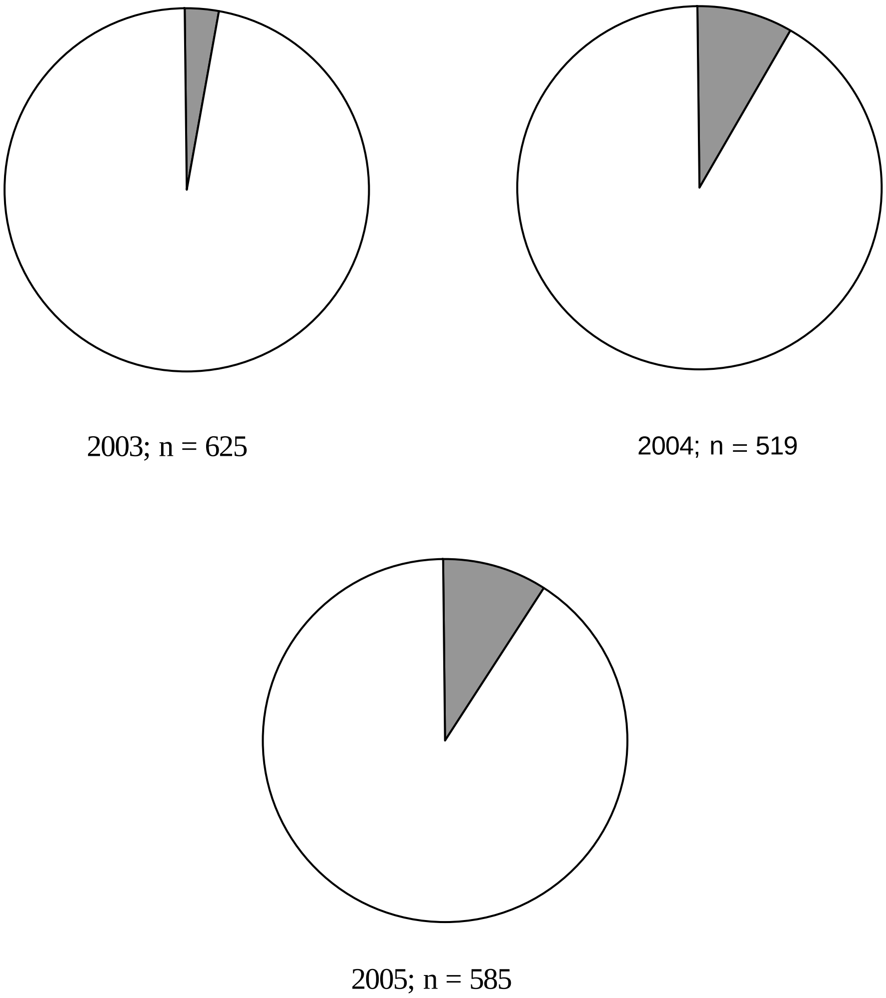

Figure 10. A summary of the proportion of finclipped fish (grey) and non-finclipped fish (not coloured) sampled in the rainbow trout spawning runs at Lake Eucumbene between 2003 – 2005.

Table 4. Lengths and weights of samples of the Lake Eucumbene rainbow trout spawning runs 2000 – 2005. Lengths are given as fork length, weight is measured in grams and SE refers to one standard error.

Year	**Number sampled**	**Mean Length ± SE**	**Length Range (fl)**	**Mean Weight ± SE**	**Weight Range (g)**
2000	303	405 ± 1	340 – 456	831 ± 7	502 – 1,164
2001	461	406 ± 1	300 – 500	834 ± 7	334 – 1,328
2002	725	429 ± 1	312 – 490	975 ± 6	390 – 1,470
2003	625	418 ± 1	320 – 535	884 ± 7	410 – 1,900
2004	519	412 ± 1	305 – 500	860 ± 7	402 – 1,436
2005	585	412 ± 1	319 – 523	853 ± 7	426 – 1,636

Table 5. Lengths and weights of samples of the Lake Eucumbene brown trout spawning runs 2000 – 2005. Lengths are given as fork length, weight is measured in grams and SE refers to one standard error.

Year	Number sampled	Mean Length ± SE	Length Range (fl)	Mean Weight ± SE	Weight Range (g)
2000	258	393 ± 5	300 – 710	758 ± 30	302 – 5,032
2001	152	433 ± 5	300 – 600	958 ± 34	320 – 2,414
2002	53	433 ± 8	335 – 560	935 ± 61	410 – 2,280
2003	13	464 ± 21	300 – 570	1,262 ± 175	236 – 2,314
2004	35	490 ± 8	376 – 623	1,317 ± 81	550 – 3,200
2005	80	468 ± 8	310 – 630	1,484 ± 85	342 – 3,300

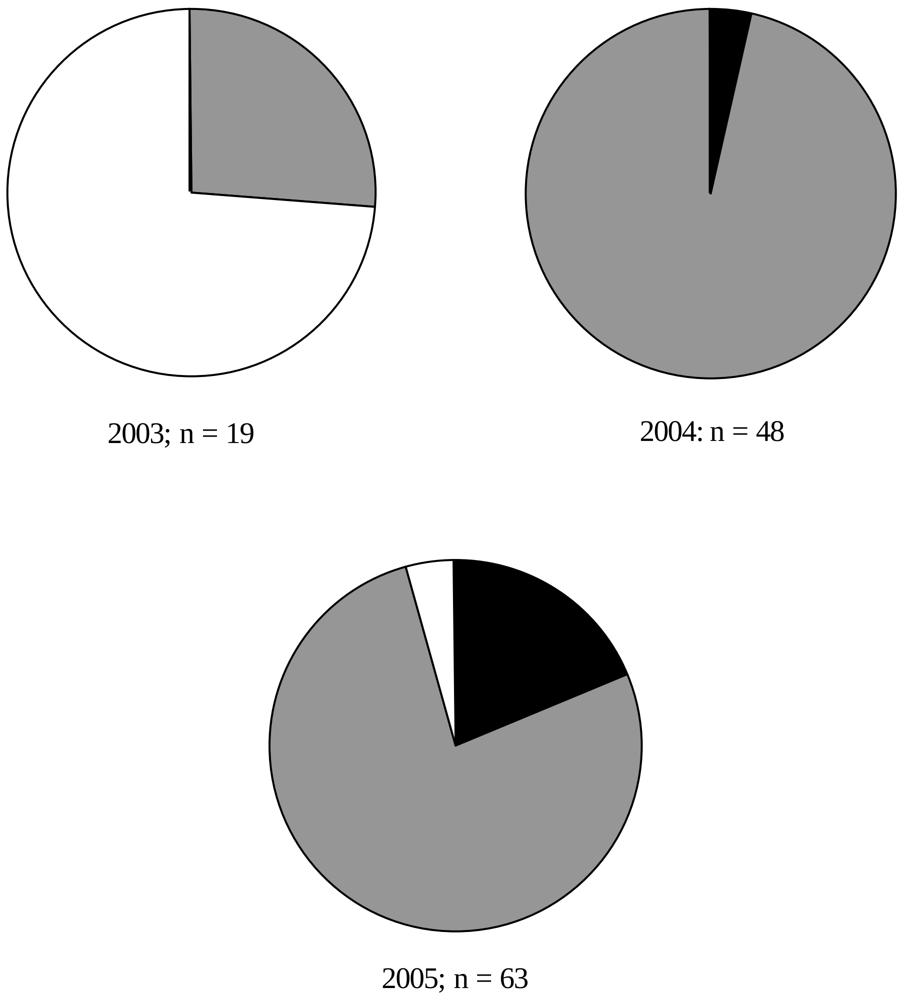

Figure 11. Proportions of age classes from fin-clipped rainbow trout in Lake Eucumbene. Shading represents 2 year olds (grey), 3 year olds (white), 4 year olds (black).

Mean Fulton's condition factor values were calculated for both rainbow and brown trout sampled as part of this study. For rainbow trout, significant differences were detected between sexes (ANOVA: df = 1, $F = 370.43$ $p < 0.001$) and also among years (df = 4, $F = 11.53$, $p < 0.001$). Generally, female fish returned higher condition factor values than males (Figure 14). Although significantly different among years, condition factors were consistently above 1.1 in each year of sampling. This indicates that spawning fish were in fair-to-good condition. Significant differences among years arose from very slight fluctuations.

Mean condition factors were highest in 2001 for male rainbow trout (mean±SE: 1.21±0.007) and equally highest in 2000 and 2002 for females (mean±SE: 1.29±0.010 and 1.2±0.006 respectively). Condition factors were lowest in 2003 for males (mean±SE: 1.15±0.05) and lowest for females in 2005 (mean±SE: 1.23±0.007). However, as all condition factors were above 1.1, it suggests that spawning rainbow trout were in fair-to-good condition each year that sampling was undertaken (Figure 14).

Condition factor values for brown trout did not differ between sexes (ANOVA: df = 1, $F = 0.09$; $p > 0.05$) but did among years (ANOVA: df = 4, $F = 41.47$; $p < 0.001$). Mean condition factors were highest in 2005 (mean±SE: 1.3±0.019 and mean±SE: 1.33±0.033) for males and females respectively. Condition factors were lowest in 2004 (mean±SE: 1.08±0.020) for males and lowest for females in 2002 (mean±SE: 1.04±0.028). All calculated condition factors were above 1.0 in each year (Figure 14).

3.1.3. Angler data

A total of 11,389 fish were caught between 1997 – 2004 in the Snowy Mountains trout festival (Table 6). In total, 5,179 rainbow trout and 6,210 brown trout were caught. More brown trout were caught than rainbow trout in three years of the study 1998, 1999 and 2000 (Figure 15). Mean lengths for rainbow trout ranged from 360 – 407mm and 400 – 420mm for brown trout (Table 6). During the Easter festival (between 2000 – 2005), 2,385 fish were caught, comprising of 1,643 rainbow trout and 742 brown trout (Table 7). More rainbow trout than brown trout were recorded every year during the six years of the study (Figure 16). Mean lengths ranged from 360 – 406 mm for rainbow trout and 365 – 450 mm for brown trout (Table 7).

After the annual stocking of fixed numbers of rainbow trout from 2001, catch per angler hour has remained relatively stable (Figure 17), and has eliminated the large variations in catch per unit effort from year to year. ANOVA determined no significant differences in annual CPUE over the period of this study (ANOVA; df = 4, $F = 0.83$, $p > 0.05$). In Lake Eucumbene the percentage of rainbow trout has remained above 50% of the catch (Figure 16). In 2001, there was an apparent anomaly where the CPUE of rainbow trout increased substantially over that from other years (Figure 17). It should be noted that this was based on a considerably smaller sample size than previous years ($n = 16$ anglers) which may have biased results.

Catches of brown trout also remained stable and no significant differences in catch rate were detected (ANOVA: df = 4, $F = 0.54$, $p > 0.05$). This suggests that the catchability of brown trout did not substantially change over the study period.

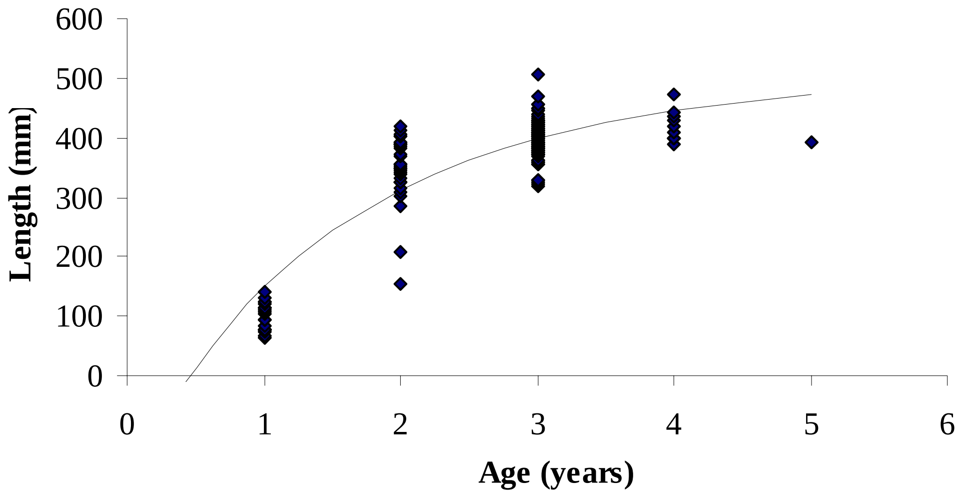

Figure 12. Growth of rainbow trout from Lake Eucumbene shown with a von Bertalanffy growth curve fitted to length-at-age data (*n* = 161).

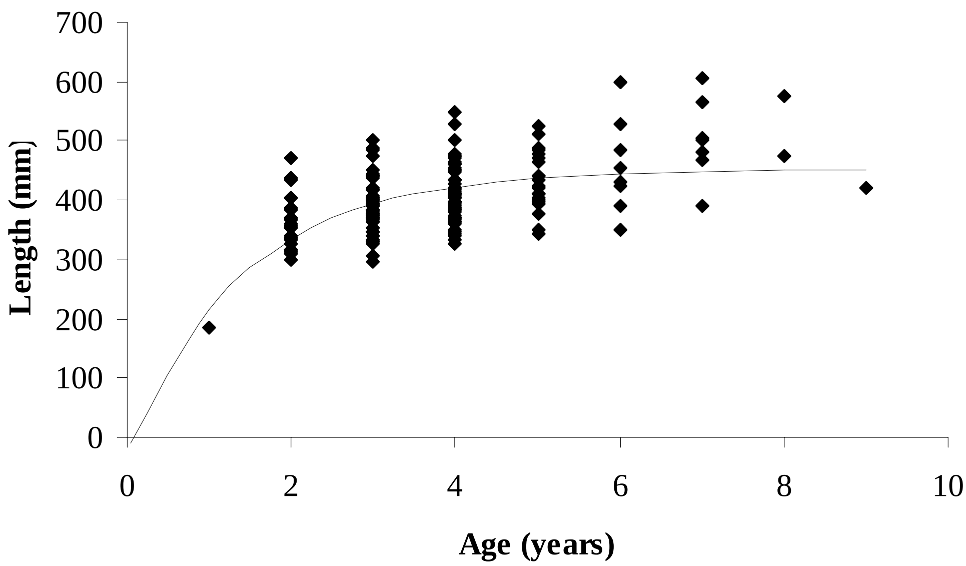

Figure 13. Growth of brown trout from Lake Eucumbene shown with a von Bertalanffy growth curve fitted to length-at-age data. (*n* = 185).

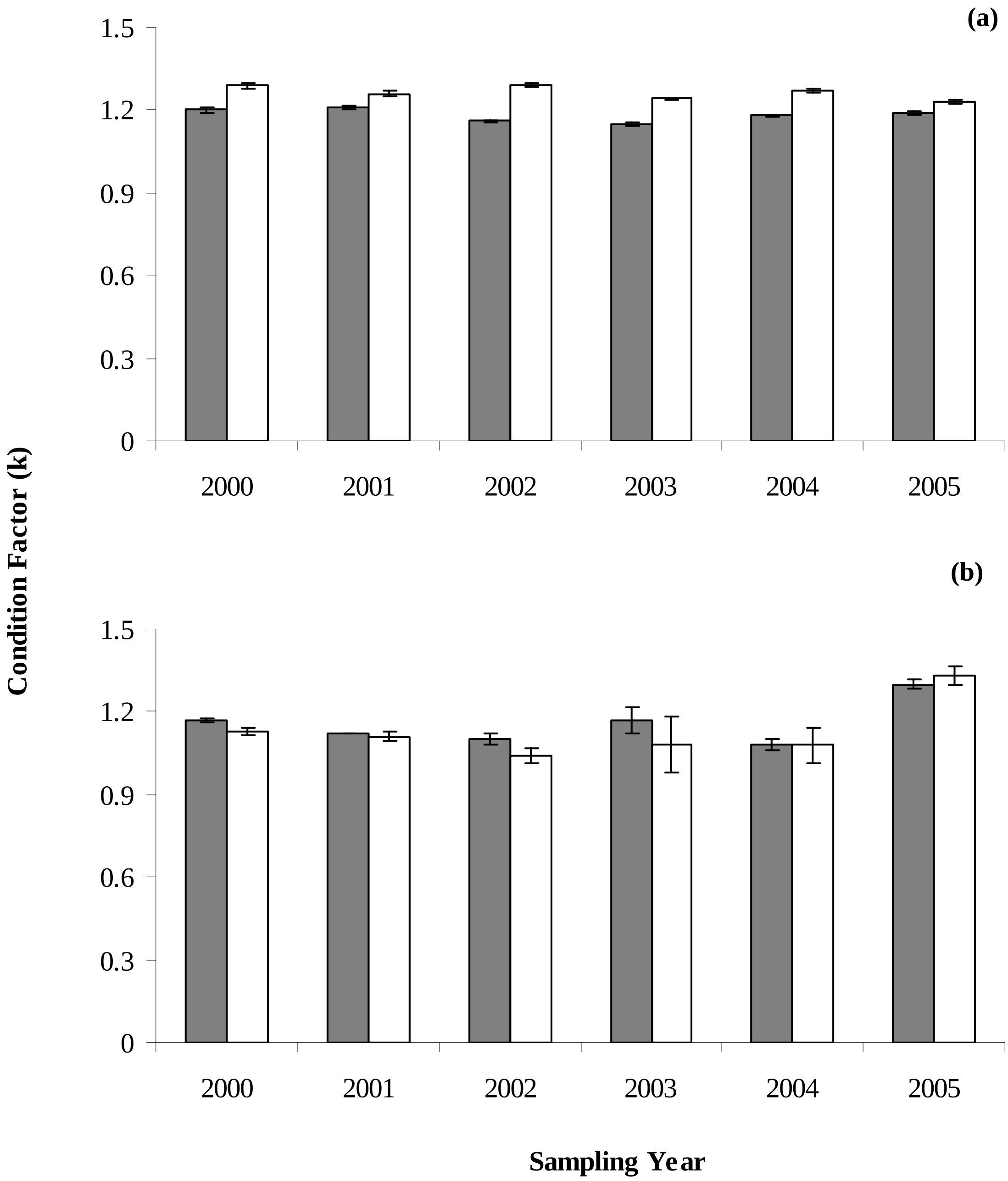

Figure 14. Fulton's condition factors for rainbow trout (a) and brown trout (b) males (grey) females (white).

Table 6. Snowy Mountains Trout Festival Catches 1997 – 2004 for rainbow and brown trout. Undersized fish but only fish above minimum legal size limit, e.g., 250 mm, were included in analysis of mean length and size range. Numbers in brackets indicate numbers of fish that were measured in the sample if different from actual sample number (some recreational anglers recorded weights rather than lengths).

Year	Rainbow Trout			Brown Trout		
	Number	Mean length (mm FL)	Size range (mm FL)	Number	Mean length (mm FL)	Size range (mm FL)
1997	2,458	383	310 – 540	1,717	404	320 – 640
1998	188	378	350 – 500	1,166 (1,165)	420	350 – 720
1999	1,185	386	350 – 530	1,560	405	350 – 680
2000	514	407	350 – 510	1,225 (1,220)	412	330 – 640
2001	304 (303)	367	250 – 550	295 (294)	401	250 – 560
2002	183 (122)	377	250 – 582	96 (95)	407	250 – 540
2003	191 (127)	385	250 – 520	66 (47)	400	250 – 570
2004	156 (154)	360	250 – 480	84 (78)	407	250 – 600

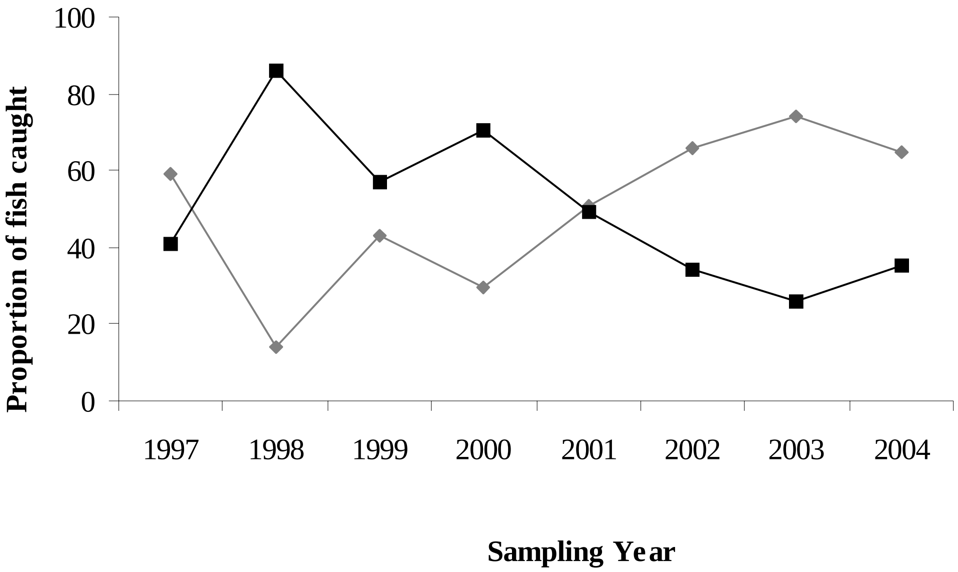

Figure 15. Proportion (%) of rainbow (grey) and brown trout (black) in sample of recreational catch data from Lake Eucumbene (Snowy Mountains Trout Festival 1997 – 2004).

Table 7. Lake Eucumbene Easter Festival Catches 2000 – 2005. Numbers and percentages of each species caught incl. undersized fish but only fish above minimum legal size limit, e.g., 250 mm, were included in analysis of mean length and size range.

Year	**Rainbow Trout**			**Brown Trout**		
	Number	**Mean length (mm FL)**	**Size range (mm FL)**	**Number**	**Mean length (mm FL)**	**Size range (mm FL)**
2000	403	393	250 – 720	229	365	250 – 600
2001	438	364	250 – 650	344	392	250 – 620
2002	107	384	300 – 623	25	450	320 – 520
2003	271	406	250 – 540	56	402	260 – 600
2004	145	382	280 – 510	45	419	315 – 620
2005	279	366	250 – 520	43	389	250 – 600

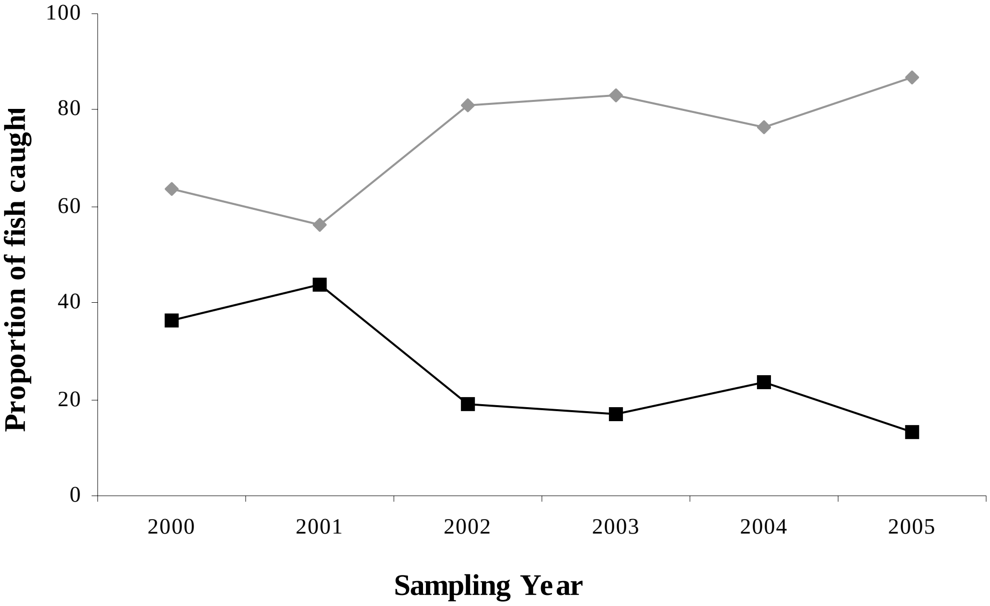

Figure 16. Proportion (%) of rainbow trout (grey) and brown trout (black) in sample of recreational catch data from Lake Eucumbene Easter Festival (2000 – 2005).

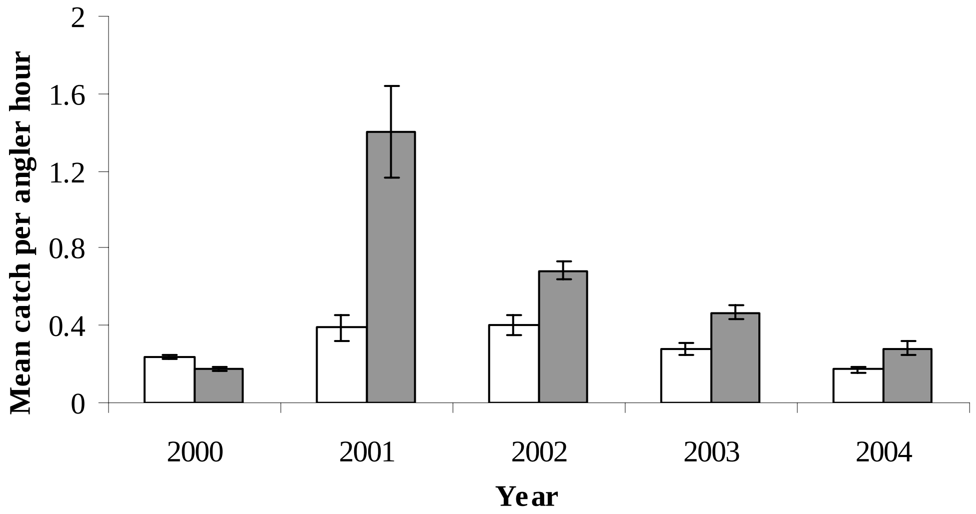

Figure 17. Mean catch per unit effort (CPUE) rainbow trout (grey) brown trout (white).

3.2. Lake Jindabyne

3.2.1. Trapping spawning runs

A total of 5,793 fish were sampled from the Jindabyne spawning run between 2000 and 2005 comprising rainbow (n = 3,907) (Table 9) and brown (n = 1,886) trout (Table 10). In 2003, 844 rainbow trout were captured ranging between 335 and 620 mm were sampled from the fish trap (Table 9). Finclipped 2 year olds (n = 19) ranged from 370 to 415 mm and finclipped 3 year olds (n = 41) ranged from 390 to 480 mm, although only one fish was less than 415 mm (Table 8).

There was minor overlap of size classes between 2 and 3 year olds but, for the purpose of estimating the percentages of finclipped (i.e., stocked) fish, the 2 year olds were judged to be 415 mm or less and the 3 year olds between 420 and 480 mm. The equivalent percentage of finclipped (i.e., stocked) 2 year old and 3 year old fish in the spawning run from Lake Jindabyne in 2003 was estimated as 39.0% and 11.8 – 14.7% respectively.

In 2004, finclipped 2 year olds (n = 151) ranged from 360 to 440 mm and finclipped 3 year olds (n = 14) ranged from 415 to 530 mm, although 11 of 14 were 450 mm or larger (Table 8) (Figure 18). Two finclipped 4 year olds (465 and 495 mm) were also trapped. The equivalent percentage of finclipped (i.e., stocked) 2, 3 and 4 year old fish in the spawning run from Lake Jindabyne in 2004 was therefore calculated as 64.7%, 21.7 – 42.7 % and 5.1 – 7.0 % respectively. Catches of known age fish comprised 2 (n = 31; 350 – 400 mm), 3 (n = 263, 375 – 485 mm) and 4 year old (n = 10, 422 – 487 mm) fish. The percentage of finclipped four year old fish was estimated at between 8.3 and 11.1% (Figure 19).

Table 8. Length of fin-clipped hatchery bred rainbow trout recaptured from rainbow the spawning run in Lake Jindabyne catchment (Thredbo River).

Release year	% of fish finclipped before release	Trapping Year	Age at trapping (years)	No. of finclipped Fish (% males)	Length range of finclipped fish	Mean FL of finclipped fish
2001	50%	2003	3	41 (56%)	390 – 480	447
2002	25%	2003	2	19 (74%)	370 – 415	398
2001	50%	2004	4	2 (100%)	465 – 495	480
2002	25%	2004	3	14 (86%)	415 – 530	468
2003	50%	2004	2	151(92%)	360 – 440	401
2002	25%	2005	4	10 (20%)	422 – 487	457
2003	50%	2005	3	263 (56%)	375 – 485	433
2004	25%	2005	2	31 (84%)	350 – 400	377

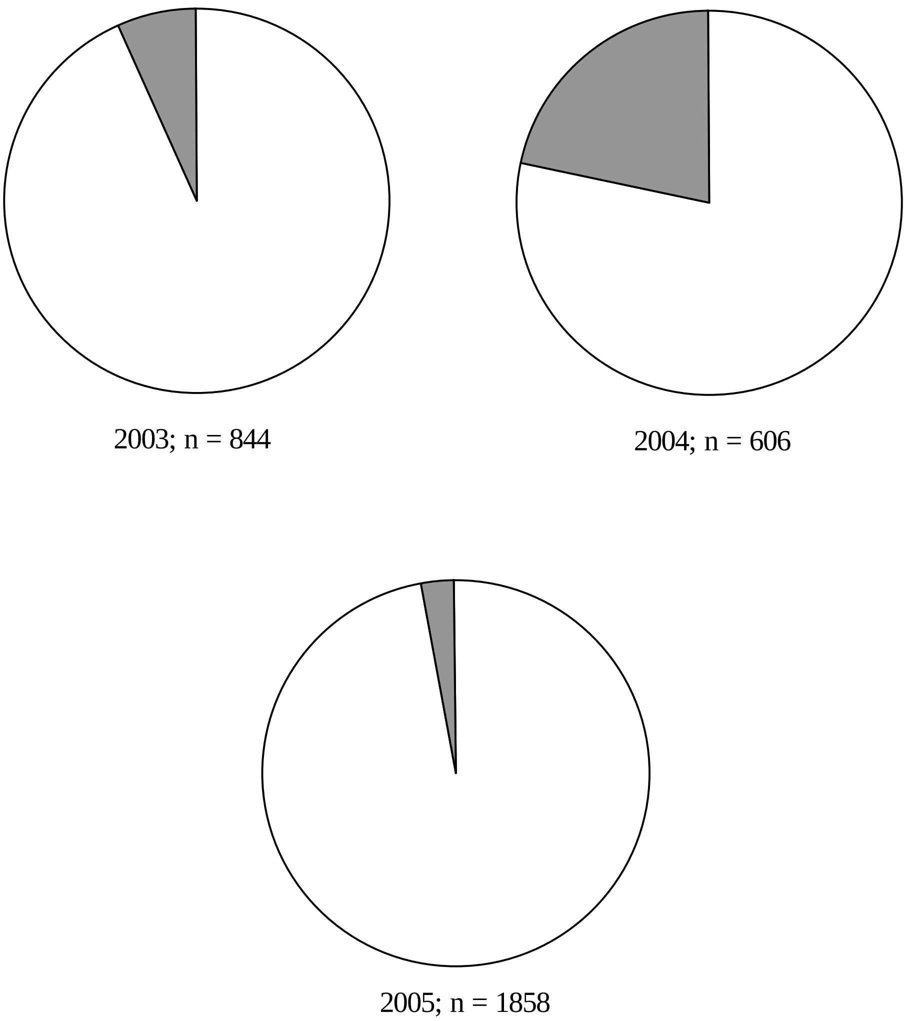

Figure 18. A summary of the proportion of finclipped (grey) and non-finclipped rainbow trout (not coloured) sampled in the Lake Jindabyne spawning runs between 2003 – 2005.

Table 9. Lengths and weights of samples of the Lake Jindabyne rainbow trout spawning runs 2000 – 2005. Lengths are given as fork length, weight is measured in grams and SE refers to one standard error.

Year	**Number sampled**	**Mean Length ± SE**	**Length Range (fl)**	**Mean Weight ± SE**	**Weight Range (g)**
2000	199	426 ± 2	328 – 590	942 ± 16	384 – 2,312
2001	200	407 ± 2	350 – 520	894 ± 14	530 – 1,690
2002	200	465 ± 2	360 – 530	1,263 ± 14	520 – 1,970
2003	844	445 ± 1	335 – 620	1,108 ± 18	470 – 2,156
2004	606	420 ± 1	335 – 575	922 ± 9	468 – 2,034
2005	1,858	419 ± 0	313 – 575	900 ± 4	398 – 2,166

Table 10. Lengths and weights of samples of the Lake Jindabyne brown trout spawning runs 2000 – 2005. Lengths are given as fork length, weight is measured in grams and SE refers to one standard error.

Year	**Number sampled**	**Mean Length ± SE**	**Length Range (fl)**	**Mean Weight ± SE**	**Weight Range (g)**
2000	233	424 ± 2	328 – 565	971 ± 19	414 – 2 244
2001	227	457 ± 3	333 – 670	1,218 ± 27	418 – 2,984
2002	306	437 ± 3	325 – 585	1,042 ± 21	378 – 2,368
2003	201	451 ± 3	340 – 620	1,186 ± 27	370 – 3,174
2004	200	485 ± 4	320 – 670	1,508 ± 44	374 – 3,600
2005	719	426 ± 1	315 – 585	920 ± 12	338 – 2,398

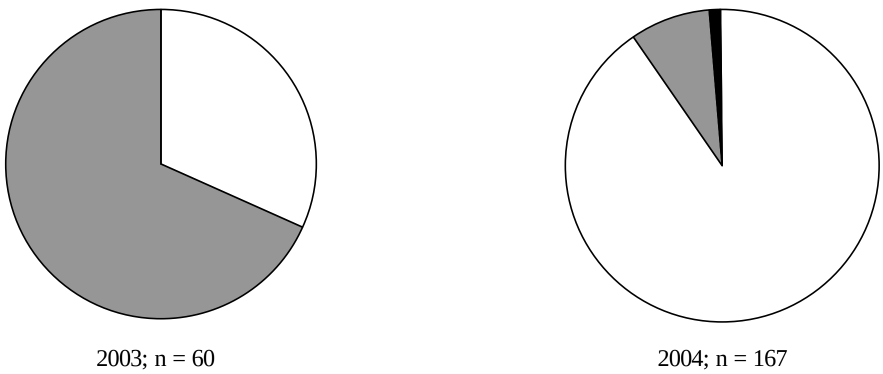

Figure 19. Numbers within each age class of re-captured rainbow trout with fin clips. Shading represents two year olds (grey), 3 year olds (white), 4 year olds (black).

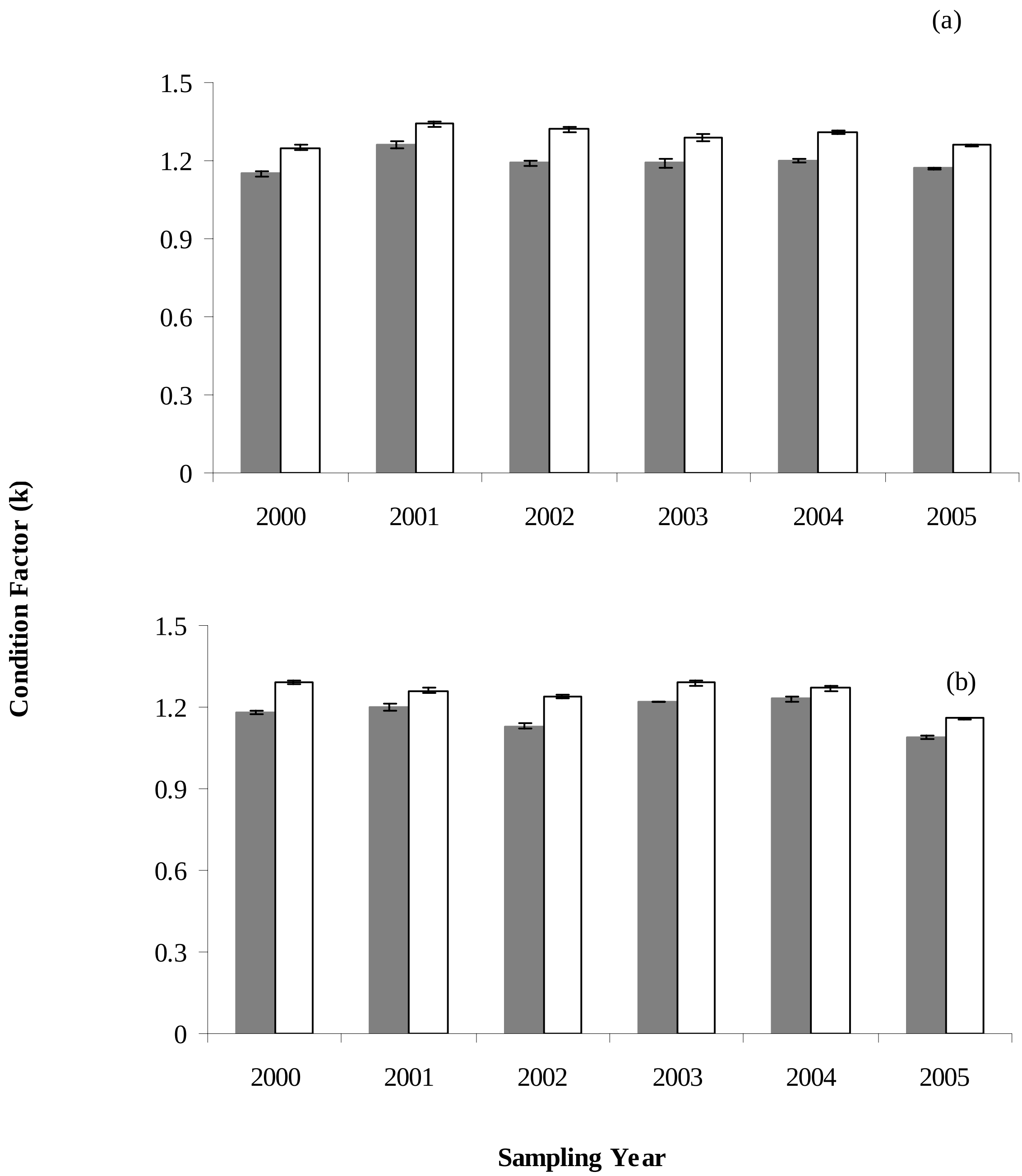

Figure 20. Fulton's condition factors for Rainbow trout (a) and brown trout (b) males (grey) females (white) in Lake Jindabyne.

3.2.2. Biological data

The presence of 4 year old rainbow trout in the Thredbo River spawning run sampling was confirmed by otolith examination. Rainbow trout fingerlings stocked into Lake Jindabyne in 2002 were chemically marked with alizarine complexone before release (for methods see Van der Walt & Faragher 2003) and the otoliths of finclipped 4 year olds in 2005 (n = 8) were removed to confirm the accuracy of finclipping. All eight fish examined had chemically marked otoliths.

Condition factors of fish caught in the Thredbo River were calculated annually for both spawning rainbow and brown trout sampled as part of this study. For rainbow trout, significant differences were detected between male and female fish (ANOVA: df: 1, F = 114.07, p = < 0.001). Significant differences were also detected among years (ANOVA: df: 4, F = 1571.72, p = < 0.001). In general, female (1.25 – 1.34) fish returned higher condition factor values than males (1.15 – 1.26) (Figure 20). mean condition factors were highest in 2001 (females mean±SE: 1.34±0.012; males: 1.26±0.008) but lowest in 2000 (females: 1.25±0.009; males: 1.15±0.009) (Figure 20). However, all condition factors were above 1.1, suggesting that migrating fish were in fair-to-good condition each year of sampling.

Significant differences were detected between sexes for brown trout (ANOVA: df = 1, F = 38.67, p < 0.001) and also among years (ANOVA: df = 4, F = 91.10; p < 0.001). Female fish returned higher condition factor values than males every year during this study (Figure 20). Mean condition factors were equally highest in 2000 and 2003 for females (mean±SE: 1.29±0.007 and 0.011 respectively) and lowest in 2005 (mean±SE: 1.16±0.004). Male fish returned the highest condition factor values in 2004 (mean±SE: 1.23±0.011) and lowest in 2005 (mean±SE: 1.09±0.008) (Figure 20). However, as with rainbow trout, all calculated condition factors were above 1.1 in each year. This also suggests that migrating fish were in fair-to-good condition during sampling.

3.2.3. Angler data

A total of 4,518 fish were caught between 1997 – 2004 in the Lake Jindabyne trout festival (Table 11) In total, 1,578 rainbow trout and 2940 brown trout were caught. More brown trout than rainbow trout were caught from 1997 – 2003 and rainbow trout exceeded brown trout numbers in 2004 (Figure 21). Mean lengths ranged from 373 – 420mm for rainbow trout (small sample in 2003 excluded) and from 394 – 470 mm for brown trout (Table 11).

During the Easter festival (between 2000 – 2005), 730 trout were caught, comprising of 504 rainbow trout and 226 brown trout (Table 12). Catches of brown trout only exceeded those of rainbow trout in 2002 (Figure 22). Mean lengths ranged from 345 – 634mm for rainbow trout and 368 – 452mm for brown trout (Table 12).

Table 11. Lake Jindabyne Trout Festival Catches 1997 – 2004 (rainbow trout and brown trout only). Numbers of each species caught between 2001 and 2004 included. Undersized fish but only fish above minimum legal size limit, e.g., 250mm, were included in analysis of mean length and size range.

Year	Rainbow Trout			Brown Trout		
	Number	Mean length (mm FL)	Size range (mm FL)	Number	Mean length (mm FL)	Size range (mm FL)
1997	796	395	330 – 600	891	428	330 – 660
1998	225	373	350 – 520	714	429	350 – 665
1999	184	398	350 – 570	613	443	350 – 660
2000	241	407	320 – 510	550	437	350 – 640
2001	29	400	250 – 490	57	470	250 – 610
2002	17	420	250 – 500	43	438	250 – 580
2003	4	452.5	350 – 530	34	434	270 – 580
2004	82	408	250 – 650	38 (16)	394	290 – 560

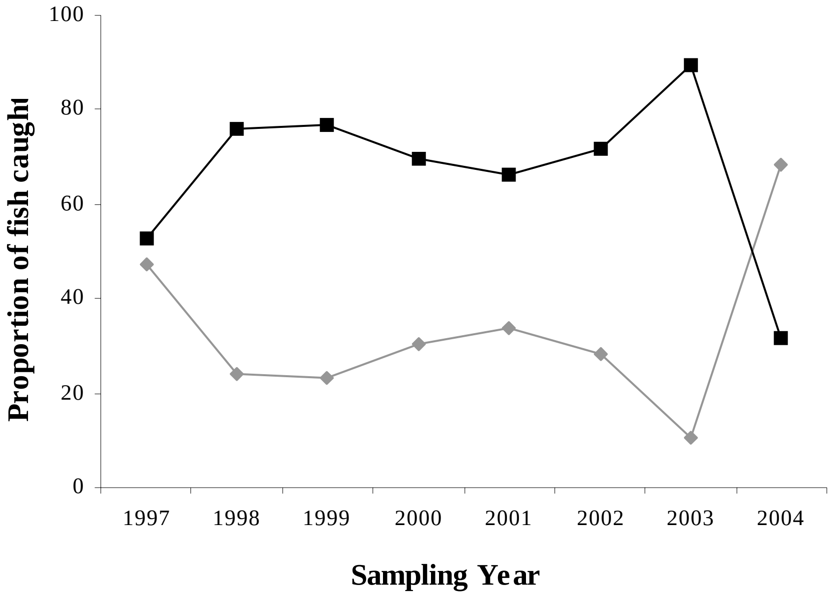

Figure 21. Proportion (%) of rainbow trout (grey) and brown trout (black) in sample of recreational catch data from Lake Jindabyne trout Festival (1997 – 2004).

Table 12. Lake Jindabyne Easter Festival Catches 2000 – 2005 (rainbow trout and brown trout only). Numbers of each species caught incl. undersized fish but only fish above minimum legal size limit, e.g., 250 mm, were included in analysis of mean length and size range.

Year	Rainbow Trout			Brown Trout		
	Number	Mean length (mm FL)	Size range (mm FL)	Number	Mean length (mm FL)	Size range (mm FL)
2000	133	634	250 – 520	63	368	250 – 600
2001	165	345	250 – 600	68	400	250 – 630
2002	19	395	250 – 500	28	452	300 – 600
2003	87	396	250 – 690	34	377	250 – 600
2004	71	381	270 – 501	19	381	260 – 580
2005	29	381	260 – 550	14	425	300 – 660

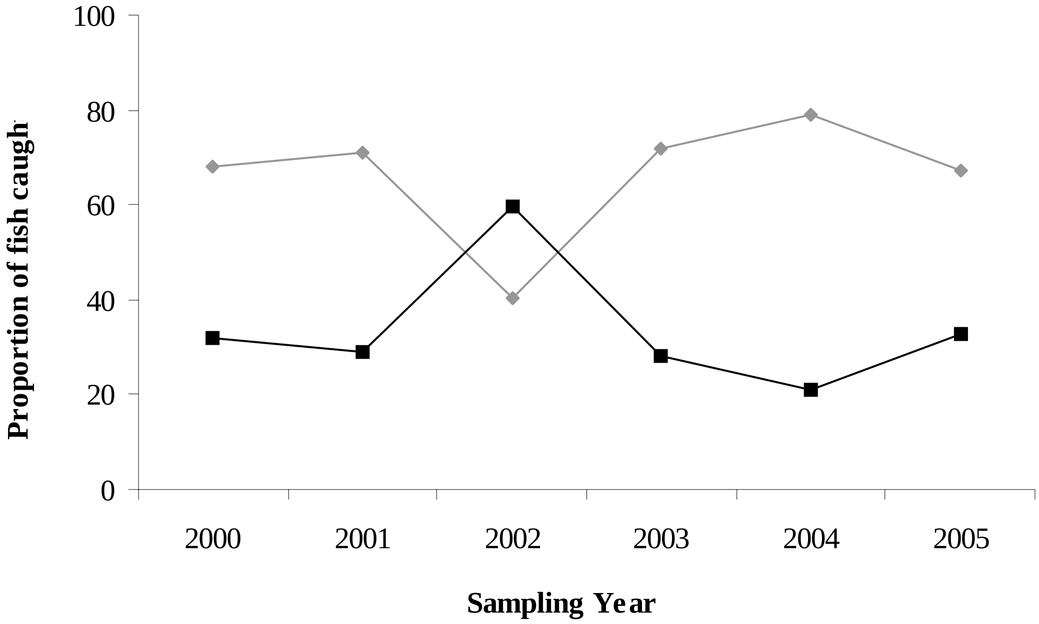

Figure 22. Proportion (%) of rainbow trout (grey) and brown trout (black) in sample of recreational catch data from Lake Jindabyne Easter Festival (2000 – 2005).

4. DISCUSSION

4.1. Lake Eucumbene

This study demonstrated that large migrations of trout continue to occur annually into tributaries of the Lake Eucumbene system. The age structure of fish sampled during the course of trapping and electrofishing suggest that spawning and recruitment occurred in each year despite the prevailing drought conditions. The overall condition of both species was fair to good and angler catches were relatively high. Therefore, the current stocking strategy for Lake Eucumbene appears to be maintaining a healthy, and largely self-sustaining, recreational fishery.

There is a strong relationship between angler catch rates and the percentages of rainbow trout in the Lake Eucumbene trout population. High percentages of rainbow trout in the catch are to be expected, as they are easier to catch than brown trout. However, high percentages of rainbow trout in the catch may also be related to the predominance of lure fishing from boats on Lake Eucumbene and the fact that much of the shoreline is inaccessible to anglers, limiting catches of brown trout, which predominantly inhabit the benthic habitat and lake margins. Recreational anglers mostly fish the surface layers of the lakes (Williamson, 1999) and this contributes to increased catches of the largely pelagic rainbow trout that feed in the midwater and surface layers.

In Lake Eucumbene, mean catch per unit effort for the Snowy Trout Festival in the years 1997 – 2004 (low 0.25; high 0.48 fish per hour) was similar to the CPUE figures of Bucknell (1965) for the period 1959 – 1964 (low 0.28; high 0.43), but were lower than monthly mean values recorded by Tilzey (1979) for the period 1967 – 1977 (low 0.32; high 0.64). Tilzey (1986) noted that between 1967 – 68 and 1976 – 77, CPUE averaged 0.44 fish per angler hour. Tilzey (1970) demonstrated that CPUE for Lake Eucumbene peaked in November and March, so CPUE during the months of the catch surveys (November and March to April) may be higher than at other times of the year. These methods overestimated CPUE values by excluding some (or all) fishless trips. However, comparisons between years suggest that the CPUE in recent years has remained relatively stable, given the large variation in volume of data collected. Since 2001, 150,000 rainbow trout have been stocked annually into Lake Eucumbene and the catch has remained at satisfactory rates of fish caught per angler hour (CPUE). It appears that fish stocked at that order of magnitude have alleviated the marked fluctuations in rainbow trout numbers that have historically occurred.

Both brown trout and rainbow trout sampled as part of this study were in fair-to-good spawning condition. Condition factors of greater than 1.2 indicate fair condition (DPI VIC, 1998), which was characteristic of both male and female fish from both species during this study. In general, the higher condition factor of female fish is probably representative of greater body mass arising from gonad development (Nicholls, 1957), as male gonads do not develop as large. Therefore, for fish of a given size, females would tend to weigh more when in spawning condition. Most remarkable was the lack of variation in condition factor among seasons. Despite receiving relatively low rainfall throughout the study period, migrating individuals did not show any signs of distress. Trout populations of the Lake Eucumbene region have traditionally exhibited good condition, especially post-damming (Tuma, 1962; 1963). This information suggests that the populations of both species are in balance with available food supplies and that water quality is sufficient during periods of spawning migration. Overall, there is little data to suggest than any management intervention is needed to improve the condition of spawning fish.

Brown trout appear to be recruiting to the fishery and maintaining their strong population, possibly because of lower exploitation and mortality rates (Faragher and Gordon, 1992). The fact that brown trout spawn earlier than rainbow trout, and have first use of the limited spawning habitat, available probably enhances their chances of successful recruitment in any given year. Condition factors of male brown trout in the Lake Eucumbene spawning run samples were often equal to or higher than that of female brown trout. This result may be partly explained by the technique used to sample the brown trout in the Lake Eucumbene catchment (electrofishing versus trapping). Swamp Creek is generally the habitat electrofished and this stream has spawning gravels and undercut banks with ideal water depth, so the larger, more aggressive male brown trout are probably occupying the best spawning grounds and excluding the smaller males from these areas. When fish are sampled by trapping, a more representative sample is taken as the fish are caught while moving upstream to other spawning habitats.

The finding that the brown trout population in Lake Eucumbene includes many age groups (spawning run fish were aged from 3 – 9 years) indicates that at least some brown trout contribute to the spawning run over a period of many years. This finding, combined with the lower exploitation rate of brown trout in comparison to rainbow trout (Faragher and Gordon, 1992; Tilzey, 1986), supports the policy of not stocking brown trout into Lake Eucumbene. In New Zealand, brown trout have been aged to at least 14 – 15 years and growth rates can be as slow as 1cm per year (or less) once fish have reached three to five years of age (Jellyman, 1991). In Norway, two brown trout were aged from otoliths at 34 and 38 years at lengths of 56 cm (1.54 kg male) and 66.5 cm (2.45 kg female), respectively (Svalastog, 1991). Overlapping length-at-age estimates indicates that length of brown trout is no indication of age with relatively small fish being aged at 6 – 9 years old. Therefore any estimation of age from length data would be invalid. Although most ageing studies of brown trout reveal that fish live to a maximum of around 10 years of age, individuals in some populations can live significantly longer.

Very few Eucumbene rainbow trout sampled by either angler catch or spawning run sampling were aged over three years. This is further evidence of this species higher exploitation rate and high annual mortality. Scott and Crossman (1973) noted that in some populations survival of rainbow trout is often low and that the number spawning more than once can be less than ten percent. McDowall (1984) also suggested that large numbers of rainbow trout probably die after first spawning. Between 2003 and 2005, very few four-year old finclipped fish were captured in the spawning run and only two four-year olds were identified in 2004, and no four-year olds were identified in 2005 (n = 585). These findings are further confirmation that few hatchery-reared rainbow trout live or spawn past three years in Lake Jindabyne or Lake Eucumbene.

The proportion of stocked to wild rainbow trout was generally low over the study period. The presence of two, three and four year old finclipped fish in annual spawning runs demonstrate that stocked fish are contributing to the rainbow trout spawning run, but natural recruitment still accounts for the bulk of the spawning population. Males dominated (60 – 100%) the make-up of 2 year old finclipped fish in all years whereas females generally dominated (44 – 71%) the make-up of 3 year old finclipped fish. Male rainbow trout often mature a year earlier than females (Scott and Crossman, 1973) possibly accounting for this difference. The maximum recapture rate for stocked fish was 8% (in 2005), which is relatively low given the large sample sizes captured as part of this project. When assessing the contribution of stocked fish to trout migrations, management intervention is usually required when the recapture rate exceeds 50% (Alistair McBurnie, Personal communication). In terms of managing the rainbow trout population in Lake Eucumbene, no management intervention is currently required as natural recruits are currently dominating the spawning run.

It is important to note that fish were only ever trapped or electrofished from a single tributary (Gang Gang Ck or Swamp Creek) during each assessment, despite many potential spawning tributaries existing in the Eucumbene catchment. In addition, it was impossible to continually trap the entire spawning run (usually only 1 to 3 weeks were possible) so in effect, these samples are a small representation of all spawning fish. Therefore, a key assumption of this work is that stocked fish migrate into all tributaries in relatively similar proportions. Additional sampling at degraded sites of less significance may yield additional information regarding the importance of smaller tributaries for spawning and recruitment in the Eucumbene catchment.

4.2. Lake Jindabyne

Annual trapping of the Thredbo River demonstrated that good numbers of fish are migrating and spawning within the system. As with Lake Eucumbene, migrating fish (from both species) were in fair-to-good condition and angler catches were high; with little variation among years. The recapture rate of stocked fish was relatively low, but substantially greater than that recorded within Lake Eucumbene. This observation suggests trout populations within the Lake Jindabyne catchment are more reliant upon regular stocking to maintain the recreational fishery.

Angling data revealed consistent catches in each year, with similar catch rates for both species. In general, the CPUE for brown trout was greater than in Eucumbene and may be related to differences in water level variation within the lake. Lake Jindabyne water fluctuations rarely exceed 10 m per year, whereas levels in Lake Eucumbene can vary by up to 15 m in a nine month period (see Figure 1). The effect of this in Lake Eucumbene is that there can be periods of several years when no littoral macrophytes develop on many of the steeper exposed shores, reducing littoral fauna. Brown trout are predominantly benthic feeders and are likely to be impacted more by decreasing lake levels than the pelagic rainbow trout. However, flooding ground that has re-established vegetation increases food sources (e.g. yabbies) for benthic feeders such as brown trout. Variations in the growth rate of trout (mainly brown trout) in these impoundments are largely a result of the fluctuations in water level that affect the productivity of their predominantly invertebrate food source. As these factors are likely to influence brown trout survival within the lake, it may account for increased catch rates.

Trapping the spawning run of rainbow trout in the Lake Jindabyne catchment (Thredbo River) revealed larger proportions of finclipped fish than Lake Eucumbene for both 2 and 3 year olds in all years (2003 – 2005). Two year old fish were more abundant in 2004 than in other sampling years. This unusual increase is possibly related to increased survival of fish stocked in 2003, poor natural recruitment in the winter-spring of 2002, or a combination of these factors. Degradation and silting of the Thredbo River noted from the mid to late 1980’s (Stock 1989) was supposedly caused by development upstream of Gaden hatchery. Although trout are migrating into, and aggregating in, the Thredbo River for spawning purposes, natural recruitment appears insufficient to maintain the rainbow trout stock. Given the high exploitation rate of rainbow trout and higher proportion of stocked fish in the annual spawning migrations, it appears that stocking of Lake Jindabyne with rainbow trout is essential to maintain the recreational fishery.

Fluctuations in water level are known to affect the littoral invertebrate fauna (which in turn affect the availability and utilisation of this fauna by trout populations), particularly in impoundments (e.g. Hunt and Jones 1972, Davies and Sloane 1988). The effect of a minor change in lake level may affect the rate of growth of fish for many years (Hunt & Jones 1972). The flooding of new ground is associated with a recovery of mean weight of brown and rainbow trout (Davies and Sloane 1988). As Lake Eucumbene and Lake Jindabyne first reached their full supply levels during the 1970s, this phenomenon only occurs when revegetated ground is inundated. Falling lake levels result in decreases in overall primary production, invertebrate production and, at the end of the food chain, trout production (Tilzey 1979). CPUE is known to rise in years when new ground was inundated (eg. 1968 and 1977) (Tilzey, 1979). However, the level of Lake Jindabyne has been kept relatively constant in recent times to allow an upgrade of the dam and water release facilities. Once these works are completed, levels within the Lake will return to a more natural flow regime and the proportion of natural recruits in the spawning run may increase.

Both brown trout and rainbow trout caught from the Thredbo River were in fair-to-good spawning condition. As with Lake Eucumbene, mean condition factors of male and female fish (both species) were over 1.1 in all sampling years. Females exhibited higher condition factors than males in all seasons except 2003. The consistency and magnitude of these values again demonstrate that spawning fish are demonstrating few signs of distress.

5. CONCLUSION

Overall, there are few data to suggest that any immediate management intervention is required to improve the condition of spawning trout in the Snowy Lakes.

The results from the five year study suggest that both rainbow and brown trout populations of Lake Jindabyne and Eucumbene are in excellent condition. Spawning fish all displayed high condition factors and migrated in good numbers during each year of sampling. Information from angler catch returns demonstrates that the recreational fishery is healthy; and that annual catch rates are consistent and vary little among years. These results suggest that stocking should continue at the present rates as there are no signs of population distress in either waterbody. In Lake Jindabyne, current stockings of 50,000 rainbow trout per annum appear adequate to maintain the population. In Lake Eucumbene, the current rate of 150,000 should also continue. No brown trout have been stocked into either waterbody for almost 20 years and the species appears to have maintained self-sustaining populations over that time. Therefore, there is no immediate requirement to stock brown trout into either lake.

Specific stocking and monitoring recommendations:

- Continue current stockings of 50 000 rainbow trout per annum into Lake Jindabyne
- Continue stockings of 150 000 rainbow trout per annum into Lake Eucumbene
- No need to stock brown trout in either waterbody
- Continue electrofishing brown and trout spawning stock in Eucumbene R tributaries to monitor condition factor as an indicator of the health of the brown trout population
- Continue electrofishing brown and rainbow trout spawning stock in Thredbo R tributaries to monitor condition factor as an indicator of the health of the brown trout population
- Continue to mark rainbow trout fingerlings released into both impoundments to enable continual monitoring of stocked vs wild fish ratios
- Consider sampling in smaller tributaries in poorer condition to determine if stocked/wild fish ratios and fish condition vary between sites
- Consider the development of new marking techniques (e.g., Chemical induction) to reduce the labour and time requirement of fin-clipping

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