The re-establishment of endangered Macquarie perch *Macquaria australasica* in the Queanbeyan River, New South Wales, with an examination of dietary overlap with alien trout

Working together for the future of our freshwater resources

Mark Lintermans

June 2006

CRC FOR FRESHWATER ECOLOGY

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environment ACT

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Environment ACT and
Cooperative Research Centre for Freshwater Ecology

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Lintermans, Mark (2006) *The re-establishment of endangered Macquarie perch* Macquaria australasica *in the Queanbeyan River, New South Wales, with an examination of dietary overlap with alien trout.* Technical report. CRC for Freshwater Ecology, Canberra.

ISBN 0 9577048 9 5

Published June 2006

Further copies of this report are available from the author at:
Wildlife Research & Monitoring, Environment ACT, PO Box 144, Lyneham, ACT, 2602

Editing, design and typesetting: Science Text Processors Canberra and TechType, Canberra

Printing: Elect Printing, Fyshwick ACT

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Acknowledgements

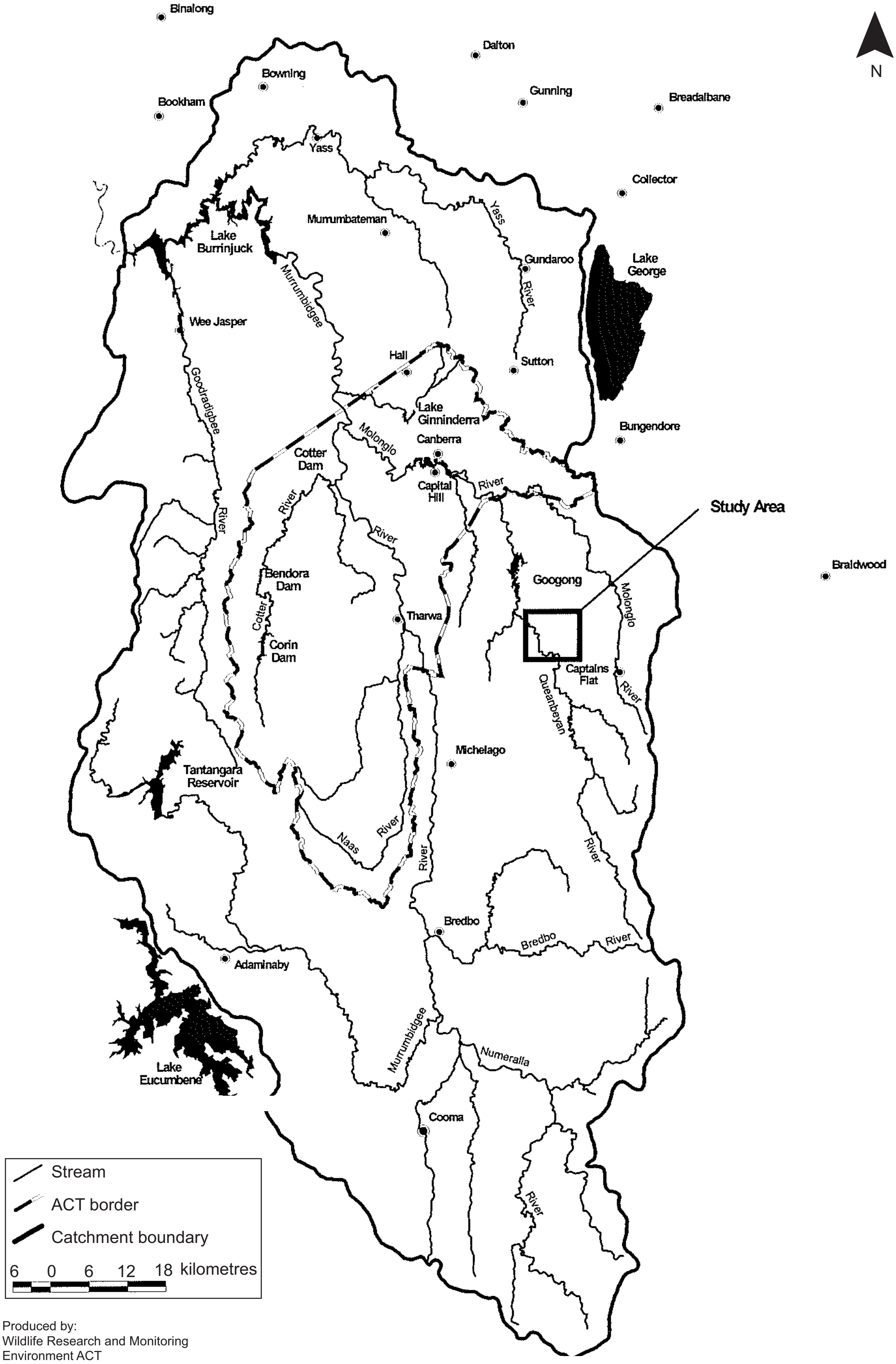
This research was done during the mid to late 1990s when the Cooperative Research Centre for Freshwater Ecology was in its first funding round and comprised a different set of partner organizations. NSW Fisheries, one of those partners, was a significant supporter of this research.

Kruno Kukolic and Terry Rutzou carried out the early monitoring of the Googong fishery and were responsible for the relocation of the Macquarie perch upstream of Curleys Falls. Mark Jekabsons assisted with the field work in the 1996 and 1997 surveys and identified the Macquarie perch dietary samples. Bernard Morris also assisted with identification of the trout dietary samples. Mark Dunford prepared Figures 1 and 3 and Lara Zambelli assisted with data entry. David Shorthouse, John Harris, Tarmo Raadik and John Koehn provided comments on a draft of this report. Thanks also to Ann Milligan for her editorial assistance with the report.

Summary

Googong Reservoir was constructed on the Queanbeyan River in 1978 in response to the need for an additional domestic water supply reservoir for Canberra. Monitoring of the reservoir fishery between 1978 and 1980 revealed that the nationally threatened fish species, Macquarie perch, was present in the reservoir, but was not recruiting. In an attempt to prevent the local extinction of this population of Macquarie perch, a total of 57 adult fish were removed from Googong Reservoir in November 1980 and released into the Queanbeyan River upstream. This report presents the results of a comprehensive survey of the resulting Macquarie perch population in the Queanbeyan River above Googong Reservoir and the reasons for the decline of the species within the Murray-Darling Basin and the Canberra region.

Macquarie perch were sampled at three sites in late summer 1996 and again in 1997. The fish were measured and examined, then anaesthetised and stomach-flushed to examine their diet, before being released. Trout caught at the same time were also examined. This report discusses the potential for dietary overlap between Macquarie perch and trout and future management considerations for the re-established Macquarie perch population.



Produced by:
Wildlife Research and Monitoring
Environment ACT
March 1999

Figure 1. The upper Murrumbidgee catchment showing the location of the Queanbeyan River and Googong Reservoir

1. Introduction

The Queanbeyan River catchment lies in New South Wales (NSW) to the east of the Australian Capital Territory (ACT). The Queanbeyan River is a major tributary of the Molonglo River in the upper Murrumbidgee catchment (Figure 1).

The need for an additional domestic water supply reservoir for Canberra resulted in the construction of Googong Reservoir on the Queanbeyan River in 1978. The reservoir has a storage capacity of 124.5 GL, a surface area of 680 ha, an average depth of 17.3 m and a maximum depth of 62 m. The reservoir and some 5212 ha of the surrounding catchment are managed by Environment ACT on behalf of the ACT Government, to protect the water quality and nature conservation values in the reservoir and its immediate catchment.

It was known that there was a small population of the endangered Macquarie perch *Macquaria australasica* (Plate 1) in the Queanbeyan River before the construction of Googong Dam. Macquarie perch is considered a threatened species in all the States and Territories where it occurs. It is listed as 'endangered' nationally (DEH 2005) and in the ACT (ACT Government 1999) and is listed as a threatened species under the *Flora & Fauna Guarantee Act 1988* in Victoria where it has also been assessed as 'endangered' (DSE 2003). The species is listed as 'vulnerable' in New South Wales.

Macquarie perch are moderate size fish (maximum length 495 mm, maximum weight 3.5 kg) which are typically found in the cooler, upper reaches of the Lachlan, Murrumbidgee and Murray catchments, and the coastal catchments of the Shoalhaven and Hawkesbury–Nepean rivers. It is considered that there are at least two taxa of Macquarie perch, one of which

Plate 1. Macquarie perch, *Macquaria australasica* (Murray-Darling form)

occurs in the western rivers (the Murray-Darling form) and the other in the eastern or coastal rivers (the coastal form) (Dufty 1986; Harris & Rowland 1996). This report deals only with the Murray-Darling form because this is the taxon that is found in the Canberra region.

The preferred habitat of Macquarie perch is cool, shaded, upland streams with deep rocky pools and substantial cover. The species will also survive well in impoundments with suitable feeder streams in which to breed. The species now seems to be confined to the upper reaches of catchments (Cadwallader 1981) which are relatively pristine and not heavily affected by agriculture and sedimentation (ACT Government 1999).

Males are reported to reach sexual maturity at two years of age and approximately 210 mm total length, and females at three years of age and 300 mm total length (Harris & Rowland 1996). However in some streams fish may mature at smaller lengths, with male fish recorded as mature at approximately 140–150 mm in the Cotter River in the ACT (Lintermans & Osborne 2002), 140 mm in the Mitta Mitta River (Douglas 2002), 117 mm in Lake Dartmouth, Victoria (Douglas *et al.* 2002) and 134 mm in Hughes Creek, Victoria (Appleford *et al.* 1998). Spawning occurs in late spring–summer in flowing water when water temperatures reach approximately 16.5°C. The fish deposit eggs above riffles or fast-flowing sections of river, and the eggs are washed downstream and lodge in gravel or rocky areas until hatching (Cadwallader & Rogan 1977; Douglas 2002). Hatching usually occurs after 10–11 days at water temperatures of 15–17°C; the larvae are about 7 mm long at hatching.

The Macquarie perch is a quiet and docile species that generally feeds on shrimps and small benthic aquatic insect larvae, particularly mayflies, caddisflies and midges.

1.1. Decline of Macquarie perch in the Canberra region

Macquarie perch were probably present historically throughout the middle and lower reaches of the Queanbeyan and Molonglo rivers and they are still occasionally caught in the Murrumbidgee River in the ACT (Lintermans 1995b, 2000a, 2002, unpublished data), but they are now in low abundance (Lintermans 1991a, 2000a, 2002). Their decline is thought to be due largely to habitat modification such as by sedimentation or the construction of dams and weirs, and to interactions with alien fish species (Lintermans 1991a,b, 2002). Downstream of the Googong Reservoir, the most likely reasons for the disappearance of Macquarie perch are related to the construction and operation of the reservoir and the construction of barriers to fish passage on the Queanbeyan and Molonglo rivers (Lintermans 1998b).

The upper Queanbeyan River catchment still has substantial areas of native forest cover, and the catchment for the current study area is largely forested with little evidence of sediment input.

1.1.1. Effects of sedimentation

Macquarie perch are particularly susceptible to sedimentation in streams because they deposit their adhesive demersal eggs amongst rocks and gravel. Interstitial spaces are important for the successful breeding of Macquarie perch; they provide attachment sites for the eggs until hatching (Cadwallader & Rogan 1977; Battaglene 1988). Sediment can smother either the spawning beds, rendering them unsuitable, or the eggs themselves.

Poor land management practices in the mid to late 1800s and three large floods between 1850 and 1870 in the upper Murrumbidgee catchment resulted in extensive erosion and sediment addition to the river (Starr 1995; Starr *et al*. 1997). This sediment originated predominantly in the Bredbo and Numeralla catchments with most of it coming from gully and channel erosion (Olley 1997). Large volumes of the sediment stored in the channel are being repeatedly reworked, and will be for the foreseeable future (Erskine 1997). Construction of dams and weirs is a known major source of sediment addition. Sediment deposits caused by the construction of the Thompson Dam in Victoria filled the downstream interstitial spaces between stones to a depth of at least 60 cm (Davey *et al*. 1987).

1.1.2. Effects of dams and weirs

Apart from generating sediment, the construction of dams and weirs also affects fish by preventing fish passage. The construction of Scrivener Dam to form Lake Burley Griffin in 1963 effectively isolated the Molonglo and Queanbeyan rivers from the Murrumbidgee River and prevented recolonisation by all fish species. Even small structures such as road crossings can be significant barriers to fish movement (Lintermans 2000b; Thorncraft & Harris 2000; Fairfull & Witheridge 2003). A concrete ford across the Cotter River in the ACT at Vanities Crossing prevented upstream movement by Macquarie perch for many years (Lintermans 1991a).

Dams can severely affect fish habitat quality by modifying the natural flow regimes of the rivers below the impoundments when water from spring and autumn rains is collected and stored for release in summer. In some instances, the seasonal flows have been removed almost entirely (MDBC 2004). The construction of Tantangara Reservoir on the upper Murrumbidgee River has diverted approximately 99% of in-flowing water to Lake Eucumbene as part of the Snowy Mountains Hydro-electric Scheme (Pendlebury 1997). The upper Murrumbidgee River still contains a viable population of Macquarie perch above and around the Cooma area, but the future of this population may be threatened by the current operation of Tantangara Reservoir (Lintermans 1998c, 2004a). Flow releases are urgently required to flush sediment accumulations from the downstream river channel.

The quality of water released from dams may also be a problem in that it is usually released from the lower levels of the reservoir and is much colder than the surface waters. Macquarie perch use the rise in water temperature associated with late spring–early summer flows as a cue to commence spawning (Llewellyn & MacDonald 1980; Cadwallader 1981; Cadwallader

& Backhouse 1983). The release of cold water during the breeding season is thought to inhibit the spawning behaviour of Macquarie perch and other native fish species. Koehn *et al*. (1995) found that populations of Macquarie perch in the Mitta Mitta River downstream of Dartmouth Dam have disappeared following its construction during 1973–80. This is attributed to the effects of releases of cold water from the dam during the Macquarie perch spawning season. Changed thermal regimes also affect invertebrate communities and food webs and, consequently, the growth rate of fish (Wager & Jackson 1993). Recent experiments on a range of native fish species have demonstrated significant suppression of growth rates with cold-water discharges from dams (Phillips 2001; Ryan *et al.* 2001; Astles *et al.* 2003). Lintermans (1998b) recorded that the water temperature in the Queanbeyan River immediately below Googong was 2.5–4.5ºC lower than at sites further downstream, and this was thought to be a result of releases of cold water from Googong Reservoir.

1.1.3. Effects of alien fish species

Alien fish species such as carp *Cyprinus carpio*, redfin perch *Perca fluviatilis*, goldfish *Carassius auratus*, and eastern gambusia *Gambusia holbrooki*, are often cited as a cause of native fish decline in Australia. However, much of the evidence is anecdotal because the majority of non-native species were introduced in the mid-to-late 1800s (Lintermans 2002), when the distribution and abundance of native fish were poorly known or documented.

Trout are blamed for affecting native fish species, mainly through predation and competition for food, spawning or territorial areas (Frankenberg 1966, 1974; Tilzey 1976; Fletcher 1979, 1986; Jackson & Williams 1980; Jackson 1981; Koehn & O'Connor 1990a,b; Pollard *et al*. 1990; Lintermans 2000b). Brown trout *Salmo trutta* were first introduced into the Canberra region in 1888, and this was one of the first areas of New South Wales to be stocked (National Trust of Australia 1980; NSW Fisheries 2003). Rainbow trout *Oncorhychus mykiss* were first introduced into Australia and New South Wales in 1894 (Faragher 1986), so both trout species have been established in south-eastern NSW for a century or more. The diets of Macquarie perch and the alien trout species are very similar (Butcher 1945; Cadwallader 1978; Cadwallader & Eden 1979; Jackson 1981; and see discussion below in section 3.4). Trout are also known to prey upon juvenile Macquarie perch (Butcher 1967; Winstanley 2000). Carp and redfin perch may also compete with Macquarie perch for food (Cadwallader 1978; Battaglene 1988).

Alien species also have the potential to introduce or spread foreign parasites and diseases to native fish species. Kinne (1984, in Stewart 1991) estimated that less than 2% of fish diseases were known and even for these the knowledge was incomplete. Carp and redfin perch are considered to be the source of the Australian populations of the parasitic copepod *Lernaea cyprinacea* (Langdon 1989a). Carp, goldfish or eastern gambusia are probably the source of the introduced tapeworm *Bothriocephalus acheilognathi* which has recently been recorded in native fish species (Dove *et al*. 1997). This tapeworm causes widespread mortality in juvenile fish overseas.

The most serious threat to Macquarie perch from alien fish species may lie in the impacts of the disease Epizootic Haematopoietic Necrosis Virus (EHNV). This virus, unique to Australia, was first isolated in 1985 in redfin perch (Langdon *et al*. 1986). It is characterised by sudden high mortalities of fish. On autopsy, the fish display necrosis of the renal haematopoietic tissue, liver, spleen and pancreas (Langdon & Humphrey 1987).

Experimental work by Langdon (1989a,b) demonstrated that Macquarie perch was one of several species extremely susceptible to the disease. When Macquarie perch were held in aquaria and exposed to low concentrations of EHNV in water, all ten fish in two separate trials died within five days. Autopsies revealed the necroses typical of EHNV.

The virus was first recorded from the Canberra region in 1986 when an outbreak occurred in redfin perch in Blowering Reservoir near Tumut (Langdon & Humphrey 1987). Subsequent outbreaks have occurred in Lake Burrinjuck in late 1990, Lake Burley Griffin in 1991 and 1994, Lake Ginninderra and Googong Reservoir in 1994 (Whittington *et al*. 1996).

The spread of EHNV has been aided by its relative resistance. It can be readily transmitted from one location to another on nets, fishing lines, boats and other equipment. Langdon (1989b) found that the virus retained its infectivity after being stored dry for 113 days. Once EHNV has entered a water body it is considered impossible to eradicate.

The Murrumbidgee and the Googong Reservoir populations of Macquarie perch have been exposed to the virus and it is highly likely the Queanbeyan River population has also been exposed through the movement of infected adult trout between the reservoir and the river. It is now speculated that the sudden and severe depletion of the Macquarie perch population in Lake Eildon, Victoria, may have been partly due to EHNV (Langdon 1989b). Currently there is no redfin perch in the Queanbeyan River above Curleys Falls but it is likely that the species will become established in this area. Redfin perch are abundant in Googong Reservoir and the river below the reservoir (Lintermans 1998b) and are probably present in farm dams within the catchment. The distribution of redfin perch in the Canberra region has been greatly expanded in recent years (Lintermans *et al*. 1990) through human intervention. There is a real chance that unthinking anglers will transport the species past the barrier posed by Curleys Falls, either deliberately as bait fish, or unwittingly to stock farm dams in the upper catchment (Lintermans 2004b).

A community education program could be an effective way of highlighting the potential problems if redfin perch become established in the Queanbeyan River catchment upstream of Curleys Falls.

1.1.4. Status of the Googong Reservoir population of Macquarie perch

In 1978 a fish monitoring program was established for the new impoundment, Googong Reservoir. Between 1978 and 1980, the fish monitoring program revealed that Macquarie perch were present in the reservoir but were not recruiting (Figure 2), and the future of the population appeared threatened.

It is believed that the construction of the reservoir had flooded all available Macquarie perch spawning sites, and that the species was unable to reach the river above the reservoir because of a waterfall, Curleys Falls, that formed a natural barrier (Plate 2). Curleys Falls is at the upstream limit of the impounded waters and consists of a series of small (1–3 m) drops through a small rocky gorge (Plate 2).

In November 1980, a total of 57 adult Macquarie perch were netted from the reservoir, transported upstream past Curleys Falls, and released at two sites

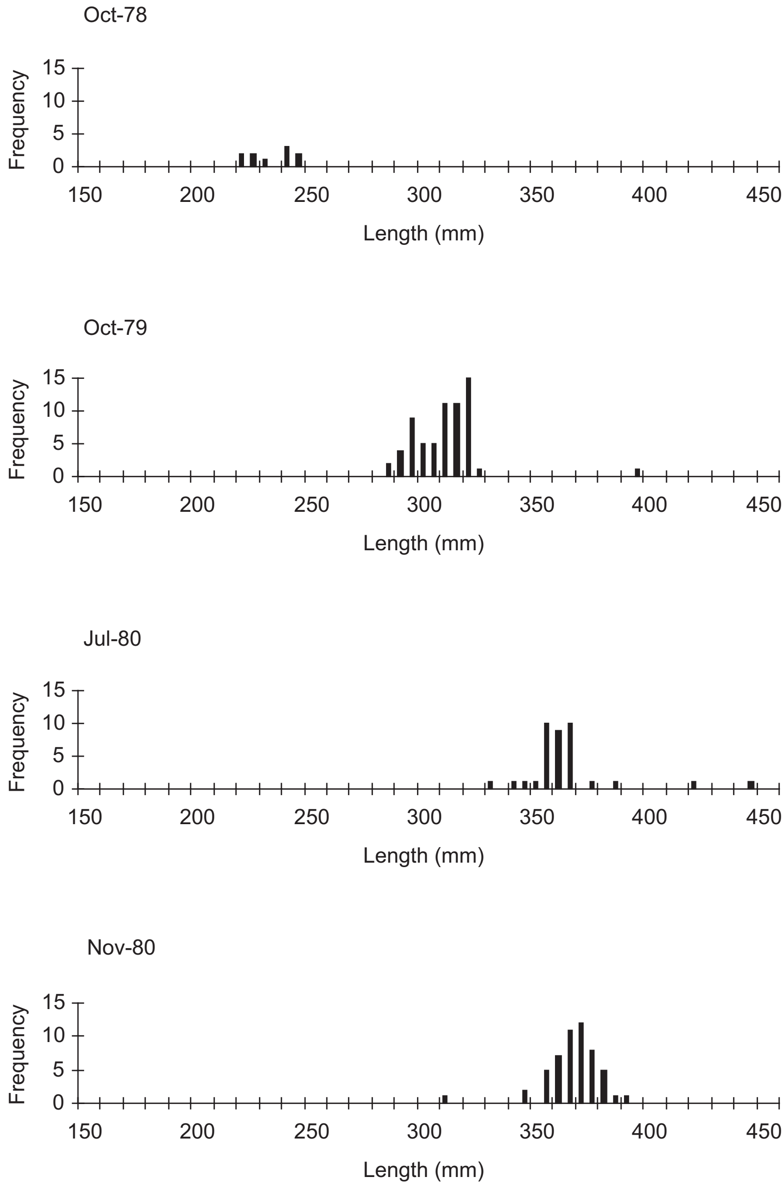


Figure 2. Length frequency of Macquarie perch captured in Googong Reservoir between October 1978 and November 1980.

Plate 2. Curleys Falls

on the Queanbeyan River. It was hoped this would allow the species access to suitable spawning sites and ensure the survival of the population in the Queanbeyan River.

Monitoring of the release sites between 1981 and 1985 did not detect the presence of Macquarie perch and it was feared the relocation attempt had failed. However, in 1985 an angler reported catching a Macquarie perch at one of the release sites, and additional captures were reported by anglers over the next few years. In March 1991, a preliminary survey of the Queanbeyan River revealed that there was a small population of Macquarie perch, with at least three age classes of fish present (Kukolic & Rutzou 1992).

This report presents the results of a comprehensive survey of the Macquarie perch population in the Queanbeyan River above Googong Reservoir, including an examination of the diet of Macquarie perch and potential dietary overlap with trout.

2. Methods

2.1. Field sites and sampling

The population of Macquarie perch in the Queanbeyan River above Googong Reservoir was sampled in 1996 and 1997. Sites were sampled between February 15 and 29 in 1996 and between February 19 and March 3 in 1997. Three sites were sampled each year (Figure 3):

- Above Curleys Falls (Grid Ref 706500E, 6067800S) (Plate 3);
- ACTEW Pool (Grid Ref 708500E, 6066500S) (Plate 4);
- Hayshed (Grid Ref 709200E, 6065400S) (Plate 5).

Plate 3. Above Curleys Falls sampling site

Plate 4. ACTEW Pool sampling site

Plate 5. Hayshed sampling site

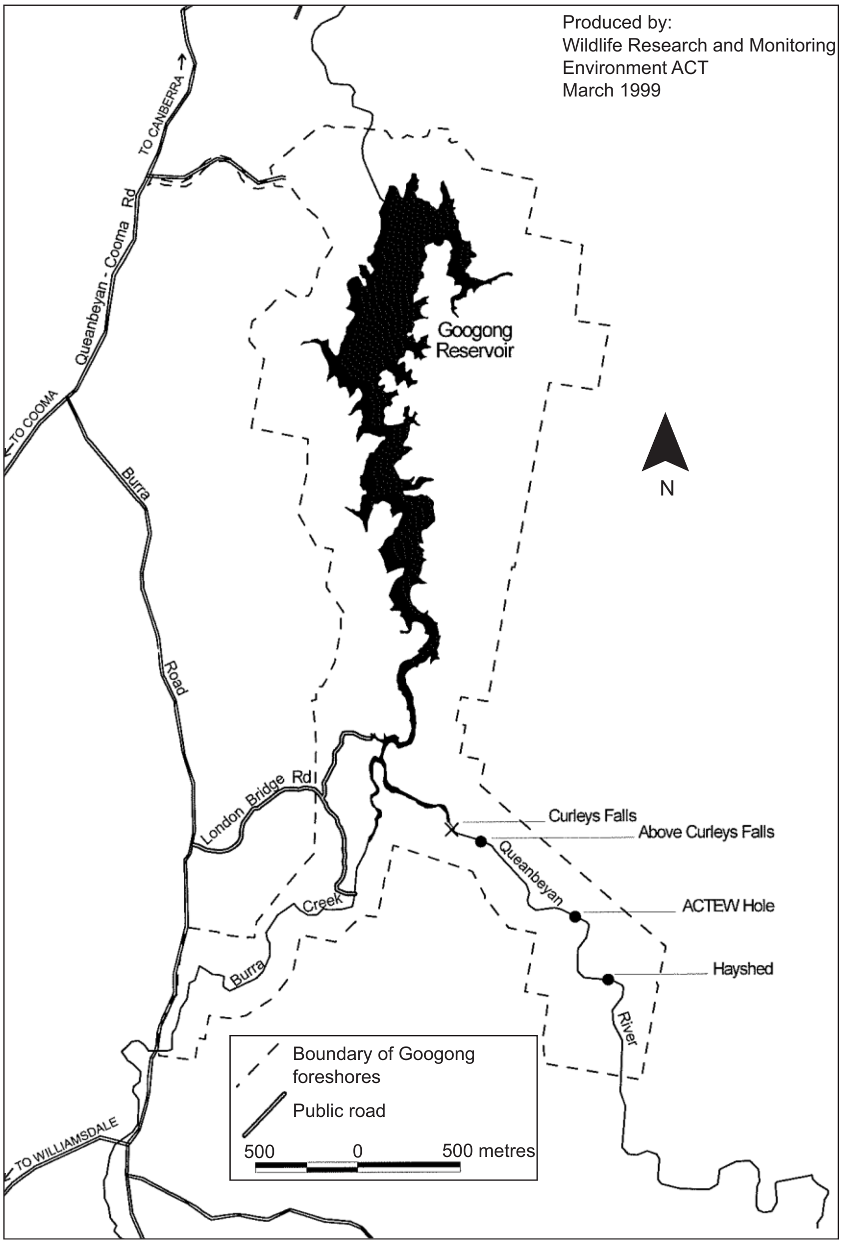


Figure 3. Googong Reservoir showing location of sites (solid circles) sampled for Macquarie perch in 1996 and 1997

At each site the following sampling equipment was used:

(i) three nylon multifilament mesh or gill nets (each ~35 m long) (mesh sizes used were 50, 75 and 100 mm stretched mesh);

(ii) ten single-winged fyke nets (15 mm stretched mesh);

(iii) ten bait traps (for collection of smaller fish species and juveniles).

Gill nets were usually set with one end of the net attached to the bank and the other end attached to an anchor mid-stream. Gill nets were unweighted and attached to a float line with the drop of each net being 100 meshes deep. Gill nets were set between 1530 hours and 1600 hours, were monitored hourly from dusk until 2130, and any non-target animals such as platypus *Ornithorhynchus anatinus*, or eastern long-necked tortoise *Chelodina longicollis*, were removed. The gill nets and the manner in which they are set and patrolled was consistent with the technique outlined by Grant & Carrick (1974) for minimising platypus mortality. Gill nets were retrieved between 2130 hours and 2200 hours, and emptied of all fish, giving an initial six-hour soak time. Nets were then reset and left overnight before being removed between 0730 hours and 0830 hours the next morning. The reason for gill netting over two distinct time periods was to assess the percentage increase in the catch of Macquarie perch from the longer setting. Overnight gill netting has been a standard practice for Environment ACT for many years and the longer soak time allows comparison with previous nettings. However, in recognition of the national conservation status of Macquarie perch and the potential adverse effects of lengthy periods of restraint of fish in gill nets, it is now standard practice by Environment ACT to employ only a six-hour gill net soak time when targeting a threatened species (Lintermans 1995a).

Fyke nets were set between 1530 hours and 1630 hours and retrieved the next day between 0730 hours and 0930 hours. Fyke nets were attached to the bank at the cod-end and then set at an angle downstream with a weight attached to the wing to hold the net securely. In the cod end of each fyke net, a 150 mm diameter polystyrene float provided an airspace to prevent mortality of non-target animals.

Bait traps were set at 1800, baited with a chemical light stick (Cyalume, Yellow, 12 hour), and attached to the banks with a short length of cord. Traps were retrieved at approximately 0800 the next morning.

2.2. Fish collection and processing

All fish collected were identified to species and measured (total length or caudal fork length) to the nearest millimetre. Trout collected by gill nets were quickly killed by a blow to the back of the head and then taken to the laboratory for processing.

Macquarie perch were removed from gill nets as soon as possible and placed in aerated containers of water, ready for processing. The fish were anaesthetised, using a 100 mg/L solution of tricaine methanesulfonate (MS 222) buffered with sodium bicarbonate, until they could no longer swim upright. Their stomach contents were removed by gastric lavage (Plate 6). The gastric flushing system used was modified from that of Georges *et al*. (1986) and consisted of a bilge pump operated from a 12 V battery which passed a stream of water (approximately 200 mL/min) through a flexible, soft rubber surgical catheter. The catheter was inserted into the stomach through the mouth of the fish, and the stomach contents were flushed out through the mouth. The stomach contents were caught in a gauze-lined sieve and then preserved in 70% ethanol. The fish were allowed to recover in aerated plastic drums and were held in these drums overnight ready for

Plate 6. Stomach-flushing Macquarie perch

release the next morning. Only fish longer than approximately 140 mm were stomach-flushed because of the limitations imposed by the sizes of the catheter and the fishes' throats. Macquarie perch collected from fyke nets in the morning were processed in a similar fashion except that they were released immediately after recovery from the anaesthetic.

In 1997, a number of small juvenile Macquarie perch were gilled in the fyke net mesh and could not be released. These fish were preserved whole in 70% ethanol for later examination of stomach contents. The stomach contents of all trout collected were examined and identified to at least Order.

2.3. Dietary analysis

Stomach contents were identified under a stereo dissecting microscope. Dietary items were generally identified to family level although terrestrial prey items were identified to order only. Oligochaetes were identified to class only. Dietary items were identified by using dichotomous keys, with Williams (1980) and CSIRO (1991) as the major references. The number of items and a visual assessment of the percentage volume of each dietary category were recorded for each stomach.

Dietary importance was evaluated using four methods:

(i) percentage occurrence,

(ii) numerical abundance,

(iii) subjective volumetric abundance, and

(iv) Index of Relative Importance (IRI).

Percentage occurrence is simply the number of stomachs in which a dietary item occurs, expressed as a percentage of the total number of non-empty stomachs in a sample. Numerical abundance is the number of items of any particular category expressed as a proportion of the total number of dietary items present in the sample. Subjective volumetric abundance is a visual estimate of the relative percentage volume of each dietary category in an individual stomach.

The Index of Relative Importance (IRI) combines values from the numerical abundance (N), subjective volumetric abundance (V) and percent occurrence (O) methods into a single index (Pinkas *et al*. 1971; Scrimgeour & Winterbourn 1987), according to the formula:

$$\text{IRI} = (\text{V} + \text{N}) \text{ O}.$$

An IRI value was calculated for each dietary category in each season of sampling.

The use of more than one method of dietary analysis is likely to provide a fuller picture of the dietary composition of a species (Hyslop 1980; Wootton 1990). The numerical method is likely to overestimate the importance of small but abundant items whilst the volumetric method suffers from a higher degree of subjectivity in estimating the relative volume of food categories. The occurrence method measures only presence or absence of a dietary category and gives no information on its relative abundance within an individual fish.

Macquarie perch were categorised into three presumptive general age classes based on analysis of the length-frequency histograms of the fish. Fish less than 70 mm length were considered to be in their first year of life and were classified as ‘juvenile’. Fish of 71–165 mm total length were classified as ‘immature’ (in their second year), and fish >165 mm total length were classified as ‘mature’ (greater than two years of age). Samples were grouped according to age class in each year of sampling

Too few brown or rainbow trout of either species were captured to allow their data to be subdivided into size classes. Consequently the data for each trout species were combined for the two years of the study. To examine dietary overlap between Macquarie perch, rainbow trout, and brown trout, Schoener’s (1970) index (C_{xy}) was calculated for the IRI method of dietary analysis according to the formula:

$$C_{xy} = 1 - 0.5(\Sigma |p_{xi} - p_{yi}|) ,$$

where p_{xi} is the proportion of dietary group i used by species x, and p_{yi} is the proportion of dietary group i used by species y. The Schoener index was computed to two decimal places only (Crowder 1990) because confidence intervals can be quite large (Ricklefs & Lau 1980). The Schoener index provides a reasonable estimate of trophic niche overlap while requiring few assumptions (Hurlbert 1978; Wallace 1981).

2.4. Capture of non-target species

Non-target species captured in gill nets and fyke nets were removed as soon as possible after capture. Tortoises were identified to species and then released immediately. Platypus were removed, and then held overnight in large plastic drums (complete with nesting material) to eliminate the possibility of recapture.

3. Results

3.1. Species composition

A total of 291 fish of four fish species, (two native and two alien), were recorded over the two years of sampling (Table 1):

- Macquarie perch *Macquaria australasica*
- mountain galaxias *Galaxias olidus*
- rainbow trout *Oncorhynchus mykiss*
- brown trout *Salmo trutta*.

In both 1996 and 1997, the most fish were recorded at Hayshed, followed by the ACTEW Pool and Above Curleys sites. In 1997, there were more fish at all sites than in 1996. Species diversity was similar at all sites: all four species were recorded at each site except in 1996 when rainbow trout were absent from Above Curleys. The highest numbers of Macquarie perch were recorded at the Hayshed site in both years of sampling (Table 1).

3.2. Success of different gear types

The majority of Macquarie perch were caught in fyke nets in both years (Table 2), with most fish being juveniles. Only two Macquarie perch were caught in bait traps. The majority of both brown trout and rainbow trout were captured in gill nets and neither species was captured in bait traps. Mountain galaxias were only captured in bait traps (Table 2).

Table 1. Species and numbers of fish caught at each site on the Queanbeyan River in 1996 and 1997

Species	Above Curleys		Hayshed		ACTEW Pool		Total per year		Combined total
	1996	1997	1996	1997	1996	1997	1996	1997	
Macquarie perch	3	11	43	73	28	31	74	115	189
Mountain galaxias	9	4	13	13	2	1	24	18	42
Rainbow trout	–	3	4	10	2	5	6	18	24
Brown trout	5	5	7	6	5	8	17	19	36
Total per year	17	23	67	102	37	45	121	170	291
Combined Total	40		169		82		291		

Table 2. Number of each species caught each year by gear type

	Gill nets		Fyke nets		Bait traps	
	1996	1997	1996	1997	1996	1997
Macquarie perch	13	20	60	95	1	–
Mountain galaxias	–	–	–	–	24	18
Rainbow trout	6	14	–	4	–	–
Brown trout	13	19	4	–	–	–
Total per year	32	53	64	99	25	18
Combined total	85		163		43	

Table 3 compares the numbers of Macquarie perch caught in gill nets in the short (six hour) soak time and the long (~16 hour) soak time. Seventy-nine percent of the Macquarie perch captured in gill nets were caught within the first six hours.

3.3. Length frequency analysis

Macquarie perch ranged in length from 48 to 413 mm in 1996 and from 56 to 400 mm in 1997 (Figure 4). There appear to be at least three distinct cohorts in the length frequency histograms with recruitment from the previous year obvious in both 1996 and 1997.

3.4. Diet of Macquarie perch

The stomach contents of a total of 25 and 36 Macquarie perch were examined in 1996 and 1997, respectively. The length frequency distributions

Table 3. Numbers of Macquarie perch captured in gill nets during two soak times; numbers in the long soak indicate additional fish caught between 2130 hours and 0730 hours

Year	Above Curleys		Hayshed		ACTEW Pool		Total	
	6 hr	16 hr	6 hr	16 hr	6 hr	16 hr	6 hr	16 hr
1996	1	0	1	5	6	0	8	5
1997	2	1	6	0	10	1	18	2
Total	3	1	7	5	16	1	26	7

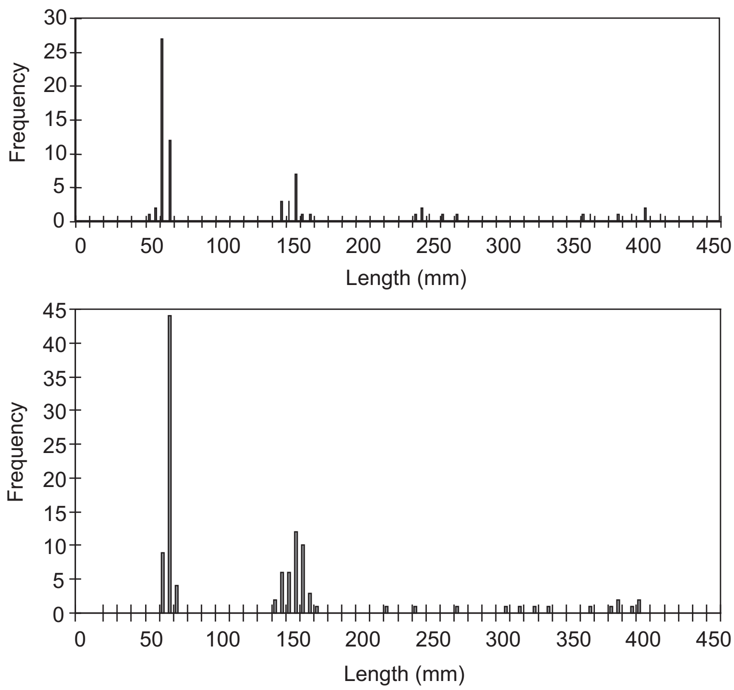


Figure 4. Length frequency histogram of Macquarie perch from the Queanbeyan River in 1996 (top) and 1997 (bottom)

of the fish whose stomachs were examined in each year are shown in Figure 5.

No empty stomachs were encountered in the samples. In 1996, no fish from the juvenile age class were examined because they were too small to stomach-flush and there was no accidental mortality in fyke nets. Dietary information was collected from 12 immature and 13 mature fish that year. In 1997, 11 juvenile, 18 immature and 7 mature fishes' stomach contents were examined.

A total of 1985 items in 41 food categories were recorded for Macquarie perch over the two years of the study (Table 4). The most numerous dietary items over the whole sample were members of the ephemeropteran family Baetidae, followed by Chironomidae, Atyidae, Leptophlebiidae, Leptoceridae and Corixidae respectively.

However, on the basis of the IRI method of analysis, the diet of Macquarie perch appeared to differ between the two years of the study with ephemeropterans dominating the diet in 1996 and dipterans much more prominent in 1997 (Figure 6).

The relative contribution of dietary categories for the four methods of dietary analysis are shown in Tables 5 and 6. Information from the percent volume, number and occurrence methods is presented to allow comparison with other published studies that have used these summary techniques. Comparison of the four methods shows that the volumetric method tends to elevate the ranking of larger dietary items such as decapods and odonata at

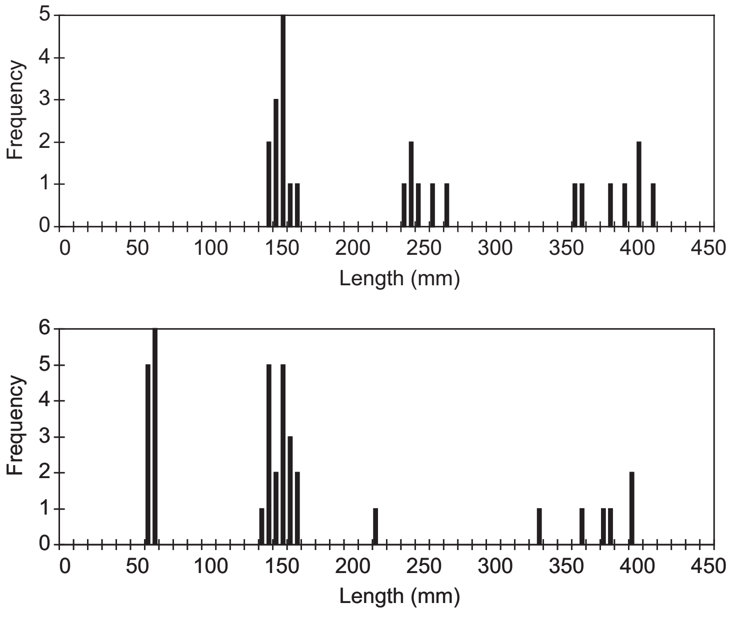


Figure 5. Length frequency of Macquarie perch from the Queanbeyan River in 1996 (top) and 1997 (bottom) whose diet was examined

Table 4. Number of items recorded in each dietary category from all Macquarie perch stomachs examined during the study

Dietary category	No.	Dietary category	No.	Dietary category	No.
Ephemeroptera		**Diptera**		**Odonata**	
Baetidae	770	Chironomidae	446	Corduliidae	18
Leptophlebiidae	103	Tabanidae	1	Gomphidae	6
Caenidae	38	Chaoboridae	2	Anisoptera unknown	2
Trichoptera		Ceratopogonidae	29	**Cladocera**	
Hydropsychidae	2	Culicidae	4	Daphniidae	48
Hydroptilidae	3	Diptera unknown	1	**Decapoda**	
Polycentropidae	7	**Hemiptera**		Parastacidae	6
Limnephilidae	1	Corixidae	70	Atyidae	191
Leptoceridae	74	Gerridae	1	Palaemonidae	10
Ecnomidae	29	Veliidae	1	**Ostracoda**	30
Odontoceridae	1	**Coleoptera**		**Nematoda**	32
Conoesucidae	1	Gyrinidae	1	**Bivalvia**	
Calamoceratidae	4	Haliplidae	3	Sphaeriidae	4
Philorheithridae	1	Elmidae	1	**Gastropoda**	
Trichoptera unknown	13	Dytiscidae	7	Physidae	9
Megaloptera				**Fish unknown**	2
Corydalidae	2			**Terrestrial arthropods**	8

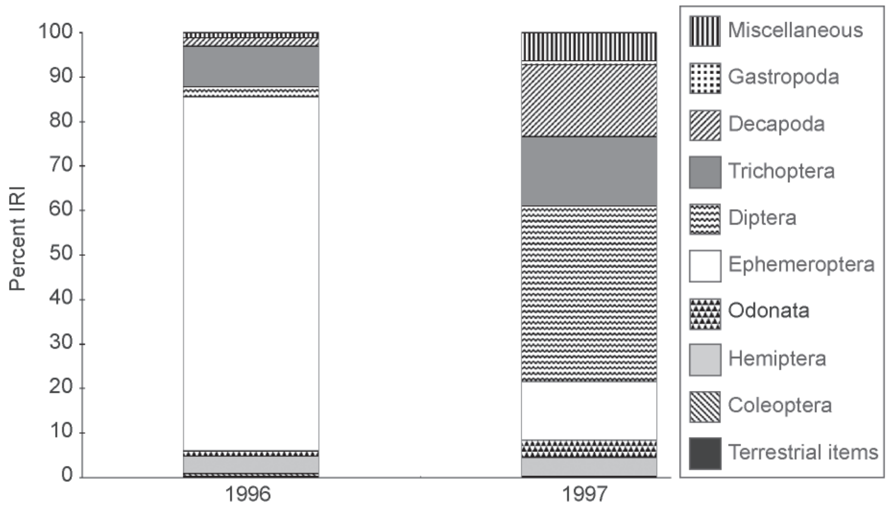


Figure 6. Comparison of the diets of Macquarie perch from the Queanbeyan River in 1996 and 1997 (legend reads from top to bottom of histogram)

the expense of smaller items such as diptera. In both years, the volumetric, numerical and IRI methods agreed on the most and least abundant food categories: ephemeroptera and gastropoda, respectively, in 1996, and diptera and coleoptera, respectively, in 1997. In 1997, these three methods also agreed with each other on the dietary categories ranked 2, 6, 8, and 9 as well, where 1 is most abundant and 10 is least abundant.

Analysis of the 1996 Macquarie perch diet by age class, using the IRI method, revealed little difference in diet between immature and mature fish

Table 5. Comparison of the four methods used to analyse the 1996 diet of Macquarie perch; the rank of each dietary category is shown in parentheses for each method (the = sign indicates a tied rank)

	% volume	% number	% occurrence	% Index of Relative Importance (IRI)
Terrestrial items	3.2 (7)	0.3 (9)	12 (9)	0.3 (9)
Coleoptera	2.7 (9)	1.0 (6)	24 (=7)	0.6 (8)
Hemiptera	8.0 (3)	3.9 (2)	48 (4)	4.0 (3)
Odonata	5.2 (5)	0.9 (7)	24 (=7)	1.0 (7)
Ephemeroptera	50.9 (1)	85.1 (1)	84 (1)	79.6 (1)
Diptera	2.8 (8)	3.7 (3)	60 (3)	2.3 (4)
Trichoptera	15.4 (2)	2.6 (4)	68 (2)	9.0 (2)
Decapoda	7.8 (4)	0.8 (8)	32 (=5)	1.9 (5)
Gastropoda	0.1 (10)	0.1 (10)	4 (10)	<0.1(10)
Miscellaneous	3.8 (6)	1.5 (5)	32 (=5)	1.2 (6)

Table 6. Comparison of the four methods used to analyse the 1997 diet of Macquarie perch; the rank of each dietary category is shown in parentheses for each method (the = sign indicates a tied rank)

	% volume	% number	% occurrence	% Index of Relative Importance (IRI)
Terrestrial items	1.7 (9)	0.5 (9)	11 (9)	0.2 (9)
Coleoptera	0.3 (10)	0.4 (10)	6 (10)	<0.1(10)
Hemiptera	9.1 (6)	3.4 (6)	39 (6)	4.4 (6)
Odonata	13.6 (4)	1.7 (7)	28 (7)	3.8 (7)
Ephemeroptera	15.9 (3)	9.2 (5)	58 (3)	13.1 (4)
Diptera	18.8 (1)	44.6 (1)	69 (2)	39.5 (1)
Trichoptera	11.7 (5)	9.9 (=3)	81 (1)	15.6 (3)
Decapoda	18.5 (2)	19.4 (2)	47 (4)	16.1 (2)
Gastropoda	3.3 (8)	1.2 (8)	22 (8)	0.9 (8)
Miscellaneous	7.1 (7)	9.9 (=3)	42 (5)	6.4 (5)

with ephemeropterans comprising the bulk of food items. Immature fish contained a higher proportion of hemipterans, while mature fish contained larger prey items such as shrimps, *Paratya australiensis*, and odonata nymphs (Figure 7). In contrast, there were marked dietary differences between age classes in the 1997 sample (Figure 7), with the juvenile and immature diets dominated by chironomids (Diptera) and trichopterans, and mature fish consuming large quantities of shrimps (Decapoda).

3.5. Diet of rainbow trout and brown trout

The stomach contents of a total of 26 rainbow trout and 31 brown trout were examined over the two years of the study. The length-frequency distributions of the trout examined are shown in Figure 8.

Neither trout species was subdivided into age classes because almost all the fish caught would be considered mature. There were too few small fish to allow analysis of potential dietary shifts with size.

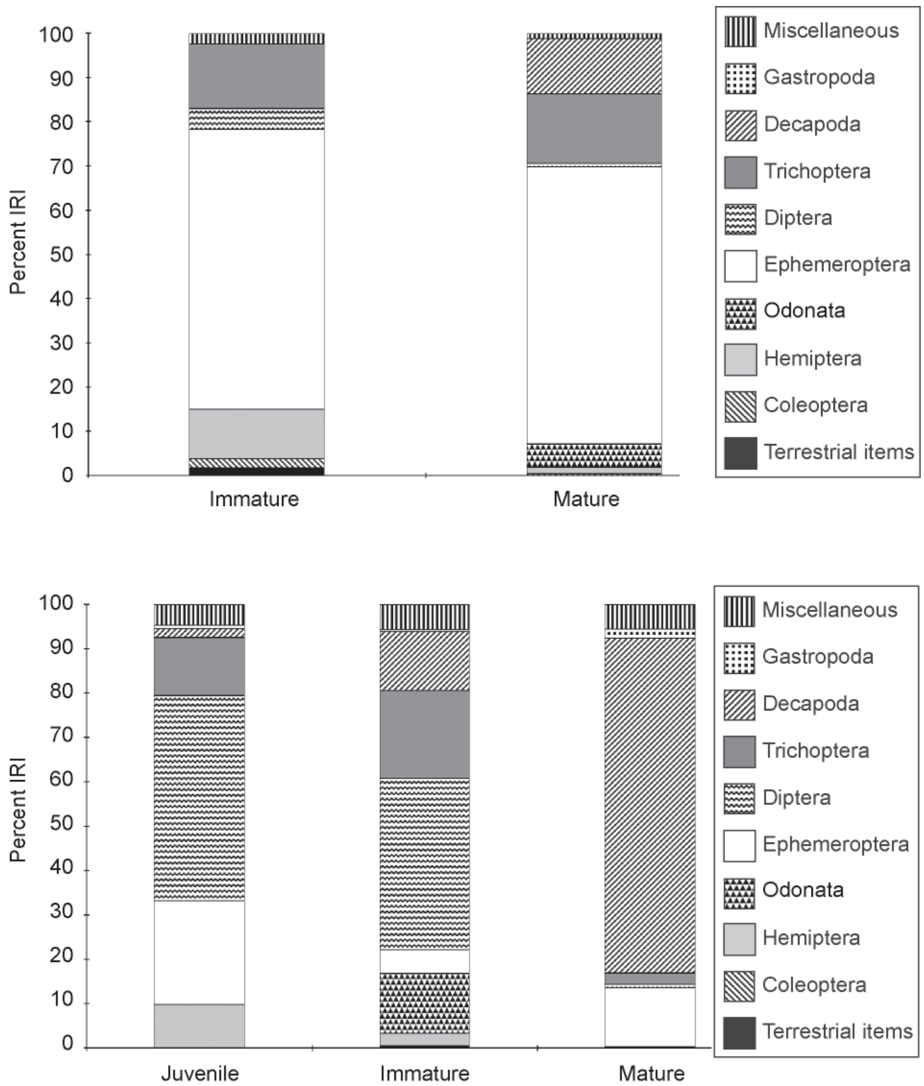


Figure 7. Comparison of the diets of Macquarie perch grouped by age class from the Queanbeyan River in 1996 (top) and in 1997 (bottom)

A total of 423 items in 15 food categories were recorded for rainbow trout over the two years of the study (Table 7). Only one empty fish was recorded. The most numerous dietary items over the whole sample were members of the ephemeropteran family Leptophlebiidae, followed by Corixidae, snails, and terrestrial arthropods, respectively.

A total of 197 items in 21 food categories were recorded for brown trout over the two years of the study (Table 8). Eight empty fish were recorded. The most numerous dietary items over the whole sample were terrestrial arthropods, followed by Gerridae, snails and gomphid dragonfly larvae, respectively.

The food categories for trout were amalgamated into ten broader categories to allow comparison with the diet of Macquarie perch and other published

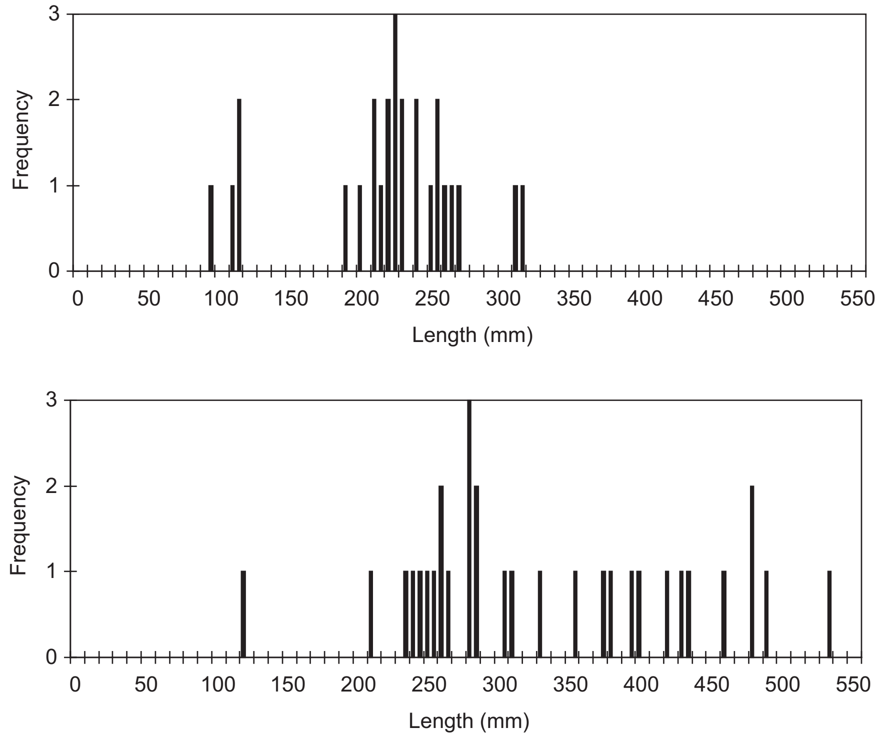


Figure 8. Length frequencies of rainbow trout (top) and brown trout (bottom) from the Queanbeyan River in 1996 and 1997 whose diet was examined

Table 7. Number of items recorded in each dietary category for all rainbow trout captured during the study

Dietary category	No.	Dietary category	No.	Dietary category	No.
Ephemeroptera		**Trichoptera**		**Megaloptera**	
Baetidae	1	Leptoceridae	34	Corydalidae	2
Leptophlebiidae	104	Ecnomidae	7	**Gastropoda**	66
Hemiptera		**Odonata**		**Decapoda**	
Corixidae	69	Corduliidae	49	Atyidae	1
Gerridae	8	Gomphidae	6	Palaemonidae	1
Notonectidae	6	Aeschnidae	3	**Terrestrial arthropods**	54

Table 8. Number of items recorded in each dietary category for all brown trout captured during the study

Dietary category	No.	Dietary category	No.	Dietary category	No.
Ephemeroptera		**Diptera**		**Decapoda**	
Baetidae	2	Diptera unknown	3	Parastacidae	7
Leptophlebiidae	15	**Coleoptera**		Atyidae	5
Ephemeroptera unknown	12	Coleoptera unknown	1	Palaemonidae	2
Trichoptera		**Megaloptera**		**Gastropoda**	
Leptoceridae	2	Corydalidae	1	Gastropoda unknown	31
Philorheithridae	7	**Odonata**		**Terrestrial arthropods**	35
Trichoptera unknown	2	Corduliidae	3	**Fish**	
Hemiptera		Gomphidae	21	Fish unknown	2
Corixidae	9	Aeschnidae	2		
Gerridae	32				

research on trout. The results for the two years of the study were pooled for each trout species (Figure 9).

3.6. Dietary overlap between Macquarie perch and trout

The values of Schoener's index of niche overlap for the IRI method of dietary analysis are presented in Table 9. Values can vary from 0 (no overlap) to 1 (total overlap) with values at or above 0.60 considered by some authors to indicate biologically significant niche overlap (Zaret & Rand 1971; Mathur 1977), although Mittelbach & Chesson (1987) considered overlap values of approximately 0.50 to be potentially significant.

Table 9 shows that dietary overlap varies between 0.23 and 0.56, with only four values reaching the range of 0.50–0.60 accepted by this study as indicating biologically significant overlap.

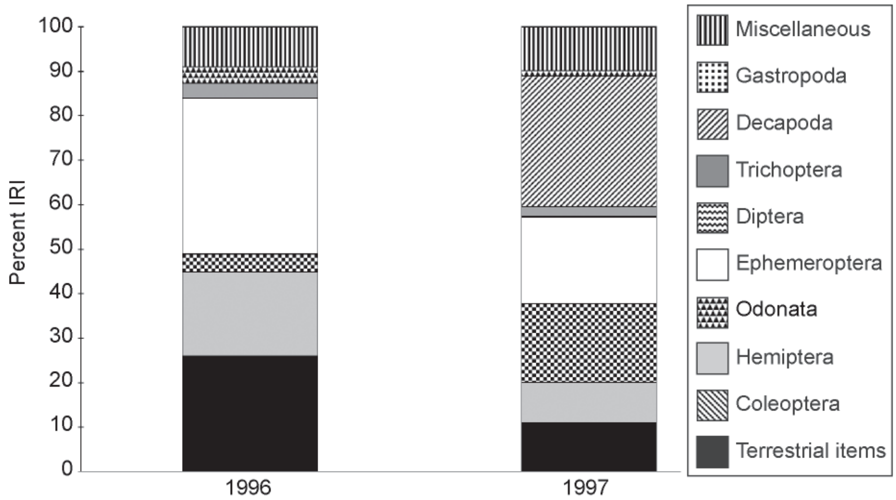


Figure 9. Comparison of the diets of rainbow trout and brown trout from the Queanbeyan River in 1996 and 1997; results of both years are pooled by species; diet was assessed using the Index of Relative Importance (IRI)

Table 9. Values of Schoener's index of niche overlap between two trout species and Macquarie perch; values are calculated for overlap between separate age classes within a year, combined age classes within a year, and all age classes combined over two years; values are based on the IRI method of dietary analysis. Bolded figures indicate potentially significant dietary overlap.

		Rainbow trout	Brown trout
Macquarie perch 1996:	immature	**0.54**	0.44
	mature	0.46	**0.56**
	combined	0.44	0.30
Macquarie perch 1997:	juvenile	0.42	0.39
	immature	0.23	0.44
	mature	0.24	**0.52**
	combined	0.32	0.48
Macquarie perch 1996 and 1997		**0.50**	0.42

4. Discussion

4.1. Success of the relocation attempt

The relocation in 1980 of Macquarie perch from Googong Reservoir to the Queanbeyan River upstream has been successful, with an actively recruiting population present above Curleys Falls in 1996 and 1997. Macquarie perch are still occasionally caught in the reservoir by anglers, but none have been caught since 1990 in the regular gill net surveys of the reservoir conducted by Environment ACT (Table 10). It is thought that the anglers may be capturing fish displaced downstream from the Queanbeyan River population.

The geographical extent of the Queanbeyan River population is unknown because the current sampling program was confined to the approximately 5 km of river managed by Environment ACT. A survey of fish in the upper Queanbeyan River, approximately 17 km upstream from the Hayshed site, did not locate any Macquarie perch in four sampling trips spanning two years (Schiller *et al*. 1997). Similarly, recent fish surveys of the Queanbeyan River downstream of Googong failed to locate any Macquarie perch (Lintermans 1998b, Lintermans *et al*. 2001; Jekabsons & Lintermans 2005). There is a second waterfall approximately 12 km upstream of the current

Table 10. Number of Macquarie perch captured in the regular sampling of Googong Reservoir since its construction; net-nights is the number of gill nets set overnight in each year (Environment ACT unpubl. Data)

Year	No. of Macquarie perch caught	No. of net-nights
1978	12[A]	15
1979	71[A]	7
1980[B]	97[A]	~25
1981	19[A]	~60
1982	0	61
1983	0	32
1984	0	22
1985	6	40
1986	3	40
1987	1	80
1988	6	80
1989	1	40
1990	1	40
1991	0	40
1992	0	40
1993	0	40
1994	0	40
1995	0	40
1997	0	40
1999	0	40
2001	0	40

[A] Numbers caught in 1978–1981 probably include multiple captures of some individuals
[B] 57 adult fish removed from reservoir and relocated upstream to Queanbeyan River

sampling limit that probably forms a natural barrier to Macquarie perch, as was the case with Curleys Falls. If this is correct, the Queanbeyan River population of Macquarie perch is likely to be confined to only 17 km of river. Consideration should be given to translocating Macquarie perch past this second waterfall to extend the habitat available to this population and to assist in increasing overall population size.

4.2. Diet of Macquarie perch

The diet of Macquarie perch in both lacustrine and riverine environments has been previously investigated by a number of authors. Butcher (1945, 1947) noted the predominance of Diptera in the diet of Macquarie perch in Victoria; they comprised 54% of food items in the fish stomachs examined. Trichoptera were another major food item, comprising 24% of the diet (Butcher 1945). Cadwallader & Rogan (1977) also concluded that dipterans and trichopterans were the most important food items in the diets of 14 Macquarie perch from Lake Eildon. Cadwallader & Douglas (1986) examined 492 Macquarie perch stomachs from Lake Dartmouth and concluded that dietary composition varied markedly in response to rising and falling water levels during the initial filling phase of the lake. Odonata larvae, dipterans, shrimp and coleopterans were the dominant food items in the Dart arm of the lake while dipterans, shrimp, cladocerans, and trichopterans dominated the diet in the Mitta Mitta arm. McKeown (1934) presented information on the diet of six Macquarie perch from the Goodradigbee River; and although the sample size is too small for interpretation, trichopterans, hemipterans and terrestrial items were present. Bishop & Tilzey (1978) described the diet of 32 Macquarie perch from the Mongarlowe River in the coastal Shoalhaven catchment and found that the majority of fish contained ephemeropterans, coleopterans and trichopterans, with ephemeropterans dominating the diet. However, it is thought that the coastal stocks of Macquarie perch are a form separate from the inland stocks although the Mongarlowe River is thought to contain fish translocated from the Murray-Darling Basin (Dufty 1986; Harris & Rowland 1996). Cadwallader & Eden (1979) examined the stomach contents of 204 Macquarie perch from three streams in Victoria and found that the major food items were coleopterans, dipterans (particularly chironomids), ephemeropterans and trichopterans.

The ontogenetic changes noted in the diet of Macquarie perch in the current study have not been previously documented. They are particularly striking in the 1997 sample, with a gradual decline in the importance of dipterans and an increase in the importance of decapods (shrimps) as fish size increases. Cadwallader & Eden (1979) analysed a substantial number of juvenile fish (standard length range 46–64 mm) from the Mitta Mitta River. They found that 50.7% of dietary items of juvenile fish were chironomids, and a further 5.8% was composed of other Diptera larvae. This result is very similar to that of the current study in which 51.7% of dietary items (by number) of juvenile Macquarie perch in 1997 were chironomids. The proportion of chironomids in the diet drops to 41.7% in the immature age class and is only 10.1% in the mature age class of the current study. Cadwallader & Douglas (1986) reported that in Lake Dartmouth there were few marked changes in diet as Macquarie perch increased in length. However, they noted that ephemeroptera were more common in the 0–50 mm size class than in any other size class, and suggested that this increased ephemeropteran abundance reflected the riverine habitats of this size class of fish prior to moving downstream into the body of the lake.

Ontogenetic differences in diet may be attributable to a variety of factors including gape limitations, habitat usage by fish of different age classes, and differential susceptibility to predation between fish age classes. The smaller mouth size and gape of juvenile Macquarie perch will limit the width of prey items they can eat. In coho salmon fry of 40–80 mm length, the proportion of prey ingested decreased as prey width increased beyond a critical width of approximately 2 mm (Dunbrack & Dill 1983). As fry length (and gape) increased, so did the critical width of prey. A similar response has been shown in Atlantic salmon (Wankowski 1979). Also, as prey size increases relative to mouth size of the fish, the predator must pay an increasing cost in the handling time of prey (Wootton 1990), thus decreasing the profitability of the prey to the predator. However, Cadwallader & Douglas (1986) found no relationship between the carapace length of ingested shrimps and the length of Macquarie perch, indicating that larger fish did not necessarily take larger prey items.

In this study, in both 1996 and 1997, there is little evidence of feeding on terrestrial items, which is in agreement with the results of previous riverine dietary studies on Macquarie perch (Cadwallader & Rogan 1977; Cadwallader & Eden 1979). However, Cadwallader & Douglas (1986) in a study of a lacustrine population of Macquarie perch noted that the species took advantage of terrestrial dietary items (particularly annelids) displaced by rising water levels over previously unflooded ground.

4.3. Dietary overlap between Macquarie perch and trout

Previous authors have noted that the diets of Macquarie perch and the alien trout species are very similar, and competition is thought to occur (Butcher 1945; Cadwallader 1978; Cadwallader & Eden 1979; Jackson 1981). Douglas *et al*. (2002) reported from Lake Dartmouth that brown trout had a 54% dietary overlap and rainbow trout a 40% dietary overlap with Macquarie perch, but did not subdivide species into size-classes for this comparison. In this study, the levels of dietary overlap recorded between Macquarie perch, rainbow trout and brown trout approximate the level considered biologically significant. However, the collection of fish from a single season and the low numbers of smaller trout examined limits the conclusions that can be drawn. The borderline dietary overlap between adult trout and Macquarie perch in summer may not reflect the overlap of smaller individuals or other seasons. Seasonal variation in fish diets can be due to a number of factors including changes in the habitat available for foraging, changes in the behaviour or abundance of the food items available, or changes in the feeding behaviour of the fish. Lintermans (1998a) found that there were seasonal differences in the diet of two-spined blackfish *Gadopsis bispinosus* and dietary overlap between two-spined blackfish and rainbow trout, and that levels of dietary overlap varied with fish size.

Further investigation is required to clarify whether or not there is significant dietary overlap between trout and Macquarie perch. However, these data suggest that interactions between Macquarie perch and trout need to be managed carefully to conserve this endangered species according to the precautionary principle.

The role of trout as significant predators of Macquarie perch is also unresolved. Unidentified fish remains were found in a small proportion of trout stomachs, but they did not form a significant part of the trout diet. There is little chance of detecting egg or larval predation because fish eggs and larvae are highly digestible and would not be expected to remain identifiable in the stomach for long (Meffe 1985). Ivantsoff & Aarn (1999) reported that fish prey were recognisable in the gut contents of *Gambusia holbrooki* for less than 12 hours after ingestion. Meffe (1985) concluded that even a low predation rate on fish fry (or, presumably, eggs) could have a significant impact if the target species has low fecundity or if the predator is abundant.

4.4. Other impacts

Trout are certainly abundant in most habitats containing Macquarie perch in eastern Australia and are well documented as predators of fish (NSW Fisheries 2003). Predation is considered to be the major detrimental effect of salmonids in Australia, particularly on galaxiid species (Cadwallader 1996). There is a perception amongst Australian fisheries managers that rainbow trout are less of a threat than brown trout to native species (Clunie *et al*. 2002), but the evidence for a reduced impact is not readily apparent. Rainbow trout are reported to be more easily caught, and so form less of a predation threat because they get fished out before reaching a size that poses a risk (NSW Fisheries 2003). In contrast, brown trout are reported to be harder to catch (Tilzey 1972; Faragher & Gordon 1992), live to a greater age and so persist for longer and grow to a larger size (Butcher 1967). However, this perception of a reduced impact from rainbow trout relies upon the assumption that it is mainly the large trout individuals that pose the predation threat, or that trout pose little threat to smaller individuals such as larvae, small juveniles, or small species. This assumption is clearly invalid for galaxiid species, where small trout in small streams have eliminated or severely reduced native fish populations (Fletcher 1979; Lintermans 2000b; Raadik 1995), and where rainbow trout has been the only species present (Lintermans and Rutzou 1990; Raadik 1995; Lintermans 2000b). Fletcher (1979) reported that brown trout fed selectively on the smallest individuals in a population of mountain galaxias and laboratory studies have showed juvenile galaxiids to be vulnerable to trout predation (Crowl *et al*. 1992). The basis for the distinction in the perceived threat level between the two trout species needs to be rigorously examined.

Predation by brown trout has been listed as a threat to nine Australian threatened freshwater fish species including Macquarie perch (Wager & Jackson 1993). NSW Fisheries (2003) considers that Macquarie perch are at medium risk from the stocking of salmonids, with medium risk species considered 'likely to suffer further population declines and possible local extinction due to fish stocking as carried out under the current management arrangements'. Although the evidence of the impact of predation by brown trout on Macquarie perch is mostly anecdotal and speculative, the application of the precautionary principle precludes inaction based on lack of information. Consequently, brown trout are no longer stocked for recreational purposes in Googong Reservoir (ACT Government 2000), nor are they permitted to be stocked in the Queanbeyan River upstream of the reservoir (NSW Fisheries 2003). However, rainbow trout are still stocked in the upper Queanbeyan River and this practice should be re-examined following any review of potential risk to native fishes from this species.

Whilst Curleys Falls currently provides an effective barrier to the upstream spread of redfin perch, the potential for illegal releases or translocations of this species into the Queanbeyan River upstream of Curleys Falls is of concern. The potential effect of EHN virus on wild populations of Macquarie perch is cause for concern because of the aquarium studies by Langdon (1989a,b) that demonstrated 100% mortality of Macquarie perch exposed to low concentrations of EHN virus in water. Redfin invasion is also threatening other Macquarie perch populations in the Canberra region (e.g. the Cotter River, and the upper Murrumbidgee River) (Lintermans 2004a), and the threat to wild populations from EHN virus needs to be clarified.

5. Conclusions and future management directions

The success of the translocation of Macquarie perch from Googong Reservoir shows that translocation can be a viable management option for conserving threatened fish species (Lintermans 2003; Maitland 1995; Minckley 1995). The Googong translocation moved adult fish because the impact on the donor population was not an issue (because the population was doomed due to lack of spawning sites). Where a translocation is made for the purpose of extending the range of a population or of establishing a new population without compromising the donor population, consideration should be given to translocating juvenile or immature fish (Maitland 1995). The advantages of using smaller individuals are:

- there is minimal effect on the donor population;
- there is usually a large number of smaller individuals available;
- most juvenile fish would be expected to be lost to the donor population through natural mortality factors, so it is a low risk strategy;
- smaller individuals (of Macquarie perch) are easily caught using fyke nets (which cause minimal damage or stress to captured fish).

The disadvantages of using smaller individuals are that they are potentially more susceptible to predation from other fish species, and there will be a greater time lag before the fish reach reproductive maturity and breed. Consequently it will be longer before the success of the translocation attempt is known.

The effect of fish size on translocation can be studied with Macquarie perch in the Canberra region. The waterfall on the Queanbeyan River approximately 15 km upstream of Curleys Falls limits the distribution of Macquarie perch in this river. Similarly on the Cotter River in the ACT, several road-crossings limit or potentially limit the upstream distribution of Macquarie perch (ACT Government 1999). Translocation using different size fish could be attempted across several of these barriers.

The data on dietary overlap between Macquarie perch and trout suggest that interactions between trout and Macquarie perch need to be managed carefully to conserve this endangered species. Similarly, the potential impacts of trout predation on Macquarie perch warrant the adoption of a precautionary approach to salmonid management where the two groups co-occur. The basis for the perceived difference in threat levels between rainbow and brown trout needs to be reviewed and the justification for trout stocking needs to be carefully examined where there is potential for the trout to affect threatened species (Jackson *et al.* 2004). It is difficult to envisage a situation where the benefits of trout stocking outweigh the risk to Macquarie perch.

The potential impacts of trout predation on larval or early juvenile life stages of Macquarie perch needs to be investigated, and appropriate management actions implemented for wild trout populations. There is also a pressing need for fisheries agencies to promote and support further investigations into the potential effects of EHN virus on native fish species in the field.

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