Fish communities of the Murrumbidgee catchment: Status and trends

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Abbreviations

ACT	Australian Capital Territory
CMA	Catchment Management Authority
ECA	Environmental Contingency Allowance
EPBCA	Environment Protection and Biodiversity Conservation Act 1999
FM Act 1994	Fisheries Management Act 1994
IMEF	Integrated Monitoring of Environmental Flows
MDBC	Murray-Darling Basin Commission
MRMC	Murrumbidgee River Management Committee
NLWRA	National Land & Water Resources Audit
NSW	New South Wales
NSW WRC	New South Wales Water Resources Council
SRA	Sustainable Rivers Audit

NON-TECHNICAL SUMMARY

Fish communities of the Murrumbidgee catchment: Status and trends

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OBJECTIVES:

(1) To benchmark the current status of fish species and fish communities.
(2) To determine trends in fish species and communities up until 2004 based on pre-existing data.
(3) To compile data-sets suitable for undertaking analysis of the relative impacts of a broad range of processes.

NON TECHNICAL SUMMARY:

Fish are an integral component of aquatic ecosystems with the structure of fish assemblages providing an indication of the overall health of river systems. Further, as fish have a high public profile, they foster substantial public interest. A broad-scale fish monitoring program offers a valuable tool for catchment management, assisting in prioritisation of management options, enabling assessment of the effectiveness on-ground (or in-water) remediation and demonstration of these outcomes to the community.

Fish communities were sampled using a standardised electro-fishing protocol augmented with sampling with shrimp traps. Twenty-eight monitoring sites were randomly selected to benchmark the current (2004) fish community. An additional 22 targeted sites were selected to monitor all threatened species populations in the catchment. Floodplain wetlands within 2.5 km of riverine sampling sites were also sampled. The status of fish communities at sites and within zones was benchmarked using basic ecological parameters: species richness, total abundance, biomass, species diversity and evenness, the proportion of alien taxa and estimates of recruitment and distribution.

This report presents the results of the most comprehensive assessment of fish species and communities ever undertaken across the entire Murrumbidgee catchment. The randomised sampling design ensures that the results obtained can be inferred across all reaches of the catchment.

Current status of fish communities

Twenty fish taxa (19 species and 1 species complex) were sampled from the 28 riverine monitoring sites. Despite substantial sampling effort, only 62% of native species and 64% of alien species known to have existed in the Murrumbidgee catchment were sampled in 2004. Although a substantial number of species were not detected, this program adequately sampled the fish community present, as 20 of the 21 species had been collected from the initial 28 randomly

selected monitoring sites. Sampling at an additional 22 targeted sites only collected a single additional species, Macquarie perch.

The fish community of the Murrumbidgee catchment (as it existed in 2004) is severely degraded. Eight of the 21 native species which previously existed in the catchment are either locally extinct or survive at very low abundances. In addition to the loss of native species, there is a proportionally high number of alien fish species present (33% of the species richness) that dominate the catchment in terms of the number of individuals (70.77% of the total number of individuals) and even more-so the proportion of total biomass (89.84% of the total biomass). Further, no native species at all were sampled from 7 of the 28 (25%) sites, whereas alien fishes were only absent from 2 (7%).

Assessment of fish communities identified some significant differences between lowland areas (< 200 m altitude), slopes areas (201-400m altitude), upland areas (401m – 700 m altitude) and highland areas (>700m altitude). Lowland reaches were the least degraded, with the fish community having a higher proportion of native species and native individuals than the other three zones. However, biomass was still heavily dominated by alien species, principally carp. The remaining three zones were largely similar, with more alien species, individuals and biomass at most sites. Few wetlands were sampled, yet these were also dominated by alien fish. Fish communities in the slopes and upland zones were identified as those that would benefit most from rehabilitation activities (although the lowland zone also requires restoration – particularly lowland wetlands).

Current status of individual species

Species can be considered secure only if their abundance, their distribution and their level of recruitment remain stable or increase through time. However if any one of these factors declined significantly, that species could be considered at risk. These parameters were benchmarked for each species.

Carp, eastern gambusia and redfin perch were three of the most widespread and abundant species in the catchment. Carp made up 87% of the total biomass of all fish sampled, with redfin contributing 1.5% and gambusia 0.1%. The fact that they utilise 87% of the available fish resources within the catchment's rivers identifies carp as the single largest feature of the current poor state of the catchment's fish community and also the single largest factor preventing recovery to a more natural state. Although they do not have as high a biomass as carp, the abundance and widespread distribution of redfin perch and eastern gambusia is also likely to have significant impacts on native fish communities. Together these species made up 66% of individuals in the catchment. Any reduction in numbers of these three species is likely to result in a substantial recovery of extant populations of native fish.

Of the native species, only Australian smelt and carp-gudgeons made up more than 5% of the catch with 13% and 8% respectively. Australian smelt along with carp-gudgeons, Murray cod and golden perch were the most widespread native species, being sampled at 36%, 25%, 25% and 25% of sites across the catchment respectively. Golden perch and Murray cod made up 6% and 3% of the biomass respectively, making them the 2nd and 3rd most important species in terms of ecosystem resources. However, compared to the data for carp, redfin perch and gambusia, the values for these most secure of native species are all very low.

Recruits made up 15% or more of the sampled populations of five fish species: carp (39%), two-spinned blackfish (35%), bony herring (30%), Murray cod (21%) and goldfish (15%). No recruits were detected for several species: silver perch, river blackfish, mountain galaxias, trout cod, Murray-Darling rainbowfish, flat-headed gudgeons, dwarf flat-headed gudgeons or brown trout.

Current status of threatened species

As threatened species are by definition rare, and usually only occur as discrete isolated populations, the randomised site selection process used to benchmark fish communities and species had a high probability of missing populations of threatened species. In order to assess and monitor their status, additional samples were collected from targeted sites where threatened species are known to have existed in the past.

Seven threatened species are found, or were historically found, in the Murrumbidgee catchment. These are the trout cod and Murray hardyhead which are listed as endangered species, the western populations of olive perchlet and southern purple-spotted gudgeon which are listed as endangered populations and silver perch, Macquarie perch and Southern pygmy perch which are listed as vulnerable.

Only three of the seven listed threatened species were detected. Populations of the endangered Murray hardyhead, olive perchlet, southern purple-spotted gudgeon and vulnerable southern pygmy perch were not detected at locations where they had previously occurred in the Murrumbidgee catchment. It is highly likely that these four species are locally extinct. Two of the remaining three threatened species which were sampled, Macquarie perch and silver perch were found at only one site each, with only single individuals of each species collected. Both species are listed as vulnerable taxa. These results suggest that the status of both may require reconsideration and endangered status may be warranted. This also applies to southern pygmy perch which are currently listed as vulnerable, yet are probably extinct in the Murrumbidgee catchment. In contrast, trout cod were sampled at seven of the 14 sites targeted, representing 50% of the sample of sites where it had previously existed. The existence of this species anywhere in the catchment is a direct result of the stocking program initiated in the Murrumbidgee in 1988, the last wild bred individual having been recorded in 1976. One year old trout cod were only collected at one of the seven sites. This suggests that recruitment was limited in the 2003 breeding season. Further, there is a high probability that all five fish collected at Angle Crossing were stocked fish. This is of substantial concern given that the recovery of this endangered species is dependant on the natural recruitment and self-sustainability of the reintroduced populations. However, although no recruitment from the 2003 season was detected, natural recruitment over the previous two to three years appears to have occurred at a number of sites. Pending confirmation, the stocking program appears to have been successful at establishing a recruiting population of trout cod in the lower Murrumbidgee.

Given the apparent success of the reintroduction program for trout cod, similar programs may be considered for the four other threatened taxa which are likely to be locally extinct. However in order to be effective, it is necessary to ensure that the threatening processes that led to the extinction of the species in the first place are eliminated or controlled. Murray hardyhead, olive perchlet, southern purple-spotted gudgeon and southern pygmy perch would benefit from localised carp control, in addition to rehabilitation and adequate management in suitable wetland systems. A captive breeding and reintroduction program is required to support habitat rehabilitation activities as no adjacent source populations exist to colonise rehabilitated habitat.

A reintroduction program was initiated in 2004 for the southern purple spotted gudgeon in Adjungbilly Creek. Reintroduction into an upland stream was preferred over reintroduction into lowland wetlands as the upland habitats in the Murrumbidgee most closely resembled the habitats of the remnant source populations in the north of the state, and there are fewer threatening processes affecting unregulated upland streams than impact upon lowland wetlands. Despite the suitable habitat conditions in Adjungbilly Creek, the existence of both trout and carp in the system may prevent establishment of the reintroduced population. The same problems may be encountered during potential reintroductions of southern pygmy perch in upland streams, as predation by trout on pygmy perch species is known to be substantial. Therefore, establishment of trout free waters in upland areas may be a necessity for recovery of these two species in the Murrumbidgee.

Although Macquarie perch are still present in the catchment, their distribution is significantly reduced with populations having disappeared from many parts of the catchment. In order to prevent further decline, the control of erosion in upland catchments, the recovery of deep pools through dredging silt burdens in streams, the limitation or exclusion of trout stocking within streams containing Macquarie perch populations, the control of carp and redfin perch, the exclusion of these alien species from habitats they have not yet invaded, and the translocation of disease-free individuals between isolated populations to prevent inbreeding, are likely to aid in recovery of Macquarie perch.

The decline of silver perch coincided with an increasing number of weirs constructed in the Murrumbidgee. This may have threatened silver perch populations directly through the obstruction of fish passage, or may have resulted from the river regulation practices that were facilitated by weir construction, with a relationship also apparent for the decline of silver perch and the volume of water extracted from the river. These relationships suggest that the construction of fishways on weirs and the implementation of suitable environmental flows may result in the recovery of silver perch in the Murrumbidgee. However the impact of carp, which proliferated in the Murrumbidgee after silver perch populations had already begun to decline, could potentially impact on recovery, even if fish passage and environmental flows are provided.

A further two Murrumbidgee fish species not listed as threatened under any legislation, freshwater catfish and flat-headed galaxias, were not sampled at any of the sites surveyed. Flat-headed galaxias populations require the same recovery management as for Murray hardyhead and olive perchlet, as they are also lowland wetland species. The key threatening processes for catfish are unclear although competition with carp and their disturbance of catfish nests are likely to be a primary factor. Given that carp densities are now likely to be at the lowest levels since invasion of the catchment in 1972, stocking of freshwater catfish in the Murrumbidgee may aid in the recovery of this species.

Trends over the last 10 years

Ongoing sampling using a consistent standardised sampling methodology targeting all members of the fish community, is the most robust means of assessing changes in fish community structure and the status of individual species through time. Standardised electro-fishing data collected within NSW since 1994 provides a means of quantitatively assessing changes in fish populations through time. Analysis of data collected from the Murrumbidgee catchment over the last 10 years indicates several significant changes.

The number of species sampled at sites has increased consistently throughout the catchment. This is counter to the local extinction of several threatened species. The observed relationship could result from either the continued spread of alien species, which is a negative effect, or the recovery and spread of uncommon native species over the last decade, which is a positive change. Total abundance and total biomass have also changed consistently throughout the catchment yet the relationships were not quite statistically significant. The total number of individuals has increased whilst the total biomass has declined. The biomass relationship suggests that the carrying capacity of streams may have declined over the last 10 years.

Although alien fish species dominate much of the catchment in terms of the proportion of species, individuals and biomass at sites, no significant trends were detected in the proportion of alien species richness or proportion of alien biomass. This is indicative of some level of stability in the system and suggesting that alien species may have reached equilibrium within fish communities.

This was not the case for the proportion of individuals at sites that were native species. In this case, there was significant variability across the basin, with some zones experiencing a significant increase and others a significant decline. The highland zone experienced a significant decline in the proportion of native individuals per site. This relationship probably resulted from a non-significant decline in the abundance of native mountain galaxias and counteracting non-significant increases in the abundance of alien goldfish, gambusia and rainbow trout and significant increases in the abundance of alien redfin perch and carp in the highland zone. Sites in the slopes zone exhibited further variability, with two sites experiencing increases in the proportion of native individuals whilst the proportion of native individuals has declined at a third. No significant trends in the proportion of native individuals were observed in the lowland or upland zones.

Only three species showed significant trends in abundance over the last 10 years. Carp-gudgeons were the only native species whose population size has changed with a consistent increase throughout the catchment. Of the remaining 13 native species assessed, eight had increased and five had declined, but the trends were not significant. The declining species were fly-specked hardyhead, mountain galaxias, golden perch, Macquarie perch and bony herring.

The alien species which had exhibited significant trends were redfin perch and carp. Redfin perch have increased in abundance consistently throughout the basin. However the abundance of carp has varied among zones. Carp have declined in the lowland zone however the trend is just non-significant. Similarly, a decline in carp abundance has been observed in the slopes zone, but this trend is statistically significant. In contrast, carp abundance has increased in the upland and highland zones, although the trend is only significant in the highland zone.

The commercial fishery

Data provided by the commercial fishery in the Murrumbidgee provides the most extensive long-term data set available. Further, the very extensive period of data collection corresponds with the appearance of numerous threatening processes and enables a detailed assessment of the response of fish communities to temporal changes in river management and a wide variety of flow events. As a result, this dataset lends itself to assessment of the causes of decline of individual species and the potential responses of various fish species to implementation of environmental flows.

Brown (1992) has previously analysed the commercial catch data from the Murrumbidgee catchment from 1955 to 1978. Subsequently, Reid *et al.* (1997) collated fishery records which exist from 1883 onwards (although coverage and accuracy of the data were poor until compulsory fishers' returns were introduced in 1947) for all of NSW up until the 1994/95 season. This report completes the data-set for the Murrumbidgee catchment up until the closure of the native fishery in 2001.

Fish stocking

Fish stocking includes both the translocation of fish from one area into another as well as the hatchery production and release of captive bred fish. It is typically undertaken with the intent of either improving recreational fishing opportunities or for the conservation of endangered populations (NSWF 2003). A compilation of all stocking records from the NSW portion of the Murrumbidgee catchment since 1968 is presented.

Seven native species and four alien salmonids have been, or continue to be stocked as part of either harvest stocking programs to promote recreational fishing or conservation stocking programs to aid the recovery of threatened species.

Recommendations

Without substantial intervention, the status of fish species and communities in the Murrumbidgee will not improve. Following the recommendations of the Murray-Darling Basin Commissions Native Fish Strategy (NFS) (MDBC 2003), is the most appropriate means of restoring fish populations in the Murrumbidgee. Of the 13 goals of the NFS:

- Rehabilitation of instream and riparian vegetation.
- Rehabilitation of wetlands.
- Eliminating thermal pollution.
- Improving environmental flow management.
- Reinstating fish passage at a number of key barriers.
- Contributing to the control of alien species.
- Ensuring community ownership and support.

can be undertaken by the Murrumbidgee CMA.

An ongoing monitoring program is required to assess the effectiveness of each of these actions. Under the MDBCs SRA program, data from the Murrumbidgee will be collected on a three yearly basis, starting in 2006 and initially continuing for 6 years, and potentially for 50 years (MDBC 2004*a*). As a result, the data-gathering needs for a general fish community survey of the Murrumbidgee will be met by the SRA. However, although the SRA provides an avenue for regular data collection, the results of SRA sampling will require analysis and reporting in a catchment specific context in order to be useful for the Murrumbidgee CMA. Further, the SRA program does not include sampling of wetland habitats or the targeted sampling of threatened species populations. Ideally, the SRA program should be supplemented by regular sampling of targeted sites that will provide much more specific information on the status of fish populations in key parts of the Murrumbidgee catchment. Further, detailed assessment of any on-ground actions such as wetland rehabilitation, habitat restoration, construction of multi-level off-takes or fishways on dams would require specifically designed experiments with tailored sampling programs to assess their effectiveness, and refine their operation.

It is suggested that the Murrumbidgee CMA:

- Supports SRA sampling in the Murrumbidgee catchment on a three yearly basis as a long-term monitoring program.
- Funds additional sampling at wetland and targeted threatened species sites concurrently with SRA sampling ever three years (beginning 2006).
- Facilitates analysis and reporting on the combined SRA and CMA funded data collection.
- Acknowledges the need for fish monitoring activities associated with on-ground riverine and wetland rehabilitation activities.
- Undertakes the compilation of long term data-sets on ecological and physical processes of interest (i.e. water extraction, de-snagging activity, thermal pollution, sedimentation, river regulation, loss of aquatic and riparian vegetation etc) which will enable modelling of ecosystem responses and prioritisation of rehabilitation activities.

KEYWORDS:
Murrumbidgee, freshwater fish, threatened species

1. INTRODUCTION

Fish are an integral component of aquatic ecosystems with the structure of fish assemblages providing an indication of the overall health of river systems. Subsequently, the health of river systems reflects the broad scale cumulative impacts of both land and aquatic management practices (MDBC 2004*a*). There are several advantages to using fish as bio-assessment tools (Harris 1995) including:

- Fish are relatively long lived and mobile, reflecting long-term and broad-scale processes.
- Fish occupy higher trophic levels within stream ecosystems, and in turn, express impacts on lower trophic level organisms.
- Fish are easy to collect and identify as their taxonomy is well documented.
- Fish can be sampled and released alive in the field.
- The ecology and habits of fish are relatively well known.
- Fish are typically present in most waterbodies, including very small streams and polluted waters.
- Biological integrity of fish communities can be assessed easily.

Further, as fish have a very high public profile, with significant recreational, economic and social values, they foster substantial public interest (MDBC 2004*a*). This enables effective demonstration of past degradation of ecosystems, the effects of current management practices and the effectiveness of rehabilitation efforts to the wider community. A broad-scale fish monitoring program offers a valuable tool for catchment management, assisting informed prioritisation of available management options and enabling assessment of the effectiveness of initiatives such as implementation of on-ground (or in-water) remediation.

The Murrumbidgee catchment is the fourth largest in the Murray-Darling Basin, draining an area of 84,020 km^2 (Figure 1.1). The catchment consists of 6,749 km of streams (Norris *et al.* 2001), of which ~1,600 km are the main channel of the Murrumbidgee River. The Murrumbidgee River begins at Long Plain at an altitude of ~ 1,500 m and flows into the Murray River at Boundary Bend at an altitude of 60 m (Figure 1.2). Given the extensive altitudinal and longitudinal gradients of the catchment, streams of the Murrumbidgee catchment are ecologically diverse. The higher rainfall areas in the east of the catchment are characterised by clear, cool, mountain streams which gradually transform into a turbid, slow flowing floodplain river in the semi-arid western parts of the catchment.

Twenty-three taxa (20 species and one species complex of three tentative *Hypseleotris* species) of native fish as well as an additional three native species which are natural vagrants (a recruiting population is not resident in the catchment); spangled perch (*Leiopotherapon unicolour*), short-headed lamprey (*Mordacia mordax*), and freshwater eels (*Anguilla* spp) are known to have existed in the Murrumbidgee catchment (Table 1.1) The spangled perch and lamprey occasionally migrate upstream into the Murrumbidgee from the lower Murray River. In contrast, eels enter the catchment through over-land migration from coastal streams at the head of the Great Dividing Range (or more recently may have been artificially translocated by inter-basin water transfer from the Snowy catchment through the Snowy Hydroelectric Scheme, or deliberately introduced).

Since European settlement, an additional 11 species of alien fish have been introduced (Table 1.2). Ten of these are not endemic to Australia. The eleventh, climbing galaxias (*Galaxias brevipinnis*), is believed to have been translocated from the Snowy River catchment into the upper Tumut River via the Snowy Mountain Hydro Scheme, as is known to have occurred in the Murray catchment (Waters *et al.* 2002).

Of the 21 endemic taxa, a number have not been recorded in the Murrumbidgee catchment for several decades (Table 1.1). The southern purple-spotted gudgeon (*Mogurnda adspersa*)[1] has not been recorded for 36 years, the olive perchlet (*Ambassis agassizii*) has not been recorded for 34 years, the flat-headed galaxias (*Galaxias rostratus*) has not been recorded for 33 years and the southern pygmy perch (*Nannoperca australis*) has not been recorded for 28 years (Table 1.1). In addition to these native species, tench (*Tinca tinca*) (an alien species) has not been recorded for 24 years (Table 1.2). All are likely to be extinct in the Murrumbidgee catchment. Lamprey were last officially documented in the Murrumbigee in 1974 (30 years ago)(Reid *et al.* 1997), however occasional angler reports of single individuals suggest that it still occurs in the Murrumbidgee.

Omitting the vagrant and potentially extinct populations, the current fish fauna of the Murrumbidgee catchment probably consists of 19 native fish species and 10 alien fish species[1].

Freshwater ecosystems are among the most threatened ecological communities on earth (Duncan and Lockwood 2001; Gleick *et al.*, 2001). Freshwater fishes are the most threatened group of vertebrate taxa with 4.4% of species threatened with extinction across the world (Groombridge and Baillie 1997). Leidy and Moyle (1998) suggest that 20% may be a more realistic figure given the scarcity of information on lesser-known taxa. The fish community of the Murrumbidgee catchment is no exception. Within the Murrumbidgee, nine fish species are listed as threatened under state, territory or federal legislation (Table 1.1). Further, flat-headed galaxias are not yet listed as threatened under any jurisdiction, but are already likely to be extinct in the Murrumbidgee catchment. Therefore, 10 of the 23 (43%) native freshwater fish species occurring within the Murrumbidgee are threatened species. In recognition of this, the entire ecological community downstream of Burrinjuck and Blowering Dams has been declared endangered as part of the Lower Murray Endangered Ecological Community under the *Fisheries Management Act 1994*.

A number of authors have reviewed the threats posed to freshwater fish and aquatic ecosystems, particularly those within the Murray-Darling Basin (Pollard and Scott 1966; Butcher 1967; Lake 1967; Frith 1973; Cadwallader 1978; Faragher and Harris 1994; Kearney *et al.* 1999; Lintermans 2000*a*; Lugg 2000). Most of the threats identified are relevant to fish communities in the Murrumbidgee catchment. Recently, Kearney *et al.* (1999) identified six 'major' threats, which were (in decreasing order of priority); habitat degradation, pollution, reduced environmental flows, barriers to migration, introduced species and over-fishing. In addition, inter-basin water transfers and bushfires also pose a threat to fish communities in the Murrumbidgee. Four specific threatening processes; removal of snags from streams, the introduction of fish outside their natural range, clearing of riparian vegetation, and the installation and operation of structures which alter natural flow regimes, have been listed as key threatening processes under the *NSW Fisheries Management Act 1994*.

In order to ameliorate these threatening processes, and effectively rehabilitate the freshwater aquatic community of the Murrumbidgee catchment, the Murrumbidgee CMA requires detailed information on the current fish community within the catchment and the relative impact of each threatening process on existing fish populations. Further, data collected in the past can be used to infer the original fish community structure, and therefore provide a goal for rehabilitation activities. Lastly, data on current fish communities will enable the CMA to gauge the success or inadequacy of rehabilitation efforts through subsequent fish monitoring.

[1] However, in 2004, NSW Fisheries re-introduced 400 captive-bred juvenile southern purple-spotted gudgeons into Adjungbilly Creek in the Murrumbidgee catchment. Broodstock included a number of individuals from remnant populations in other parts of the Murray-Darling Basin. These reintroduced populations are not yet considered established and therefore, are not yet considered part of the Murrumbidgee fish community.

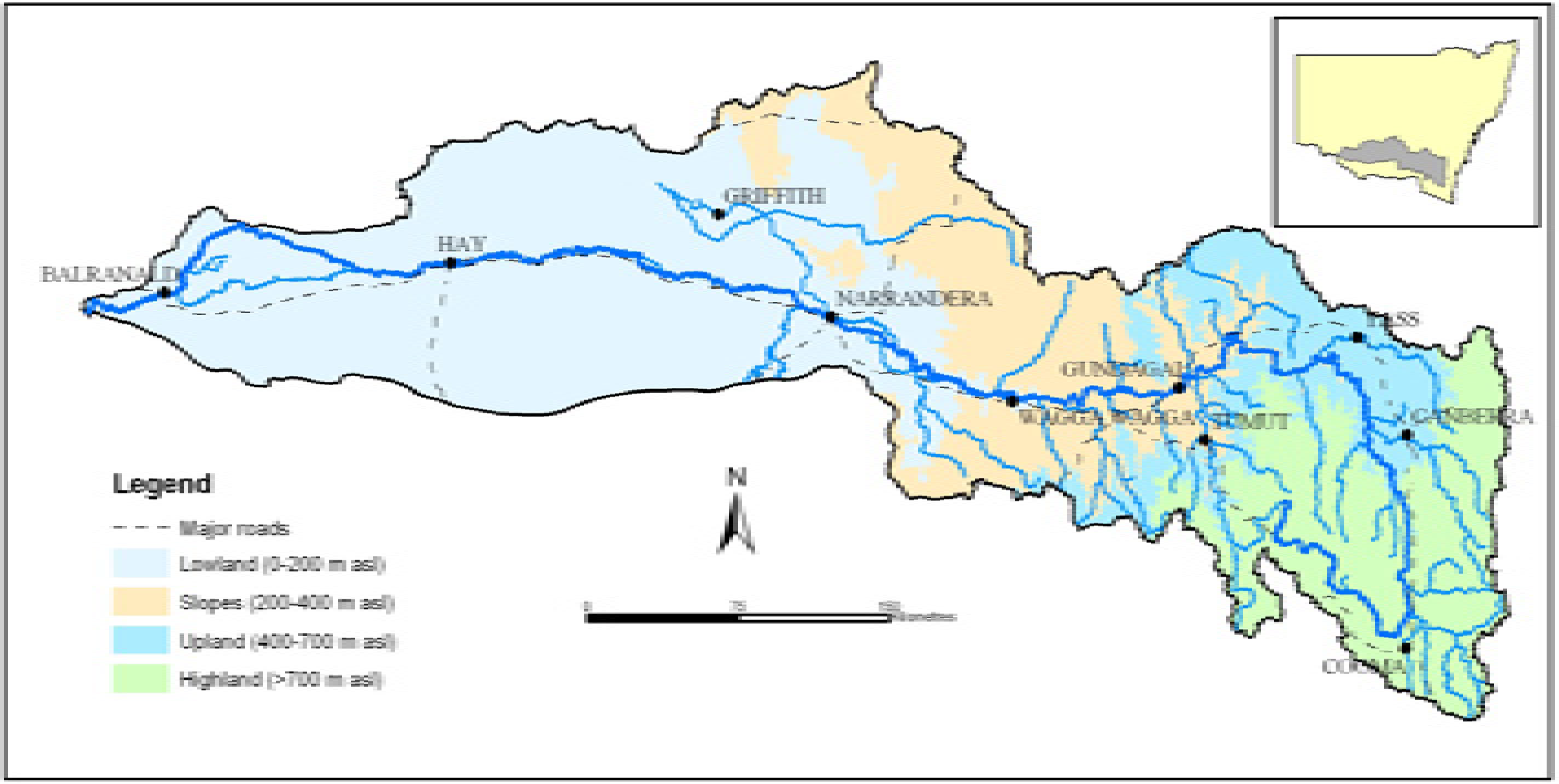


Figure 1.1. Map of the Murrumbidgee catchment. The stream network is derived from the AUSLIG 1: 250,000 and NLWRA stream networks, but reaches not providing fish habitat (ephemeral streams and drainage lines) are omitted. The catchment was divided into four zones based on altitude (as undertaken for the MDBCs SRA program) for the purposes of analysing spatial structure in fish community variables.

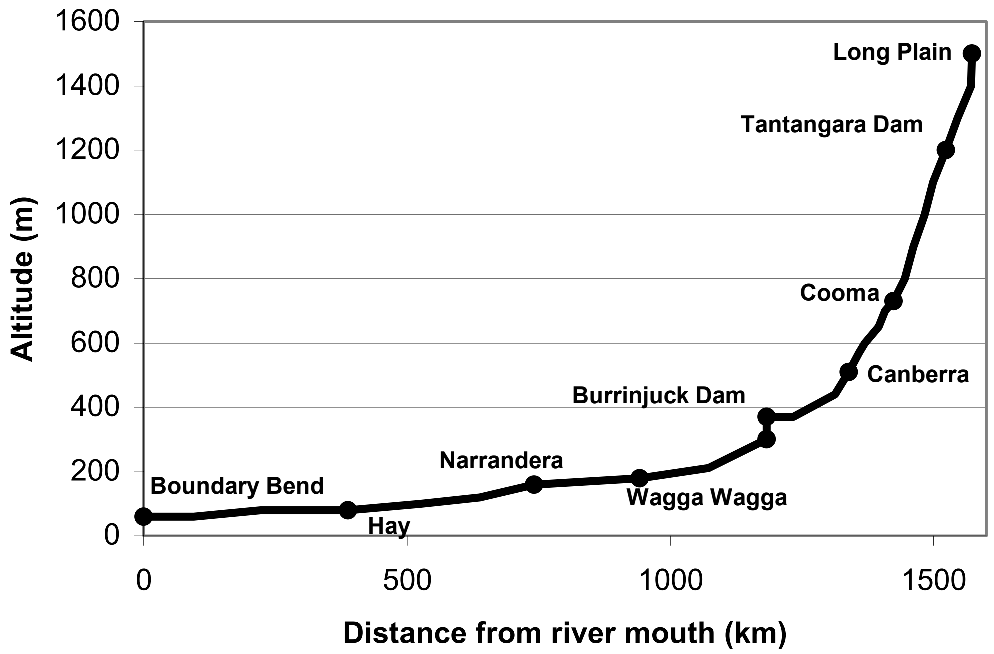


Figure 1.2. Altitude map of the Murrumbidgee River.

Table 1.1. Native fish species of the Murrumbidgee catchment, their conservation status and details of most recent records within the catchment.

Species	**Common name**	**Conservation status**	**Most recent record**
Ambassis agassizii	Olive perchlet	Endangered population [NSW]	1970 [Llewellyn]
Anguilla spp.	Freshwater eels	Natural vagrant and/or translocated	1968 [Llewellyn] + Undated [Lintermans]
Bidyanus bidyanus	Silver perch	Vulnerable [NSW] Endangered [ACT]	
Craterocephalus fluviatilis	Murray hardyhead	Endangered [NSW] Vulnerable [EPBCA]	1995 [FFD]
Craterocephalus stercusmuscarum	Fly specked hardyhead		2003 [Baum 1]
Gadopsis bispinosus	Two-spinned blackfish	Vulnerable [ACT]	
Gadopsis marmoratus	River blackfish		
Galaxias olidus	Mountain galaxias		
Galaxias rostratus	Flat-headed galaxias		1971 [Llewellyn]
Hypseleotris klunzingeri	Western carp-gudgeon		
Hypseleotris sp 4	Midgley's carp-gudgeon		
Hypseleotris sp. 5	Lake's carp-gudgeon		
Leiopotherapon unicolor	Spangled perch	Vagrant	1995[FFD]
Macquaria ambigua	Golden perch		
Macquaria australasica	Macquarie perch	Vulnerable [NSW] Endangered [ACT] Endangered [EPBCA]	
Maccullochella macquariensis	Trout cod	Endangered [NSW] Endangered [ACT] Endangered [EPBC]	
Maccullochella peelii	Murray cod	Vulnerable [EPBCA]	
Melanotaenia fluviatilis	Murray-Darling rainbowfish		
Mogurnda adspersa	Southern purple-spotted gudgeon	Endangered population [NSW]	1968 [Llewellyn]
Mordacia mordax	Short-headed lamprey	Vagrant	1974 [ICF]
Nannoperca australis	Southern pygmy perch	Vulnerable [NSW]	1976 [FFD]
Nematalosa erebi	Bony herring		
Philypnodon grandiceps	Flat-headed gudgeon		
Philypnodon sp. 1	Dwarf flat-headed gudgeon		
Retropinna semoni	Australian smelt		
Tandanus tandanus	Freshwater catfish		2000 [Baum 2]

Conservation status superscripts: [NSW] (NSW Fisheries Management ACT), [ACT] (Nature Conservation Act 1980), [EPBCA] (Environment Protection and Biodiversity Conservation Act 1999).

Most recent record superscripts: [ICF] (NSW Fisheries Inland Commercial Fishery Database), [FFD] (NSW Fisheries Freshwater Sampling Database), [Linetrmans] (reported in Lintermans 2000), [Baum 1] (reported by Baumgartner 2003), [Baum 2] (unpublished data collected by Lee Baumgartner), [Llewellyn] (unpublished data collected by Leighton Llewellyn),. Blank cells reflect known presence in 2004.

Table 1.2. Alien fish species of the Murrumbidgee catchment and details of most recent records.

Species	**Common name**	**Conservation status**	**Most recent record**
Carassius auratus	Goldfish		
Cyrpinus carpio	Common carp	Pest	
Gambusia holbrooki	Eastern gambusia	Pest	
Galaxias brevipinnis	Climbing galaxias	Translocated native species	2002[Raadik]
Misgurnus aunguillicaudatus	Oriental weatherloach	Pest	
Oncorhynchus mykiss	Rainbow trout	Stocked – self sustaining	
Perca fluviatilis	Redfin perch	Pest	
Salmo trutta	Brown trout	Stocked – self sustaining	
Salmo salar	Atlantic salmon	Stocked – not self sustaining	2002[Stocked]
Salvelinus fontinalis	Brook charr	Stocked – not self sustaining	2001[Stocked]
Tinca tinca	Tench	No longer considered present	1980 [ICF]

Most recent record superscripts: [ICF] (NSW Fisheries Inland Commercial Fishery Database), [Stocked] (NSW Fisheries Fish Stocking Database), [Raadik] (reported in Raadik 2003). Blank cells reflect known presence in 2004.

Data from a number of fish surveys, and other sources exists for the Murrumbidgee catchment. The earliest data-set available, the NSW Fisheries Inland Commercial Fishery Database (now incorporated into the Comcatch database) (Reid *et al.* 1997) contains data collected between 1955 and 1994. The next report available presents data collected during surveys of the Murray River fish community and some of its tributaries (including the lower Murrumbidgee River) undertaken by Langtry in 1949-50 (Cadwallader 1977). Twenty-five years later in 1975-76, state-wide freshwater fish surveys were undertaken by Llewellyn (Llewellyn 1983). Of the 210 sites sampled throughout NSW by Llewellyn, 11 sites were within the Murrumbidgee catchment. Surveys of Lake Burrinjuck were undertaken by Burchmore *et al.* (1990) between 1985 and 1988, but the only data reported upon was from the 1985 and 1986 seasons which is presented in an unpublished interim report (Burchmore *et al.* 1988). The remainder of the data appears to have been lost. Faragher *et al.* (1993) undertook surveys of the fish community of the upper Murrumbidgee in 1990-92 as part of an assessment of the reintroduced populations of trout cod. In 1992-93, NSW Fisheries undertook a fish recruitment study (Gehrke *et al.* 1995) that included sampling at four sites in the Murrumbidgee catchment around Narrandera. The 'NSW Rivers Survey' (Harris and Gehrke 1997) followed, with the first comprehensive standardised fish community survey from 1994-96. Sampling of NSW Rivers Survey sites was also undertaken in 1998-99, the data from which has not yet been published. Eleven of the NSW River Survey sites were within the Murrumbidgee catchment. In 1998, 10 wetlands in the Murrumbidgee catchment were sampled as part of a carp study using the same standardised sampling strategy developed for the NSW Rivers Survey. The 'Integrated Monitoring of Environmental Flows' (IMEF) project (Chessman 2003) also used the standardised strategy to sampled nine sites in the Murrumbidgee River below Burrinjuck Dam between 1999-2001. As did a study of the fish community upstream and downstream of Balranald Weir on the Murrumbidgee River (Baumgartner 2004) and Tarabah Weir on the Yanco Creek system (Baumgartner, unpublished data) that sampled between 2000 and 2001. In 2002, eight sites were sampled in the Murrumbidgee as part of the pilot study for the MDBC's *Sustainable Rivers*

Audit (SRA) reference sites sampling program (MDBC 2004*a*). This sampling used a standardised sampling procedure, slightly modified but consistent with the NSW Rivers Survey protocol. Between September 2002 and March 2003, fish communities upstream and downstream of Yanco Weir were electrofished for a study on the impact of barriers on predator/prey dynamics (Baumgartner, unpublished data). Between January and April 2003, fish were trapped in a new fishway on Balranald Weir (Baumgartner 2003). Finally, in September 2003, fish communities were surveyed using electrofishing along a 12.6 km reach of the Murrumbidgee near Narrandera (Ebner *et al.* unpublished data) as part of a study into trout cod dispersal. Many detailed surveys of fish communities in the ACT have also been undertaken. These are reviewed by Lintermans (2000*a*). Australian Museum collection records were also available, in addition to a fish community survey of Tarcutta Creek undertaken by Museum staff in April 2002.

Through these previous studies, data on the Murrumbidgee fish community spans a substantial period of time. However the available data does not incorporate the very early periods of European settlement of the catchment, when much vegetation clearing took place, the late 1800's when some of the alien species were first introduced into the catchment, the early part of the commercial fishery, or the period coinciding with the construction of the first major irrigation storage, Burrinjuck Dam. Importantly, these early periods may have been when many significant changes in fish community structure occurred. To demonstrate this, NSW Fisheries reports from 1883 suggest fish populations of some key species had already begun to decline prior to the first available commercial fishery data in 1955 (Reid *et al.* 1997).

The data presented by Reid *et al.* (1997), Cadwallader (1977), Llewellyn (1983), Burchmore *et al.* (1988), Faragher *et al.* (1993), Gehrke *et al.* (1995) and Lintermans (2000*a*) provides a useful insight into fish communities. However, in many cases sampling utilised either a non-standardised sampling protocol (either within or among projects), targeted specific species or size classes, omitted data for species then considered un-important, or provided data from only a small area of the catchment. As a result, these studies provide only glimpses of the complete picture of fish communities and the changes they have experienced since European-settlement of Australia.

Since the development of the standardised electrofishing sampling protocols for the NSW Rivers Survey in 1994 (Harris and Gehrke 1997), almost all fish community assessments undertaken by NSW Fisheries have adopted the same sampling design. This sampling protocol provides a comprehensive representation of the fish community existing at sampling sites. Further, site selection for the NSW Rivers Survey was based on a stratified random site selection process, ensuring that data collected from sites could be used to make inferences about river systems as a whole (assuming sufficient site densities). Where possible, subsequent NSW Fisheries programs utilised pre-existing sites to enable assessment of long–term trends in fish community structure. This was an important undertaking, as regular long-term monitoring sites sampled using a standardised protocol are recognised as the only means to assess change in fish communities and populations (Brown 1992; Rutzoa *et al.* 1994; Lintermans 2000*a*). However, to be effective, the number of monitoring sites must be sufficient to provide statistical power to detect change (MDBC 2004*a*), the distribution of sites must be representative of the variety of habitats existing within the catchment (ACT Government 1998), and to be most useful for management purposes, surveys must be undertaken regularly in order to enable early detection of new alien species or sudden declines in native species.

The Murray-Darling Basin ministerial council has recently committed to implementation of the SRA program (MDBC 2004*a*) to monitor changes in river health resulting from MDBC environmental initiatives. The SRA program will build upon the randomised site network and earlier standardised fish community surveys undertaken by NSW Fisheries to provide a long-term monitoring program for fish communities across the Murray-Darling Basin. However, although randomly selected sites are essential for making broad-scale inferences from the data regarding river health and fish community parameters, the high proportion of threatened taxa, which are typically highly fragmented with very restricted distributions, requires that targeted sampling of threatened species is also undertaken to monitor their status through time. Further, the SRA program excludes floodplain habitats and as a result, important wetland fish communities will not be addressed. The sampling strategy utilised for the fish survey presented in this report, incorporated all three of these important components of the fish community of the Murrumbidgee catchment; randomly selected riverine monitoring sites; randomly selected wetland monitoring sites; and targeted sampling of populations of threatened species. As a result, this Murrumbidgee catchment fish monitoring program builds upon past and upcoming fish surveys by contributing to a 10 year standardised data-set from a number of pre-existing sites within the Murrumbidgee catchment. Further, it is entirely consistent with the upcoming SRA program, which will collect standardised fish community data for at least the next six years and potentially for the next 50 years.

This report presents data on:

- The current status of fish communities.
- The current status of individual fish species.
- The current status of threatened fish species.
- Trends in fish communities and individual fish species over the last 10 years.
- Trends in commercial harvest of fish between 1955 and 2001.
- Data on fish stocking.

2. SITE SELECTION, SAMPLING PROTOCOL AND DATA MANAGEMENT

2.1. Site selection

2.1.1. Randomly selected monitoring sites

A random site selection procedure under development for the SRA was followed (see MDBC 2004*b*) for selection of monitoring sites in the Murrumbidgee catchment.

A Murrumbidgee catchment map was created in ArcView. The map displayed the NLWRA stream network (all streams 3rd order or greater with catchment areas greater than 50 km^2) overlayed upon the AUSLIG 1:250,000 'named' stream network, which includes smaller order streams. From these maps, both the author and Mark Lintermans (of Environment ACT) used local knowledge of the lower and upper parts of the catchment respectively to identify the stream network considered most likely to contain suitable fish habitat within the catchment. All permanent and perennial streams, regulated streams and waterholes within ephemeral streams were included, whilst ephemeral streams and predominantly dry drainage streams were omitted. This stream network was then divided into four altitude zones: < 200 m (lowland zone), 200-400 m (slopes zone), 400-700 m (upland zone) and > 700 m (highland zone). GIS was used to divide the stream network within each zone into 1 km long 'potential sites'. Fifty 'potential sites' were then randomly selected per zone, and listed in order of selection.

As pre-existing NSW Rivers Survey sites were also selected using a stratified random sites selection process (Harris and Gehrke 1997), they are consistent with the requirement for randomness of monitoring sites for this project. Given the value of long-term data-sets, pre-existing NSW River Surveys sites were automatically adopted as monitoring sites for this project. Of the 11 NSW Rivers Survey sites in the Murrumbidgee catchment, three were in the lowland zone, four were in the slopes zone, one was in the upland zone and three were in the highland zone. Following power analysis of pilot SRA data, the minimum number of sites required to adequately characterise the fish community of each zone was identified as seven sites (MDBC 2004*a*). The balance of sites in each zone was then selected from the randomly generated list of 'potential sites'.

Beginning with the first randomly selected 'potential site', the coordinates were plotted on a map. To maximise the value of other pre-existing sites not selected using a randomised selection process, and to ensure adequate dispersal of sites within zones, two criteria were assessed for each plotted 'potential site'. If a pre-existing site (other than NSW River Survey sites) occurred within a 2.5 km radius of the randomly selected site, then the pre-existing site was accepted. This was advantageous in that it minimised the need for a pre-sampling site inspection and it maximised the value of pre-existing data. The second criteria was designed to prevent clustering of sites and required that the 'potential site' was not within a minimum distance from a site that had already been accepted. The minimum distance was set at 5% of the stream length of the zone. If the 'potential site' satisfied these criteria, it was visited to establish site access and sampling gear requirements. If the site was accessible (preferably at the exact randomly selected coordinates, but otherwise within 2.5 km of that point) and had sufficient water to complete the electrofishing sampling requirements, it was 'accepted' and used as a monitoring site. The process was then repeated with the second randomly selected 'potential site', and continued until a total of seven sites were established for each zone[2]. The 'accepted' monitoring sites selected following this procedure are listed in Table 2.1 and plotted on Figure 2.1.

As standardised fish monitoring in wetlands has not been a feature of recent fish monitoring programs in Australia (which have generally been specifically riverine), the wetland site selection procedure had no precedent. For each riverine site, the wetland nearest to the randomly selected coordinates, but not more than 2.5 km away, was assessed on the same day as the riverine site was sampled. If the nearest wetland was dry, the next closest wetland was assessed. If no wetlands within a 2.5 km radius of the randomly selected coordinates contained water, then the wetlands at that site were recorded as 'dry' and no wetland sampling was undertaken. Following this process, only one wetland associated with a randomly selected site was eligible for sampling (Table 2.1). The location of this site, and those wetlands which were dry are plotted on Figure 2.2. Increasing the radius to 5 km around the monitoring sites did not increase the number of wetlands available for sampling.

2.1.2. Targeted threatened species sites

Data and reports from all previous fish surveys (see introduction for references), Australian Museum records and NSW Fisheries unpublished data were used to identify all sites within the catchment where threatened species had been recorded previously. The objective was to sample at least three sites in which each species had been sampled in the past, or is known to currently persist. NSW River Survey sites being used as monitoring sites could also act as targeted threatened species sites if threatened species had been collected there during previous sampling. However, there were several species that had been collected from fewer than three locations in the Murrumbidgee catchment. For these species, additional sites were identified in previously unsurveyed sub-catchments that retained potentially suitable habitat.

Twenty-two sites (21 riverine and 1 wetland) were identified as targeted threatened species sampling sites. These are presented in Table 2.2 and plotted on Figure 2.1.

Following the same wetland site selection process as for monitoring sites, three threatened species sites had floodplain wetlands within 2.5 km (Table 2.2). However, due to the number of years of drought prior to sampling, the wetlands adjacent to two of these sites were dry. An additional wetland, Bringagee, was targeted as a threatened species site (Table 2.2).

[2] An error occurring during site selection of the Woolgarlo site (Table 2) meant that during sampling it was considered one of the seven upland sites, when in fact its altitude of 360 m meant that it was in the slopes zone. The data from Woolgarlo were analysed as a slopes zone site as dictated by its altitude. Therefore, rather than having seven sites in each of the four zones, the slopes zone had eight sites whilst the upland zone only had six.

Table 2.1. Randomly selected riverine and wetland monitoring sites within each altitude zone.

Site name	Stream of waterbody	Latitude	Longitude	Altitude (metres)	Wetland
Lowland zone					
Willow Isles	Murrumbidgee River	34.7174	143.3839	60	
Glen Avon – Redgum mill	Murrumbidgee River	34.5786	143.6437	65	Yes
Wyreema	Murrumbidgee River	34.4871	144.9962	95	
Webb's Road	Murrumbidgee River	34.4532	145.4596	100	
Cookoothama	Murrumbidgee River	34.5602	145.9339	120	
Columbo 66	Columbo Creek	34.9298	146.285	120	
Rocky Waterhole	Bundidgery Creek	34.7663	146.6339	155	
Slopes zone					
Hillas Creek	Hillas Creek	35.1447	147.8014	210	
Wahroonga	Tarcutta Creek	35.1883	147.7513	220	
Brungle Bridge	Tumut River	35.1234	148.2055	240	
Readymix	Tumut River	35.3043	148.2363	270	
Glendale	Murrumbidgee River	34.9157	148.5468	280	
Kabaragong	Spring Creek	34.7036	148.4426	340	
Woolgarlo	Lake Burrinjuck	34.9149	148.7383	360	
Coodravale	Goodradigbee River	35.1465	148.6829	380	
Upland zone					
Willow Tree Waterhole	Murrumbidgee River	35.1948	148.9497	415	
Yass	Yass River	34.8828	149.0079	520	
Coppin's Crossing	Molonglo River	35.2880	149.0399	560	
Lobb's Hole	Talbingo Dam	35.7627	148.3662	565	
Bywong	Yass River	35.1129	149.256	580	
Gudgenby River – Naas	Gudgenby River	35.57689	149.0665	610	
Highland zone					
Cappawidgee	Bredbo River	35.9963	149.2077	720	
Cooma	Cooma Creek	36.2250	149.1196	790	
Foxlow	Molonglo River	35.4897	149.4417	790	
Benbullen	Queanbeyan River	35.6159	149.3484	800	
Bolaro	Murrumbidgee River	35.9776	148.8135	1,100	
Cotter Flats	Cotter River	35.6430	148.828	1,100	
Pether's Hut	Murrumbidgee River	35.6039	148.5942	1,350	

Table 2.2. Targeted threatened species sites within each altitude zone.

Site name	Stream or waterbody	Latitude	Longitude	Altitude	Wetland
Lowland zone					
Tilpee	Pee Vee Creek	34.53753	143.7229	65	
Willow Dam	Mirool Creek	34.19402	145.8311	110	
Bringagee	Bringagee Creek	34.44565	145.7008	110	Yes
Lamont's Beach	Murrumbidgee River	34.68604	146.4072	140	
Narrandera Boat ramp	Murrumbidgee River	34.7715	146.5727	145	
Downstream of Berembed Weir	Murrumbidgee River	34.88213	146.8183	160	Yes
Berry Jerry Station	Murrumbidgee River	35.01842	147.0219	165	Yes – dry
Pomingalarna	Murrumbidgee River	35.10019	147.2655	180	Yes – dry
Wantabadgery	Murrumbidgee River	35.07207	147.7404	190	
Slopes zone					
Gundagai	Murrumbidgee River	35.07033	148.0913	220	
Bona Vista	Adjungbilly Creek	35.01211	148.16372	280	
Gilmore Creek	Gilmore Creek	35.20113	148.10188	290	
Dale's Point	Lake Burrinjuck	34.99915	148.6459	360	
Upland zone					
Adelong Creek	Adelong Creek	35.24359	148.07163	460	
Bango	Bango Creek	34.82318	148.9037	480	
Brungle Creek	Brungle Creek	35.11411	148.21316	480	
Red Hill	Adjungbilly River	35.05165	148.23513	490	
Angle Crossing	Murrumbidgee River	35.62127	149.109	600	
Highland zone					
Dromore	Numeralla River	36.08749	149.1469	710	
Murrell's Crossing	Murrumbidgee River	36.11219	149.1265	720	
Cooma Weir-pool	Murrumbidgee River	36.17142	149.0903	740	
ACT EW Hole	Queanbeyan River	35.5276	149.2995	850	

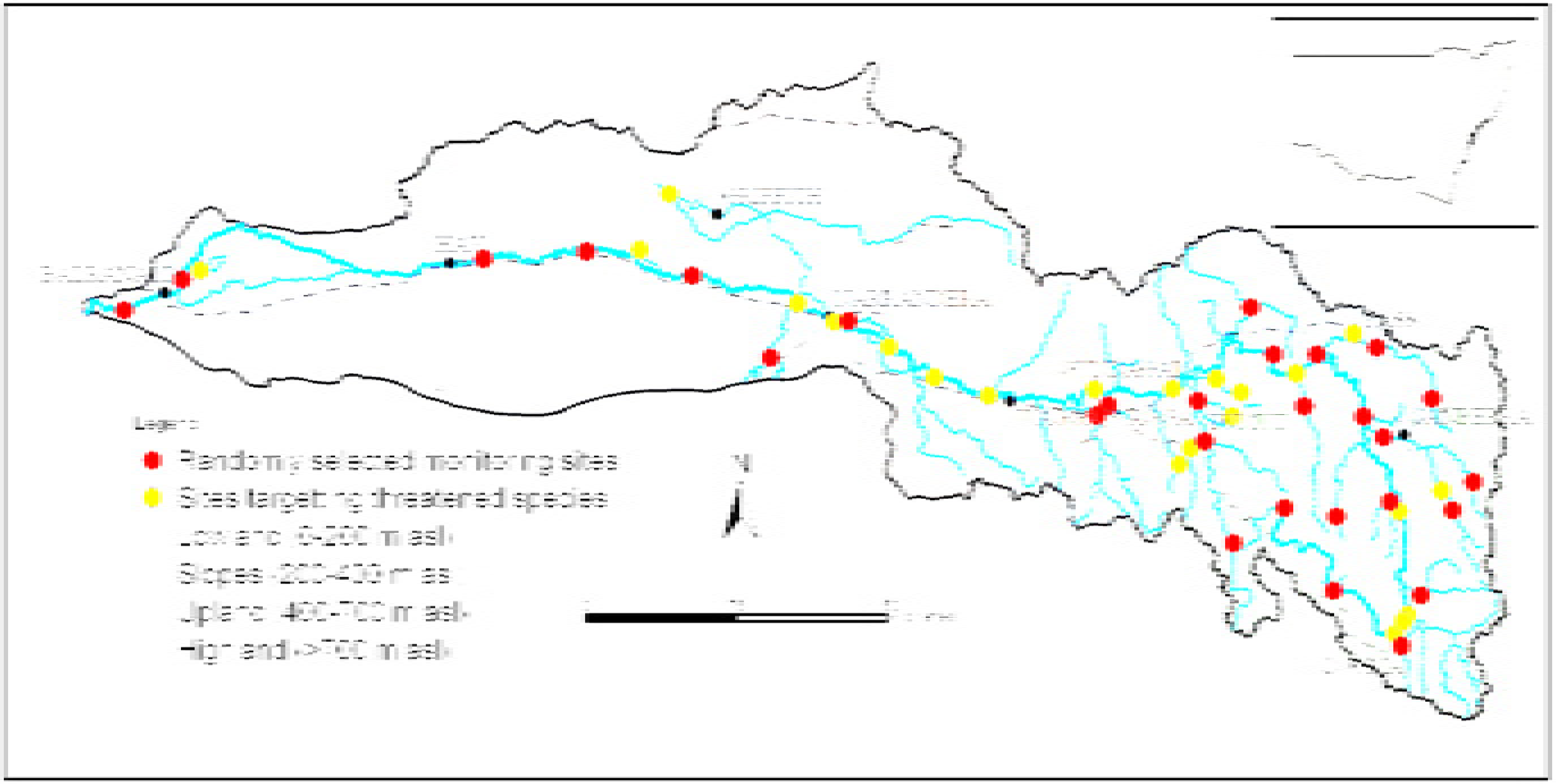


Figure 2.1. Plot of locations of randomly selected monitoring sites (red) and targeted threatened species sites (yellow) in the Murrumbidgee catchment.

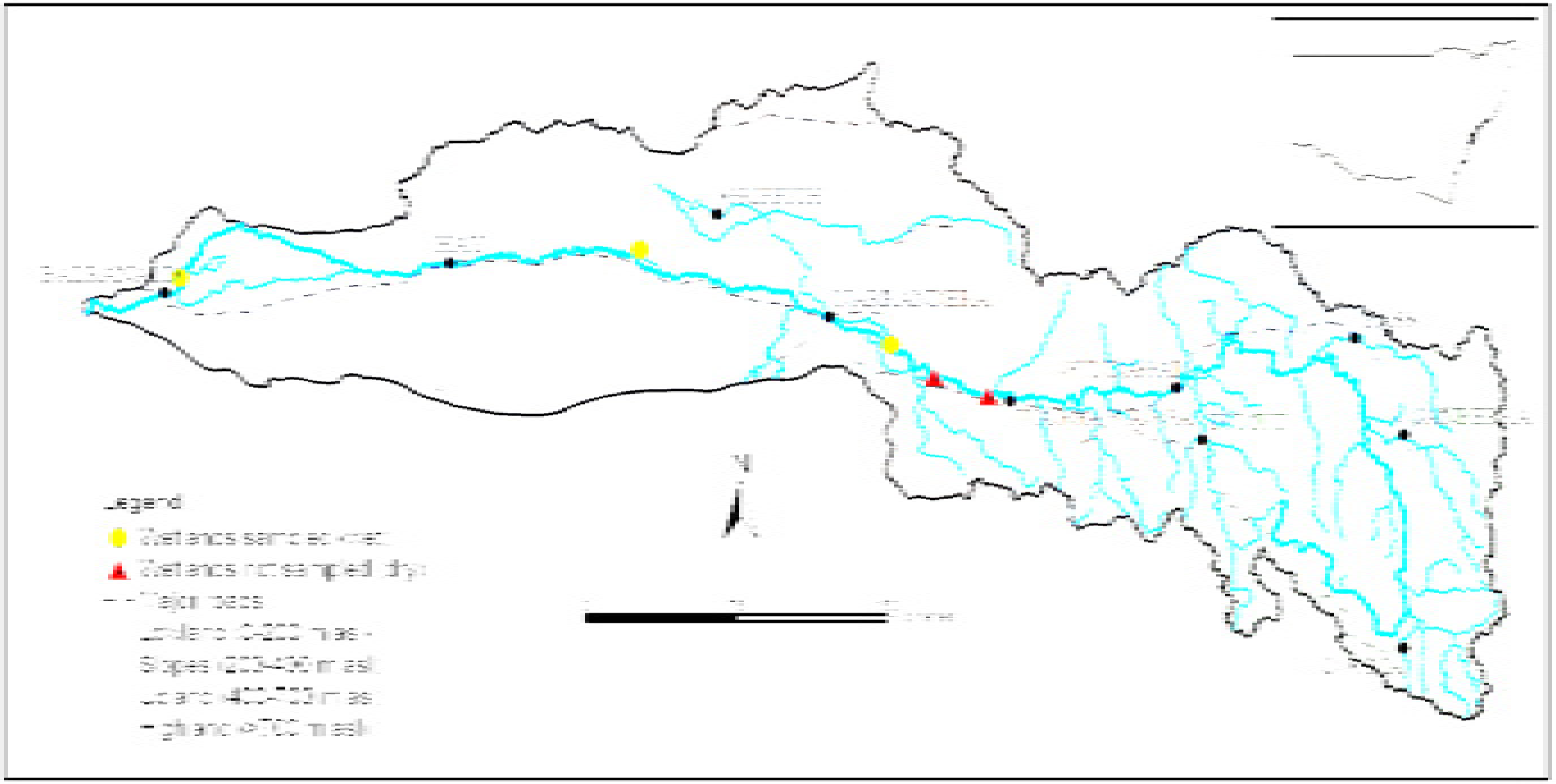


Figure 2.2. Plot of locations of floodplain wetlands selected for sampling in the Murrumbidgee catchment.

2.2. Sampling procedure

2.2.1. Riverine sites

The sampling procedure for riverine sites was based on standardised boat and/or backpack electrofishing in addition to 10 unbaited shrimp traps as developed for the SRA program (MDBC 2004b).

Either large boat (7.5 kW Smith-Root model GPP 7.5 H/L) or small boat (2.5 kW Smith-Root model GPP 2.5 H/L) electrofishing was undertaken depending on the size of the stream. In streams wider than 15 m, the larger electrofishing boats were used. Smaller streams were sampled using the smaller boat. Boats were used to sample all navigable habitats (waters deeper than ~ 0.75 m). A backpack electrofisher (400 W Smith-Root model 12) was used to sample non-navigable (but wadeable) habitats such as riffles and runs.

Boat operations consisted of 90 seconds of electrofishing (power on). Each operation was undertaken using intermittent electrofishing, with a ~10 second application of power followed by a ~10 second pause and advance of approximately 5 m. This protocol minimises the 'herding' of fish. As a further prevention of herding, each operation was undertaken on alternate banks. For streams > 5m wide, at least two 'mid-stream' shots were undertaken. For streams < 5 m wide, where the electric field covered the entire stream width, a greater spacing was used between operations to prevent herding and the boat progressed in a zig-zag fashion between banks. Each operation took an average of four minutes to complete.

Backpack operations consisted of 150 seconds of electrofishing (power on). Each operation was undertaken using intermittent electrofishing, with the backpack used to fish all areas accessible to the stationary operators (1.5 - 2 metre radius). Following electrofishing of that area, the operators moved ~3 m and repeated the process. In streams > 10 m wide, electrofishing was undertaken along both banks. In smaller streams, operators progressed in a zig-zag fashion in an upstream direction. Each operation took an average of seven minutes to complete.

The number of boat and/or backpack operations undertaken was dependent on the proportional availability of each habitat type within the 1 km sampling sites. Sites which were totally navigable by boat were sampled using 12 boat electrofishing operations. Conversely, sites with no navigable habitat were sampled using 8 backpack electrofishing operations. For sites which had both navigable and non-navigable habitats, a combination of both boat and backpack electrofishing was used, in proportion to the availability of navigable and non-navigable habitat within the 1 km site.

During each operation, dip-netters removed all electrofished individuals and placed them in a aerated live-well (boat fishing) or bucket (backpack fishing). All individuals that could not be dip-netted but could be positively identified were recorded as 'observed'. All electrofishing was undertaken during daylight hours.

In addition to electrofishing, 10 un-baited concertina-type shrimp traps were set in attempt to sample small benthic fish species typically under-represented in electrofishing samples. Traps were set for a minimum period of two hours whilst electrofishing was being undertaken. Data from each of the 10 traps were recorded as a separate operation.

At the completion of each operation (electrofishing or shrimp traps), captured individuals were identified, counted, measured and observed for externally visible parasites, wounds, diseases etc. before being released. All taxa were recorded to species level except for the carp-gudgeon species complex, which were recorded as Hypseleotris spp. unless operators were absolutely confident of their identification (usually only possible for Lake's carp-gudgeon: Hypseleotris sp5.). In the case of difficult identifications, specimens were photographed and/or preserved in 70% ethanol for laboratory identification. Length measurements to the nearest millimetre were taken as fork length for species with forked tails and total length for other species. Where large catches of a species occurred, only a sub-sample of individuals were measured and examined for each gear type. The sub-sampling procedure consisted of measuring all individuals in each operation until at least 50 individuals had been measured. Once this had happened, the remainder of individuals in that operation were measured, but any individuals of that species from subsequent operations of that gear type were only counted. Sub-sampling for health status involved careful observation of one side (usually the left) of every fish that was measured. The number of parasites, wounds etc. observed was recorded for each individual assessed.

2.2.2. Wetland sites

As electrofishing is impractical in most wetland habitats, sampling of wetland sites was undertaken using five replicate hauls of a 5 m pocket-seine (1.5 m drop and 3 mm mesh) in addition to the same shrimp-trap sampling as was used for riverine sites. Each seine haul and shrimp trap was recorded as a separate operation and the catch was processed in the same way as described for riverine sites.

2.2.3. Habitat assessment

In addition to fish sampling, a habitat assessment and water quality analysis was undertaken at each site. Habitat values for riparian and instream vegetation, substratum, mesohabitat (pool, run, riffle, rapid), and instream cover variables were scored using an AFOR scale (Abundant, Frequent, Occasional, or Rare) for the site as a whole.

Water quality parameters; temperature (^{o}C), dissolved oxygen (mg/L), pH, and conductivity (µS/cm) were measured using either a Horiba U10 or YSI 556 MPS water quality meter. Turbidity was measured using either the Horiba U10 water quality meter, a Lovibond PCcheckit turbidity meter or a secchi disk. Three replicate measurements of each parameter were made at 20 cm below the surface in addition to a single 'depth profile', where parameters were assessed at 1 m intervals between the surface and substrate (only possible for turbidity using the Horiba instrument).

2.3. Data entry and quality assurance

Data were entered onto standard NSW Fisheries data-sheets by the senior operator at the completion of each operation. Data recorded included fish information (as above), electrofishing settings, sampling time (real time plus electrofishing time), average depth, average stream width, mesohabitat sampled and distance travelled during the operation.

Data were then transferred directly into the NSW Fisheries Freshwater Fish Research Database. Within this data storage system, data are first entered into intermediate tables by technical staff. The data then run through a series of 50 range-checks to identify any outliers and inconsistencies in data recording. All potential errors are referred to the senior operator responsible for data collection at that site for confirmation and/or correction. The corrected intermediate tables are then appended into the database for storage.

3. STATUS OF FISH COMMUNITIES OF THE MURRUMBIDGEE CATCHMENT IN 2004

3.1. Introduction

Fish communities are co-occurring populations of individual fish species within habitats. Changes in fish communities are driven by a range of interactions within the ecosystem. A number of studies have attributed changes in fish community composition to natural processes such as increasing species diversity and habitat variability progressively downstream within river systems (Rahel and Hubert 1991; Paller 1994; Gehrke and Harris 2000). However human induced catchment disturbance also plays a role in driving fish community structure (Connell 1978; Ward and Stanford 1983; Puckridge *et al.* 1998). In addition, direct interactions between members of the fish community such as predation, interspecific competition, intraspecific competition, direct interactions with other aquatic organisms and indirect interactions through broader ecosystem processes also affect fish community structure. The combined effects of each of these processes governs the species composition and relative abundances of species within the community. Given the large catchment area of the Murrumbidgee River, its extensive altitudinal range, consequent range of habitats, and spatial variation in the level and type of human disturbance, the composition of fish communities occurring at sites are unlikely to be consistent throughout the catchment.

The structure of fish communities is expected to be similar in areas that contain similar habitat types which have been exposed to similar disturbances. These include both natural events such as bushfires and fish kills resulting from heavy rainfall following a prolonged dry period, as well as human induced disturbances such as, construction of barriers to fish passage, river regulation, de-snagging, introduction of alien fish and fish kills resulting from pollution. As a result, it can be hypothesised that identification of patterns in fish community structure would lead to identification of areas of habitat which require similar management or rehabilitation activities (Gehrke and Harris 2000).

Once the distribution of fish communities has been identified within the catchment, basic ecological parameters such as species richness, total abundance, biomass, species diversity and evenness, the proportion of alien taxa and estimates of recruitment can then be used to assess temporal changes in community status. Further, the status of fish communities in least-disturbed habitats can be used to set management targets for rehabilitation of those that have been disturbed.

3.2. Methods

3.2.1. Site selection and sampling procedure

Site selection and sampling followed the protocols and procedures outlined in chapter 2. All 49 riverine sites were included in the assessment of bio-zonation within the catchment. However, only data from the 28 monitoring sites were used to benchmark the current fish community and make statements about community condition in each altitude zone and eco-type.

3.2.2. Data analysis

Data from all operations at a site (boat electrofishing, backpack electrofishing and shrimp-traps for riverine sites, and seine nets and shrimp-traps for wetlands) were combined for analysis. Data were not standardised to catch-per-unit-effort as the same standardised sampling was undertaken at all sites (riverine and wetland sites were not compared directly due to the different sampling techniques used).

Biomass per site was estimated from length-weight relationships presented in MDBC (2004*a*: Table 8). The weight of each measured individual was estimated using these relationships. The weight of unmeasured and observed individuals was estimated using the average weight of all measured individuals of that species, for that gear type, at that site. In the small number of instances were a species was only observed at a site, the average weight of individuals of that species, measured for that gear type, in that zone was used.

To examine bio-zonation of fish communities throughout the Murrumbidgee catchment, multivariate analyses were undertaken using PRIMER 5.1.2 (Plymouth Marine Laboratory). Similarity matrices were created using the Bray-Curtis similarity index (Bray and Curtis 1957) for both abundance and biomass data from the 28 monitoring sites and 21 targeted threatened species sites (excluding Bringagee – which was a wetland). Data were fourth root transformed to equalise the contribution of rare and common taxa. Similarity matrices for both abundance and biomass were compared using a Spearman rank correlation coefficient generated using the RELATE function. The two parameters were highly correlated (r = 0.909, p = 0.002). As a result, only abundance data were analysed further. Data plotted using both a hierarchical agglomerative classification analysis using the group-average linking algorithm and multi-dimensional scaling (MDS) ordinations in two dimensions. ANOSIM (ANalysis Of SIMilarities) (Clarke 1993) was used to test differences in fish community structure across altitude zones. ANOSIM was also used to compare functional eco-types within each altitude zone. These were: Lowland floodplain distributary streams (all habitats off the main stream), lowland regulated 'reduced flow' reaches (the main stream below the last irrigation off-take at Gogeldrie Weir), lowland regulated 'increased flow' reaches (main channel reaches between Gogeldrie Weir upstream to 200m altitude), slopes regulated reaches (main channel reaches between the 201m altitude limit and Burrinjuck and Blowering Dams), slopes unregulated tributaries (all unregulated tributary streams between 201 m and 400 m altitude), upland reaches below the major irrigation storages (all reaches between 401 m and 700 m altitude whose confluence with the Murrumbidgee is downstream of Burrinjuck or Blowering Dams), upland reaches above the major irrigation storages (all reaches between 401 m and 700 m altitude whose confluence with the Murrumbidgee is upstream of Burrinjuck or Blowering Dams), highland reaches of the Murrumbidgee River, highland tributary streams and sites within irrigation impoundments. Permutation tests to estimate the probability of the observed results used 5000 randomisations. Where significant differences were identified, SIMPER (SIMilarity PERcentages) analyses were used to identify the species contributing most to dissimilarities.

Total species richness, total abundance, total biomass, Shannon's diversity and evenness index, proportion of total species that were native, proportion of total abundance that were native species, proportion of total biomass that were native species and proportion new recruits for each species were calculated for each site, and the average within each zone was calculated in order to provide a benchmark of the current fish communities. Proportion of total catch, proportion of total biomass and proportion of new recruits was also estimated for each individual species within each zone.

Shannon' diversity index was calculated (based on the abundance of each species) for each site, using the formula (Begon *et al.* 1990)

Diversity $H = - \Sigma P_i \ln P_i$

where the P_i is the proportion of the ith species and ln is $\log_e$. And the associated evenness index as

Evenness $J = H / \ln S$

where S is the species richness at that site.

Size limits used to estimate the proportion of new recruits were based on either the size at one year or the size at sexual maturity for species that reach sexual maturity at less than one year of age (Table 3.1). This size limit was used as a guideline to distinguish fish which had recruited to the population within the previous 12 months. These size limits are tentative only, and should be revised upon the provision of more detailed assessments of length-at-age for each species.

Each parameter was checked for normality using QQ plots in S-Plus and homogeneity of variance using F_{max}-tests (Sokal and Rohlf 1995). Only total species richness, proportion of total species that were native and Shannon's diversity were normally distributed. Further, evenness and total biomass had un-equal variances. For consistency of approach, it was decided to undertake non-parametric Kruskal-Wallis rank sum tests in S-Plus to test for differences between zones for all parameters.

No randomly selected sites were located in the lowland regulated 'increased flow' zone or the upland zone below irrigation impoundments. Consequently, no data are available to benchmark those two zones.

Power analyses were undertaken using S-Plus 6.1 to assess the minimum detectable change for each population parameter within each altitude zone, using the same sampling strategy as was used for this benchmarking study. Power analyses were not undertaken at the eco-type level. These power analyses were undertaken under the assumption of normally distributed data and analysis using ANOVA. However, as much of the data was not normally distributed, future analyses are likely to require non-parametric statistics for which power analysis frameworks are not available. Therefore the results of the power analyses are indicative only.

Table 3.1. Size limits used to estimate the proportion of new recruits for each species.

Species	Estimated size at 1 year old or at sexual maturity (mm)
Native species	
Bidyanus bidyanus	75
Gadopsis bispinosus	70
Gadopsis marmoratus	70
Galaxias olidus	30
Hypseleotris spp.	20
Macquaria ambigua	75
Macquaria australasica	75
Maccullochella macquariensis	150
Maccullochella peelii	250
Melanotaenia fluviatilis	30
Nematalosa erebi	85
Philypnodon grandiceps	40
Philypnodon sp. 1	20
Retropinna semoni	30
Alien species	
Carassius auratus	60
Cyprinus carpio	200
Gambusia holbrooki	20
Misgurnus anguillicaudatus	70
Oncorhynchus mykiss	150
Perca fluviatilis	150
Salmo trutta	150

3.3. Results

3.3.1. Catch data

Twenty fish taxa (19 species and 1 species complex: potentially three *Hypseleotris* spp.(McDowall 1996)) were sampled from the 28 riverine monitoring sites (Table 3.2). This represents 62% the native taxa (13 of 21)(54% if the three vagrant species are included in the historical species list) and 64% of the alien species (7 of 11) known to have historically occurred in this river system. The species not sampled included the three vagrant native taxa (spangled perch, short-headed lamprey and freshwater eels), five threatened species (olive perchlet, Murray hardyhead, Macquarie perch, southern purple spotted-gudgeon and southern pygmy perch), three other native species not listed as threatened (fly-specked hardyhead, Murray galaxias and freshwater catfish), and four species of alien fish (tench, Atlantic salmon, brook charr and the native but not endemic climbing galaxias).

Due to the prevailing drought conditions at the time of sampling, only three of the five wetlands selected for sampling contained water. Only five species were sampled from wetland habitats, two native species: carp-gudgeons and Australian smelt, and three alien species: eastern gambusia, goldfish and carp, with gambusia making up 92% of fish abundance (Table 3.2).

3.3.2. Spatial structure of fish communities within the Murrumbidgee catchment

Classification analysis of abundance data from the 49 riverine sites demonstrated substantial spatial variability in fish community structure within the catchment, as indicated by the deep branching pattern resulting from low similarities among sites (Figure 3.1). Further, the classification analysis demonstrated that there are relatively few associations (clusters) of sites at higher levels of similarity suggesting limited discrete bio-zonation within the catchment or an insufficient number of sampling sites to adequately reflect spatial variability in fish community structure within the catchment (Figure 3.1).

The only easily interpretable patterns were for five significantly different clusters separated at < 30% similarity. The most dissimilar site was Cooma, with 0% similarity to all remaining sites due to the absence of any fish. The next divergence at a similarity of 5.55% separated a group of 12 sites dominated by either trout or mountain galaxias from the remaining 36 sites where carp were a significant component of the fish community. The trout/galaxias dominated community was further separated at 14.22% similarity into sites dominated by either alien trout or native galaxias. The trout dominated cluster had two sites, Cotter flats and Lobb's Hole, which had < 30% similarity to each other and other sites in the cluster (Figure 3.1). However as they were not statistically different from any other site (due to insufficient replication within the cluster) they are not discussed further. The remaining 36 sites where carp were present separated into a further two significant groups based on the dominance of either the alien species carp and eastern gambusia (19 sites – largely in the slopes and upland zones) or the native species Australian smelt, Murray cod and golden perch (17 sites – largely in the lowland areas). Although subsequent breakdown of the fish community was possible, the results became harder to interpret.

Table 3.2. Number of fish sampled in 2004 during sampling for this project.

Species	Monitoring sites	Threatened species sites	Wetland sites	Total catch
Native species				
Ambassis agassizii	0	0	0	0
Anguilla spp.	0	0	0	0
Bidyanus bidyanus	1	0	0	1
Craterocephalus fluviatilis	0	0	0	0
Craterocephalus stercusmuscarum	0	0	0	0
Gadopsis bispinosus	17	0	0	17
Gadopsis marmoratus	7	77	0	84
Galaxias olidus	135	602	0	737
Galaxias rostratus	0	0	0	0
Hypseleotris spp.	435	34	559	1,028
Leiopotherapon unicolor	0	0	0	0
Macquaria ambigua	35	20	0	55
Macquaria australasica	0	1	0	1
Maccullochella macquariensis	1	24	0	25
Maccullochella peelii	53	12	0	65
Melanotaenia fluviatilis	19	0	0	19
Mogurnda adspersa	0	0	0	0
Mordacia mordax	0	0	0	0
Nannoperca australis	0	0	0	0
Nematalosa erebi	104	4	0	108
Philypnodon grandiceps	3	3	0	6
Philypnodon sp. 1	3	0	0	3
Retropinna semoni	685	772	23	1,480
Tandanus tandanus	0	0	0	0
Alien species				
Carassius auratus	35	41	1	77
Cyprinus carpio	690	503	4	1,197
Galaxias brevipinnis	0	0	0	0
Gambusia holbrooki	2,524	414	6,714	9,652
Misgurnus anguillicaudatus	81	0	0	81
Oncorhynchus mykiss	108	5	0	113
Perca fluviatilis	187	12	0	199
Salmo trutta	3	4	0	7
Salmo salar	0	0	0	0
Salvelinus fontinalis	0	0	0	0
Tinca tinca	0	0	0	0
Number of sites sampled	28	21	3	
Total	5,126	2,528	7,301	14,955

Table 3.3. Biomass (grams) of fish sampled in 2004 during sampling for this project.

Species	Monitoring sites	Threatened species sites	Wetland sites	Total biomass (kg)
Native species				
Ambassis agassizii	0	0	0	0
Anguilla spp.	0	0	0	0
Bidyanus bidyanus	239	0	0	0.239
Craterocephalus fluviatilis	0	0	0	0
Craterocephalus stercusmuscarum	0	0	0	0
Gadopsis bispinosus	280	0	0	0.280
Gadopsis marmoratus	234	3,831	0	4.065
Galaxias olidus	245	1,161	0	1.406
Galaxias rostratus	0	0	0	0
Hypseleotris spp.	168	11	191	0.370
Leiopotherapon unicolor	0	0	0	0
Macquaria ambigua	36,215	15,223	0	51.438
Macquaria australasica	0	49	0	0.049
Maccullochella macquariensis	980	15,185	0	16.165
Maccullochella peelii	19,434	9,780	0	29.214
Melanotaenia fluviatilis	41	0	0	0.041
Mogurnda adspersa	0	0	0	0
Mordacia mordax	0	0	0	0
Nannoperca australis	0	0	0	0
Nematalosa erebi	1,719	1,015	0	2.734
Philypnodon grandiceps	6	1	0	7
Philypnodon sp. 1	2	0	0	2
Retropinna semoni	624	685	15	1.324
Tandanus tandanus	0	0	0	0
Alien species				
Carassius auratus	2,495	2,836	94	5.425
Cyprinus carpio	515,213	342,020	31	857.264
Galaxias brevipinnis	0	0	0	0
Gambusia holbrooki	620	86	641	1.347
Misgurnus anguillicaudatus	394	0	0	0.394
Oncorhynchus mykiss	4,290	709	0	4.999
Perca fluviatilis	8,909	1,668	0	10.577
Salmo trutta	159	1,368	0	1.527
Salmo salar	0	0	0	0
Salvelinus fontinalis	0	0	0	0
Tinca tinca	0	0	0	0

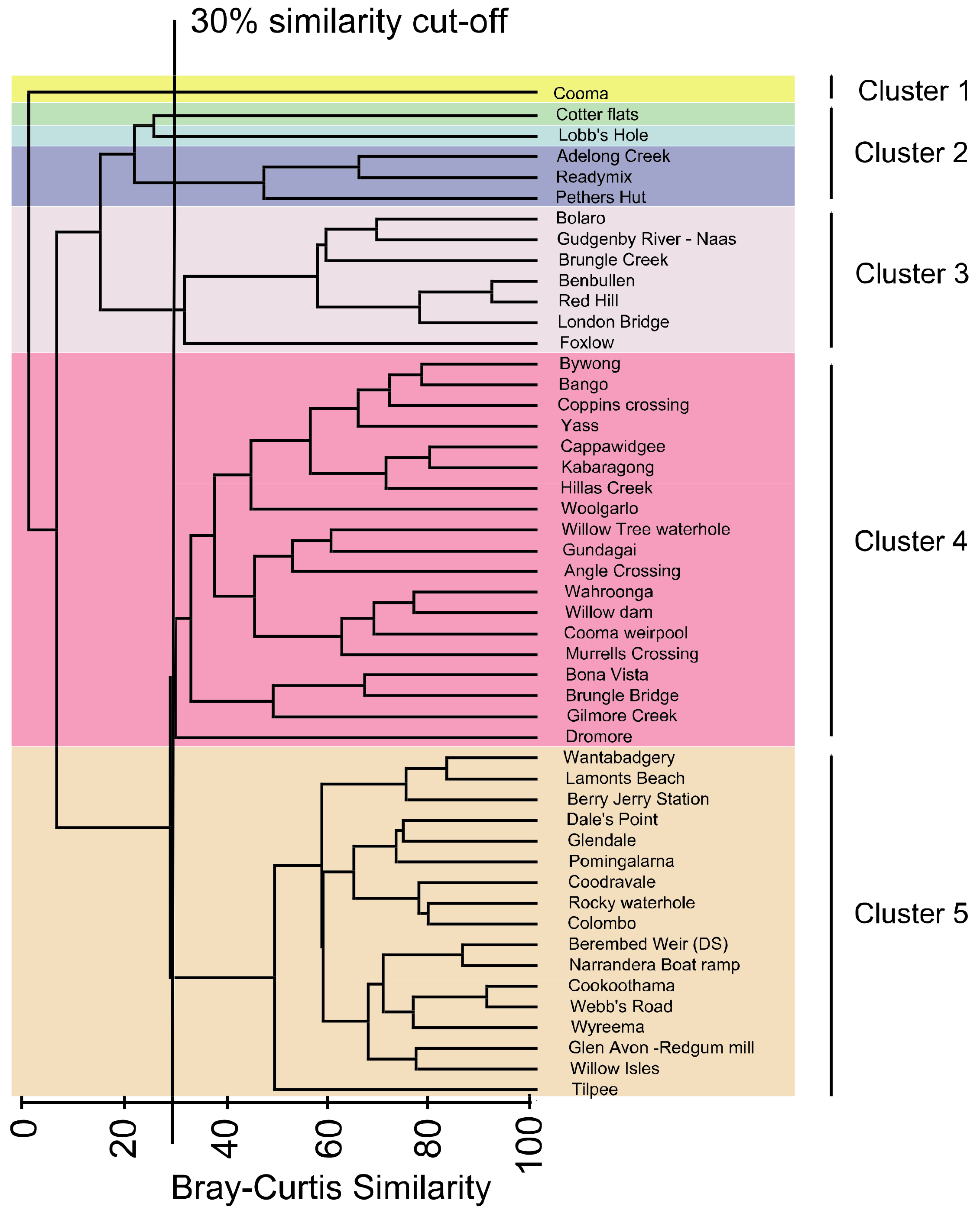


Figure 3.1. Classification analysis of sites in the Murrumbidgee catchment based on similarities calculated from abundance data. Clusters with Bray-Curtis similarities less than 30% were identified using different colours. Although the fish community at Cotter flats (green) and Lobb's Hole (blue) differed from the remainder of sites in cluster two, the relationship was not significant due to lack of statistical power. Hence they were lumped with cluster 2 rather than identified as separate clusters.

3.3.3. Analysis of altitude zones

Comparison of the fish community over the pre-determined altitude zones using ANOSIM identified significant differences between fish communities (Global $R = 0.358$, $p < 0.0001$). The lowland zone was significantly different from the slopes ($R = 0.44$, $p < 0.0001$) upland ($R = 0.533$, $p < 0.0001$) and highland zones ($R = 0.631$, $p < 0.0001$). The slopes zone was also significantly different from the highland zone ($R = 0.223$, $p = 0.004$), but not the neighbouring upland zone ($R = 0.095$, $p = 0.079$) and the upland zone did not differ from the neighbouring highland zone ($R = 0.008$, $p = 0.343$). Multi-dimensional scaling ordination illustrates these relationships and also highlights a substantial increase in fish community variability with altitude (Figure 3.2), with the scatter of sites within each zone increasing from the lowland zone where the fish community at each site was very similar and hence tightly clustered in ordinal space (with the possible exception of Willow Dam), to the highland zone where each site had a very different fish community and the sites are broadly scattered. This trend was quantified by the average similarity of sites within each zone, being 56.31% in the lowland zone, decreasing to 33.30% in the slopes zone, 21.86% in the uplands zone and finally 19.30% in the highland zone.

The lowland zone fish community was characterised by a greater abundance of Australian smelt, Murray cod and golden perch and lower abundance of eastern gambusia than the other three zones (Table 3.4). Carp also contributed to the differences but the relationship was more complex than for each of the other species which tended to change sequentially with altitude. Carp were more abundant in the slopes and highland zones than in the lowlands, but were more abundant in the lowlands than in the upland zone (Table 3.4). The significant difference between the slopes and highland zones was predominantly driven by a greater abundance of carp in the slopes zone (Table 3.4).

3.3.4. Analysis of functional eco-types

As the arbitrary altitude limits developed for the Murray-Darling Basin SRA program may not reflect characteristics of individual catchments, each zone was broken down into eco-types prior to undertaking further assessment. Unfortunately, as the experimental design catered for comparisons between SRA altitude zones, the number of replicate sites per functional eco-type were in most cases lower than the suggested minimum of seven sites. Therefore the benchmark data presented for functional eco-types are not as robust as those for altitude zones.

As was the case for the zone-based analysis, ANOSIM identified significant differences between fish communities (Global $R = 0.329$, $p < 0.001$) (Figure 3.3). Results from pair-wise analyses (Table 3.5) support the results of the zone analysis but further distinguish functional eco-types within some zones. All three functional eco-types in the lowland zone (floodplain distributary streams, regulated 'increased flow' and 'reduced flow' reaches) had significantly different fish community structures (Table 3.5). Similarly, there were significant differences between upland streams that joined the Murrumbidgee above and below the irrigation storages (Table 3.5). There were no significant differences between the regulated main channel and unregulated tributary streams of the slopes zone or between main channel and tributary streams of the highland zone (Table 3.5). Sites within irrigation storages were not significantly different from any other eco-type in any zone except for a significant difference with the regulated 'increased flow' reaches of the lowland zone (Table 3.5). Changes in fish community structure that led to significant differences between the lowland eco-types were a greater abundance of carp-gudgeons and goldfish in the floodplain streams and a greater abundance of bony herring, Murray cod, trout cod and golden perch in the riverine reaches (Table 3.6). The 'increased flow' and 'reduced flow' lowland reaches were distinguished by a greater abundance of Australian smelt and presence of trout cod in the 'increased flow' reaches, and a greater abundance of bony herring, Murray cod and golden perch and presence of redfin perch in the 'reduced flow' reaches (Table 3.6).

The fish communities in upland streams (between 401 – 700 m) were significantly different among those streams entering the Murrumbidgee upstream or downstream of the major irrigation storages of Burrinjuck and Blowering Dams, with an average dissimilarity of 91.44%. The fish communities in these two eco-types were characterised by an abundance of mountain galaxias and trout, and absence of eastern gambusia, redfin perch and carp in upland streams below the storages. There was a contrasting abundance of alien gambusia, redfin and carp in upland streams above Burrinjuck and Blowering Dams (Table 3.6).

The impoundment fish community was dominated by native carp-gudgeons and alien gambusia, redfin and oriental weatherloach, whilst the 'increased flow' lowland community had a greater abundance of Australian smelt, Murray cod and carp, as well as having trout cod which were not present in the storages (Table 3.6).

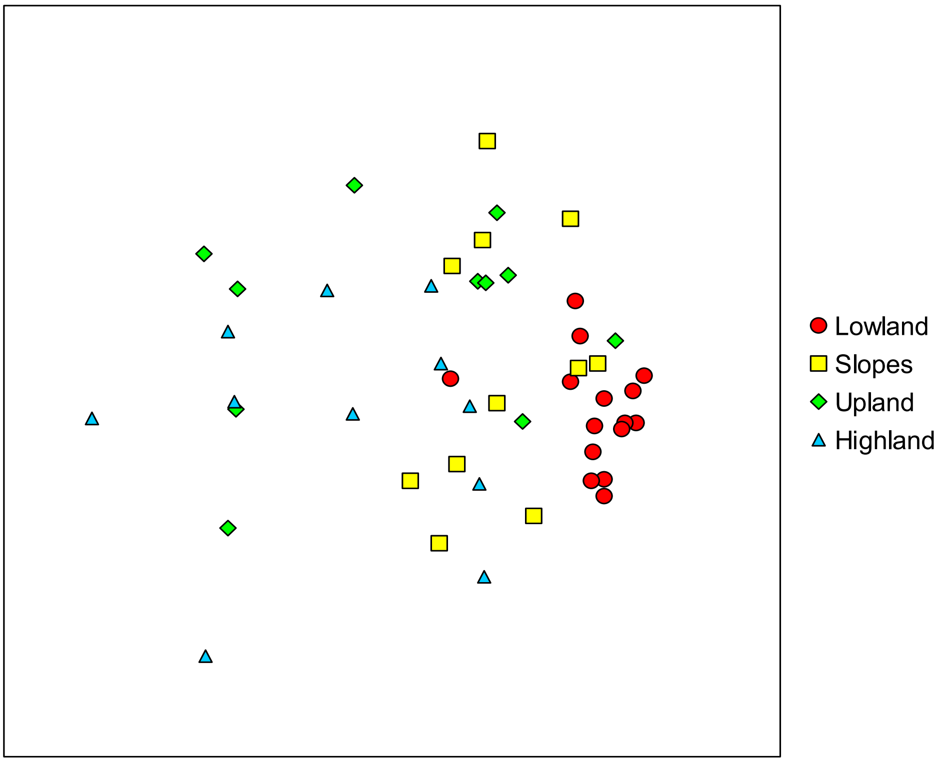


Figure 3.2. MDS ordination of fish community data from sites in the Murrumbidgee catchment. Sites are separated into one of four categories based on altitude zones of: Lowland (< 200 m), Slopes (200 – 400 m), Upland (401 – 700 m) and Highland (> 700 m). The Cooma site was excluded from the MDS ordination due to the lack of any fish at that site. Stress = 0.01.

Table 3.4. Contributions of species to the dissimilarity between fish assemblages in different zones. The consistency ratio indicates the consistency with which each species discriminates between zones, with larger values indicating greater consistency. The cumulative % column indicates the cumulative contribution of each species to the average dissimilarity between zones. The average dissimilarity (D%) is expressed as a percentage ranging from 0 (identical) to 100 (totally dissimilar).

Species	**Mean abundance**		**Consistency ratio**	**Cum. %**	**D%**
	Lowland	**Slopes**			67.14
Retropinna semoni	82.40	19.09	1.49	19.95	
Gambusia holbrooki	0.33	147.45	0.89	33.68	
Maccullochella peelii	4.20	0.00	1.18	41.78	
Gadopsis marmoratus	0.33	11.00	0.76	49.84	
Hypseleotris spp.	2.33	37.64	0.89	56.81	
Macquaria ambigua	2.47	1.09	1.15	63.65	
Carassius auratus	1.73	1.64	0.85	70.12	
Cyprinus carpio	18.13	35.00	1.10	76.50	
	Lowland	**Upland**			80.79
Retropinna semoni	82.40	1.00	1.99	20.66	
Cyprinus carpio	18.13	8.55	1.23	30.95	
Gambusia holbrooki	0.33	45.00	0.88	39.67	
Perca fluviatilis	0.53	15.82	0.92	48.00	
Galaxias olidus	0.00	44.35	0.56	55.70	
Maccullochella peelii	4.20	0.18	1.15	62.68	
Macquaria ambigua	2.47	0.55	1.14	68.85	
	Lowland	**Highland**			85.85
Retropinna semoni	82.40	0.00	2.13	22.38	
Cyprinus carpio	18.13	36.64	1.97	35.81	
Galaxias olidus	0.00	15.73	0.91	44.71	
Maccullochella peelii	4.20	0.00	1.17	52.32	
Gambusia holbrooki	0.33	74.18	0.69	59.04	
Carassius auratus	1.73	2.45	0.91	65.63	
Macquaria ambigua	2.47	0.00	1.14	72.07	
	Slopes	**Highland**			81.61
Gambusia holbrooki	147.45	74.18	0.97	17.92	
Cyprinus carpio	35.00	36.64	1.56	35.20	
Galaxias olidus	0.00	15.73	0.89	46.42	

Table 3.5. Summary of ANOSIM comparisons of functional eco-types within altitude zones. Significant differences are highlighted in grey.

Comparisons	*R*	*P*
Lowland zone		
Floodplain distributary streams v ‘reduced flow’ regulated reaches	0.417	0.029
Floodplain distributary streams v ‘increased flow’ regulated reaches	0.632	0.003
‘Increased flow’ *v* ‘reduced flow’ regulated reaches	0.452	0.015
Slopes zone		
Regulated reaches *v* unregulated tributaries	-0.093	0.662
Upland zone		
Streams entering the Murrumbidgee above *v* below irrigation storages	0.508	0.012
Highland zone		
Upper Murrumbidgee v tributary streams	-0.036	0.583
Impoundments		
Impoundments v floodplain distributary streams	0.000	0.400
Impoundments v ‘reduced flow’ lowland reaches	0.786	0.067
Impoundments v ‘increased flow’ lowland reaches	0.792	0.028
Impoundments v regulated slopes reaches	0.357	0.133
Impoundments v slopes tributaries	0.083	0.321
Impoundments v upland streams below irrigation storages	0.75	0.10
Impoundments v upland streams above irrigation storages	0.045	0.444
Impoundments v highland Murrumbidgee	0.227	0.238
Impoundments v highland tributaries	0.221	0.194

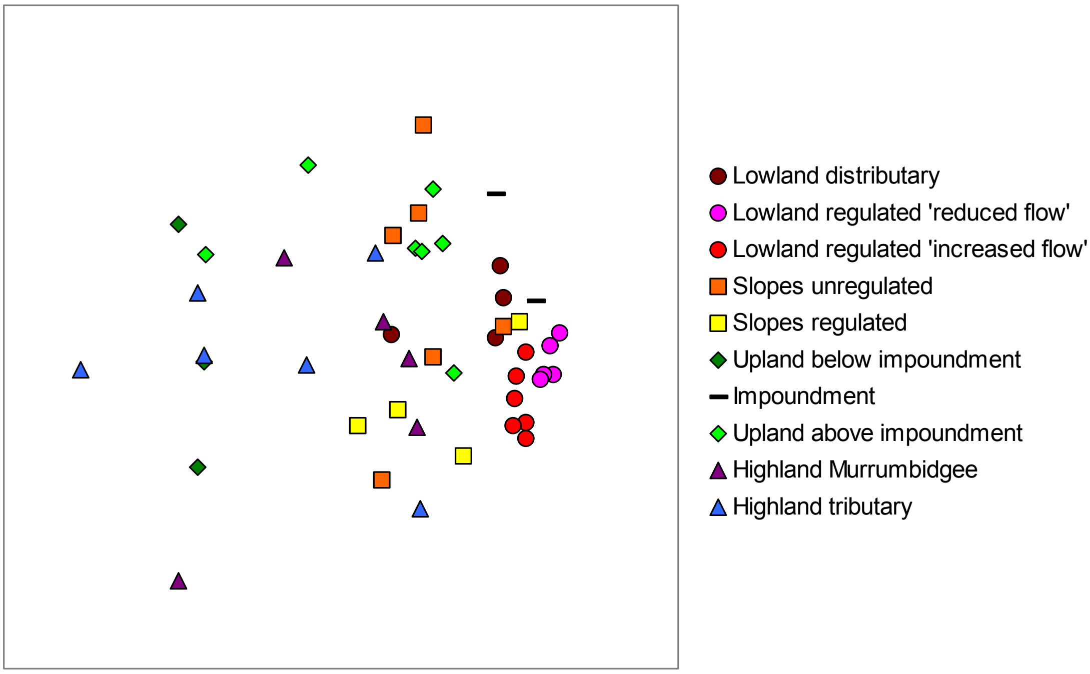


Figure 3.3. MDS ordination of fish community data from sites in the Murrumbidgee catchment. Sites were classified into functional eco-types within each altitude zone. The Cooma site was excluded from the MDS ordination due to the lack of any fish at that site. Stress = 0.01.

3.3.5. *2004 benchmark of fish communities in the Murrumbidgee catchment*

Fish community parameters for individual monitoring sites are presented in Table 3.7.

3.3.5.1. *Species richness*

Species richness decreased significantly with altitude (Species richness = 5.57 - 0.004 x (altitude), R^2 = 0.67, $F_{1,26}$ = 21.22, p < 0.001) (Figure 3.4). Differences in average species richness within zones and eco-types reflected this relationship (Figure 3.5). Species richness differed significantly for both altitudinal zones (χ^2_3 = 15.92, p = 0.001) and eco-types (χ^2_5 = 18.39, p = 0.003). However the relationship did not result from a simple process of species loss with altitude. The loss of lowland species was coincident with gain of upland species as altitude increased (Table 3.8).

3.3.5.2. *Total abundance*

There were no significant differences between altitude zones (χ^2_3 = 4.03, p = 0.259) or between functional eco-types (χ^2_5 = 5.24, p = 0.388) in the total abundance of individuals per site. The slopes zone and slopes ecotype had an average abundance greater than the remaining zones however there was substantial variance among slopes sites and therefore the relationship was not significant (Figure 3.6).

3.3.5.3. *Total biomass*

There were significant differences for total biomass between altitude zones (χ^2_3 = 11.38, p = 0.010) and eco-types (χ^2_5 = 11.60, p = 0.041). However the biomass relationship was not driven by a simple linear relationship with altitude ($F_{1,26}$ = 2.60, p = 0.12) as was the case with species richness. Instead, the slopes zone had the highest biomass of each of the zones (due to the presence relatively large carp) and the highland zone had a very low biomass per site (Figure 3.7).

Table 3.6. Contributions of species to the dissimilarity between fish assemblages in different eco-types within zones. The consistency ratio indicates the consistency with which each species discriminates between eco-types, with larger values indicating greater consistency. The cumulative % column indicates the cumulative contribution of each species to the average dissimilarity between eco-types. The average dissimilarity (D%) is expressed as a percentage ranging from 0 (identical) to 100 (totally dissimilar).

Species	**Mean abundance**		**Consistency ratio**	**Cum. %**	**D%**
Lowland zone					
	Distributary	**'Reduced Flow'**			55.11
Nematalosa erebi	1.00	22.75	2.10	15.56	
Retropinna semoni	54.00	51.00	1.15	28.50	
Maccullochella peelii	0.50	12.00	1.54	41.38	
Carassius auratus	5.50	0.25	1.81	52.81	
Macquaria ambigua	0.25	5.50	1.51	62.56	
Hypseleotris spp.	7.00	0.50	1.32	70.68	
	Distributary	**'Increased flow'**			52.93
Retropinna semoni	54.00	116.57	1.11	18.92	
Carassius auratus	5.50	0.43	1.70	32.16	
Maccullochella macquariensis	0.00	2.57	1.09	41.43	
Hypseleotris spp.	7.00	0.71	1.00	50.65	
Macquaria ambigua	0.25	2.00	1.28	59.39	
Maccullochella peelii	0.50	1.86	1.22	67.78	
Cyprinus carpio	20.00	18.29	1.40	73.15	
	'Reduced Flow'	**'Increased flow'**			39.08
Nematalosa erebi	22.75	1.86	2.69	22.48	
Maccullochella peelii	12.00	1.86	1.09	33.81	
Maccullochella macquariensis	0.00	2.57	1.11	44.46	
Melanotaenia fluviatilis	4.75	0.00	0.94	54.52	
Macquaria ambigua	5.50	2.00	1.20	64.35	
Retropinna semoni	51.00	116.57	1.19	73.52	
Hypseleotris spp.	0.50	0.71	1.04	80.63	

Table 3.6. **(continued)** Contributions of species to the dissimilarity between fish assemblages in different eco-types within zones. The consistency ratio indicates the consistency with which each species discriminates between eco-types, with larger values indicating greater consistency. The cumulative % column indicates the cumulative contribution of each species to the average dissimilarity between eco-types. The average dissimilarity (D%) is expressed as a percentage ranging from 0 (identical) to 100 (totally dissimilar).

Species	Mean abundance		Consistency ratio	Cum. %	D%
Upland zone					
	Above impoundment	**Below impoundment**			91.44
Galaxias olidus	3.00	155.62	1.17	22.88	
Gambusia holbrooki	70.71	0.00	1.27	39.44	
Perca fluviatilis	24.57	0.00	1.11	55.11	
Cyprinus carpio	13.00	0.00	1.34	68.79	
Oncorhynchus mykiss	0.29	3.33	1.17	79.18	
Salmo trutta	0.00	1.67	1.20	88.82	
Impoundments					
	'Increased Flow' lowland	**Impoundment**			54.95
Hypseleotris spp.	0.71	206.00	2.33	22.22	
Gambusia holbrooki	0.00	60.50	0.96	33.75	
Perca fluviatilis	0.00	2.00	4.39	44.22	
Retropinna semoni	116.57	38.50	1.10	52.68	
Maccullochella macquariensis	2.57	0.00	1.05	60.06	
Misgurnus anguillicaudatus	0.00	6.00	0.96	66.53	
Macquaria ambigua	2.00	2.00	1.08	72.59	
Cyprinus carpio	18.29	3.00	1.80	78.31	
Maccullochella peelii	1.86	0.50	1.28	83.87	

Table 3.7. Fish community parameters estimated from data collected from 28 randomly selected riverine monitoring sites within the Murrumbidgee catchment.

Site name	Altitude zone	Eco-type	Species richness	Total abundance	Total biomass (kg)	Shannon's *H*	Shannon's *J*	Proportion native species	Proportion native abundance	Proportion native biomass	Proportion recruits
Willow Isles	Lowland	'Reduced Flow'	9	131	27.092	1.56	0.71	0.89	0.85	0.53	0.16
Glen Avon – Redgum mill	Lowland	'Reduced Flow'	7	82	18.117	1.49	0.77	0.71	0.88	0.29	0.09
Wyreema	Lowland	'Reduced Flow'	5	87	14.126	1.16	0.72	0.8	0.87	0.33	0.46
Webb's Road	Lowland	'Reduced Flow'	5	154	18.658	1.04	0.65	0.8	0.83	0.57	0.38
Cookoothama	Lowland	'Reduced Flow'	5	86	0.488	0.97	0.60	0.8	0.86	0.21	0.14
Columbo 66	Lowland	Distributary	5	84	8.759	1.17	0.73	0.4	0.48	0.17	0.30
Rocky Waterhole	Lowland	Distributary	5	220	19.598	0.70	0.44	0.4	0.82	0.01	0.13
Hillas Creek	Slopes	Unregulated slopes	2	404	0.160	0.06	0.08	0	0	0	0.51
Wahroonga	Slopes	Unregulated slopes	4	38	27.544	0.96	0.70	0.25	0.05	0.19	0.11
Brungle Bridge	Slopes	Regulated slopes	3	13	13.723	0.90	0.82	0.33	0.54	0.02	0
Readymix	Slopes	Regulated slopes	3	26	46.482	0.64	0.59	0	0	0	0
Glendale	Slopes	Regulated slopes	6	115	88.013	1.17	0.65	0.67	0.65	0.12	0
Kabaragong	Slopes	Unregulated slopes	3	1303	152.584	0.51	0.46	0.33	0	0	0.29
Woolgarlo	Slopes	Impoundment	8	614	3.925	0.99	0.48	0.5	0.78	0.05	0
Coodravale	Slopes	Upland above dams	3	118	31.976	0.80	0.72	0.33	0.69	0	0.05
Willow Tree Waterhole	Upland	Upland above dams	4	36	47.217	0.46	0.33	0.5	0.08	0.10	0
Yass	Upland	Upland above dams	4	67	34.656	1.22	0.88	0.25	0.21	0	0.18
Coppin's Crossing	Upland	Upland above dams	4	182	1.608	1.08	0.78	0	0	0	0.30
Lobb's Hole	Upland	Upland above dams	2	124	1.027	0.08	0.12	0	0	0	0
Bywong	Upland	Upland above dams	3	60	22.802	0.93	0.84	0	0	0	0.18
Gudgenby River – Naas	Upland	Upland above dams	1	21	0.062	0	0	1	1	1	0
Cappawidgee	Highland	Highland	3	930	0.717	0.46	0.42	0.33	0.02	0.01	0.37
Cooma	Highland	Highland	0	0	0			0	0	0	0
Foxlow	Highland	Highland	2	6	0.871	0.45	0.65	0.5	0.17	0	0
Benbullen	Highland	Highland	3	76	0.376	0.43	0.39	0.33	0.89	0.36	0.07
Bolaro	Highland	Highland	2	39	0.039	0.57	0.82	0.5	0.74	0.95	0.05
Cotter Flats	Highland	Highland	2	109	2.770	0.43	0.62	0.5	0.16	0.10	0.19
Pether's Hut	Highland	Highland	1	1	0.006	0	0	0	0	0	0
Glen-Avon Wetland	Lowland	Wetland	4	2,827	0.734	0.54	0.39	0.5	0.20	0.27	0.145

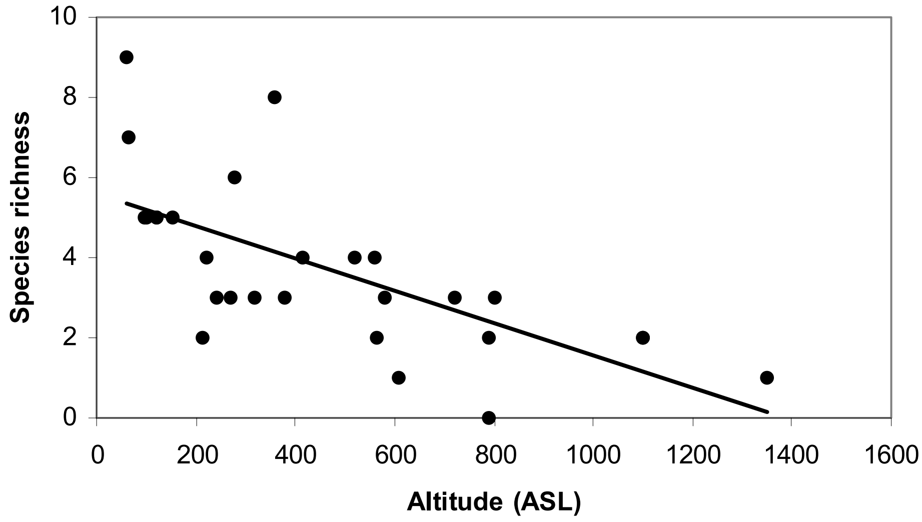
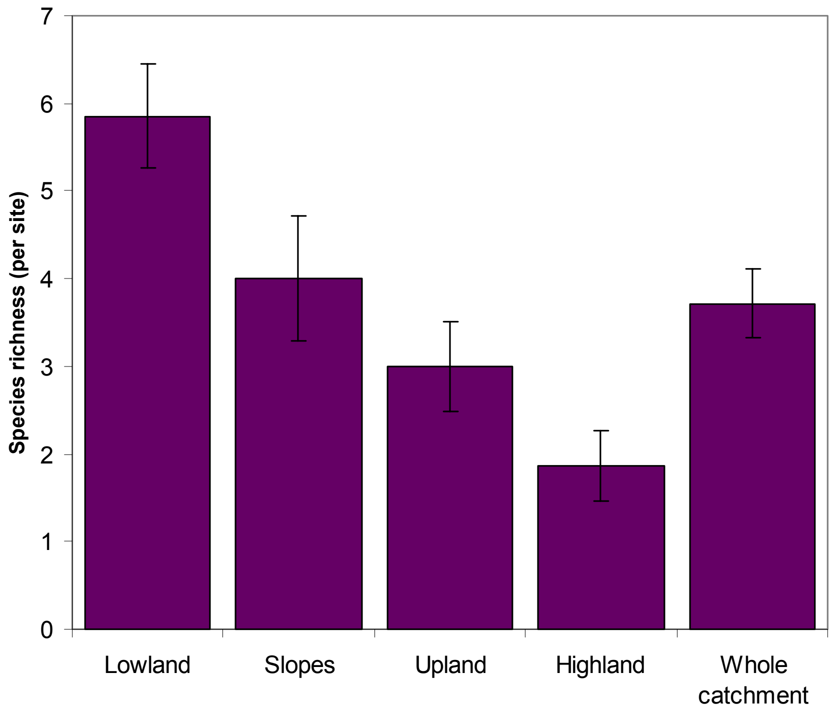


Figure 3.4. Relationship between species richness and altitude within the Murrumbidgee catchment. $R^2 = 0.44$.



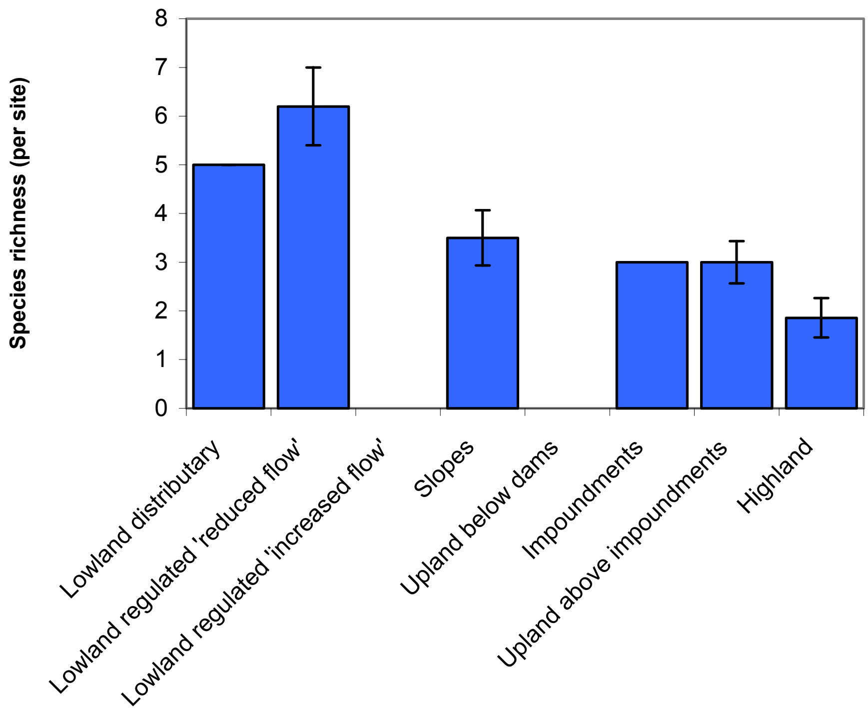
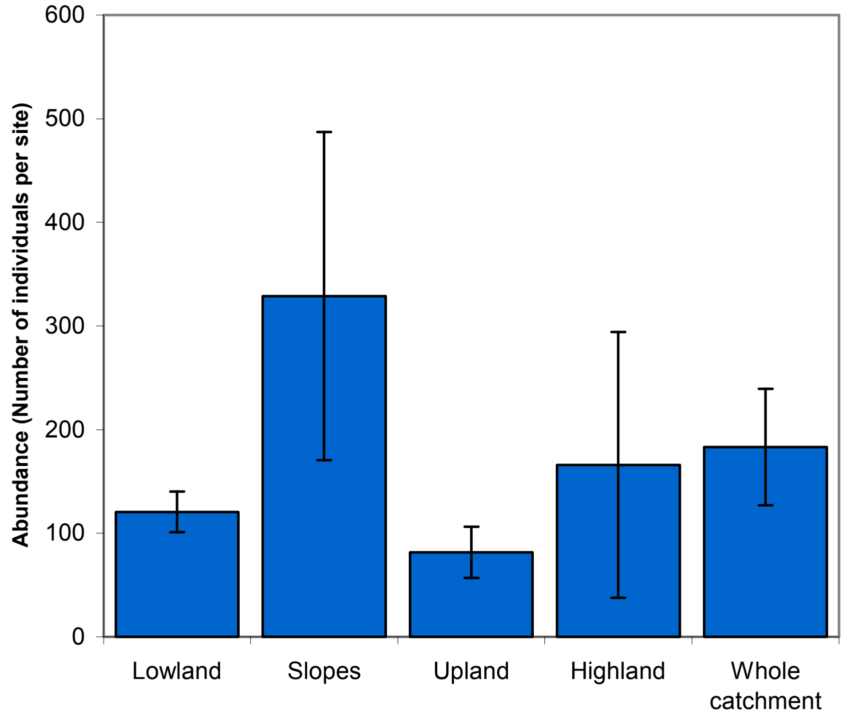


Figure 3.5. Average species richness at sites in each of the four altitude zones, the total catchment and within functional eco-types. Error bars represent the standard error. No data is presented for 'Regulated lowland 'increased flow'' or 'Upland reaches below the irrigation impoundments' habitats as no randomly selected monitoring sites were located in these eco-types.

Table 3.8. Presence/absence of fish species in each altitudinal zone. Presence of fish sampled from randomly selected monitoring sites is indicated with a •. Presence of a fish species sampled from a targeted threatened species site, but not detected at any monitoring sites within a zone are indicted with a ∅.

Species	Lowland	Slopes	Upland	Highland
Native species				
Bidyanus bidyanus	•			
Melanotaenia fluviatilis	•			
Nematalosa erebi	•			
Philypnodon grandiceps	•	•		
Retropinna semoni	•	•		
Hypseleotris spp.	•	•	•	
Macquaria ambigua	•	•	•	
Maccullochella peelii	•	∅	•	
Gadopsis marmoratus	∅	•		
Maccullochella macquariensis	∅	•	∅	
Philypnodon sp. 1		•		
Galaxias olidus			•	•
Gadopsis bispinosus				•
Macquaria australasica				∅
Alien species				
Perca fluviatilis	•	•	•	
Misgurnus aunguillicaudatus		•	•	
Oncorhynchus mykiss		•	•	•
Salmo trutta		•	∅	•
Carassius auratus	•	•	∅	•
Cyrpinus carpio	•	•	•	•
Gambusia holbrooki	∅	•	•	•



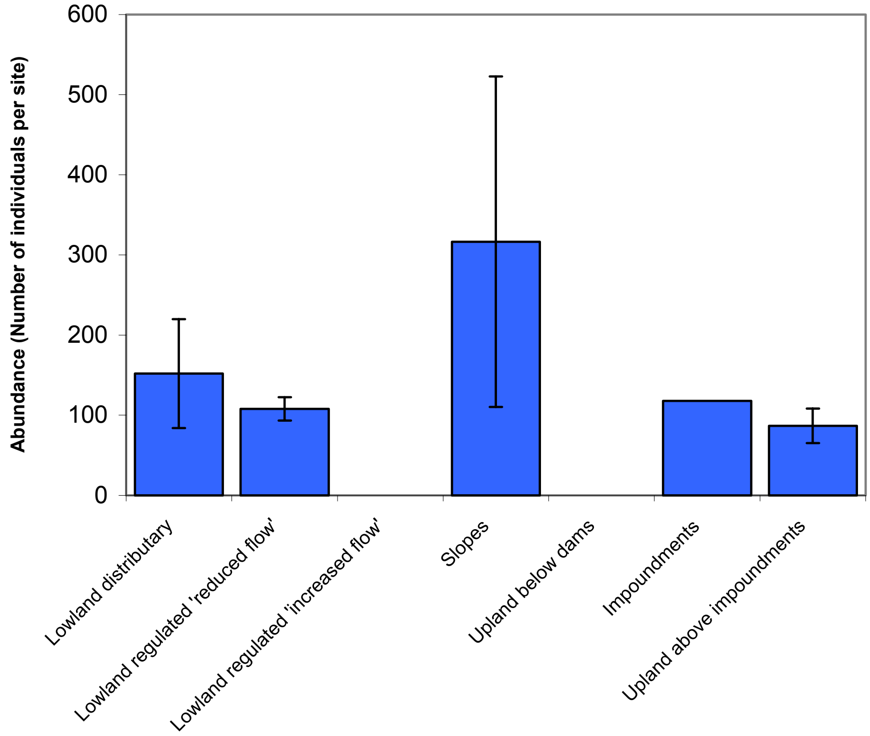


Figure 3.6. Average number of individuals at sites in each of the four altitude zones, the total catchment and within functional eco-types. Error bars represent the standard error. No data is presented for 'Regulated lowland 'increased flow'' or 'Upland reaches below the irrigation impoundments' habitats as no randomly selected monitoring sites were located in these eco-types.

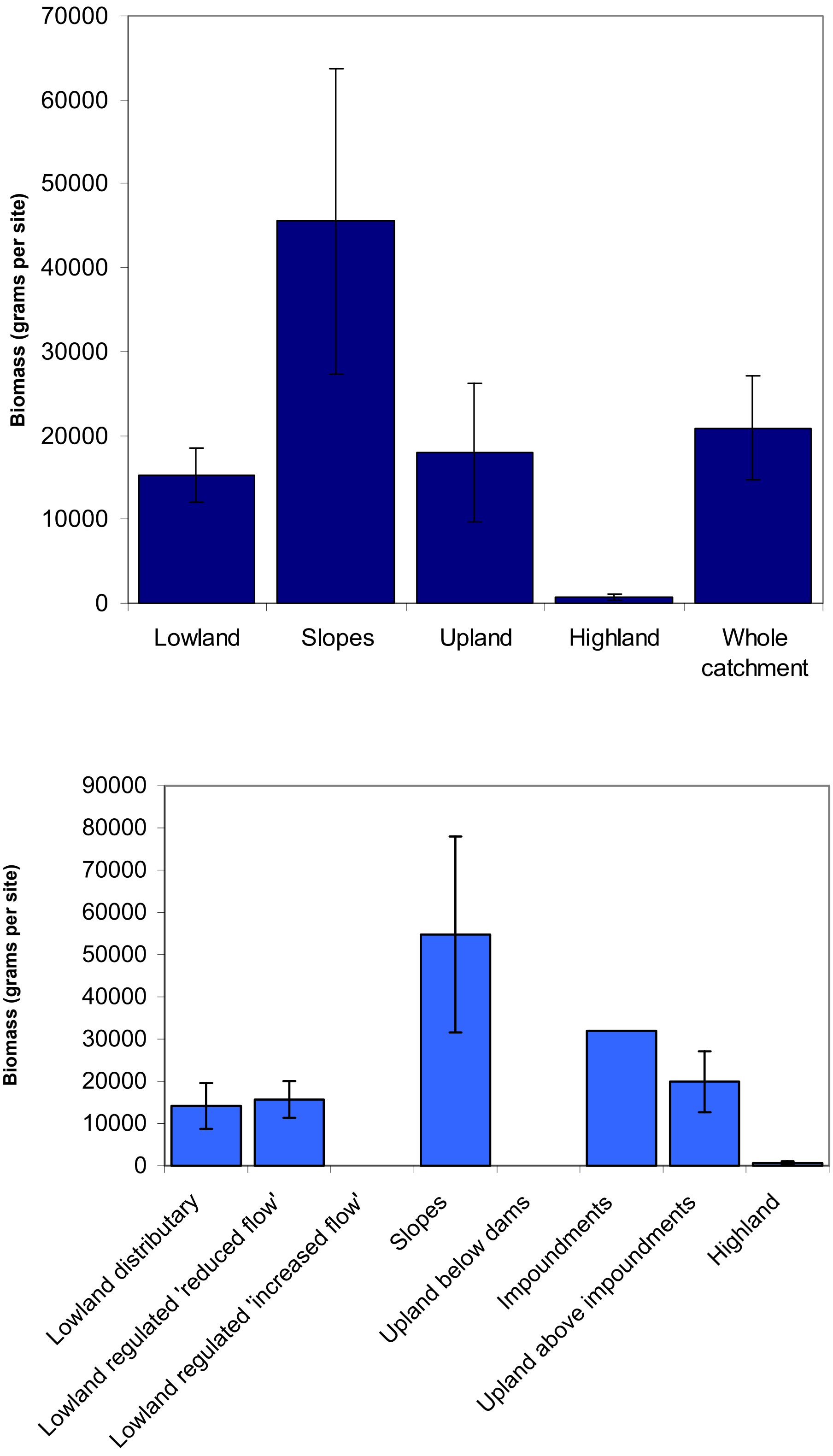


Figure 3.7. Average total biomass estimated at sites in each of the four altitude zones, the total catchment and within functional eco-types. Error bars represent the standard error. No data is presented for 'Regulated lowland 'increased flow'' or 'Upland reaches below the irrigation impoundments' habitats as no randomly selected monitoring sites were located in these eco-types.

3.3.5.4. *Shannon's Diversity H and evenness J*

Average fish community diversity across the whole catchment, estimated using Shannon's diversity index (H) was low (H = 0.72). Eighty-three percent of the fish sampled throughout the catchment belonged to just four species; Eastern gambusia (49%), common carp (13%), Australian smelt (13%) and carp-gudgeons (8%) (Figure 3.8). The proportions were very different when calculated for biomass as three of these common species are very small. With biomass, carp vastly dominated the fish community comprising 87% of total fish biomass in the catchment (Figure 3.8).

H decreased significantly with altitude (H = 1.10 - 0.0008(altitude), R^2 = 0.62, $F_{1,26}$ = 16.48, p = 0.0004) (Figure 3.9). Although evenness (J) also declined with altitude, the relationship was not significant ($F_{1,26}$ = 3.01, p = 0.095).

Differences in community diversity within zones reflected these relationships (Figures 3.10 and 3.11). Shannon's diversity H differed significantly between altitude zones (χ^2_3 = 13.13, p = 0.0044) and eco-types (χ^2_5 = 13.87, p = 0.0165). In contrast evenness J did not differ between altitude zones (χ^2_3 = 2.36, p = 0.5017) or eco-types (χ^2_5 = 2.88, p = 0.718). Consequently, the significant decrease in community diversity with altitude is being driven largely by the significant decrease in species richness, rather than changes in the evenness.

3.3.5.5. *Proportion native fish*

The relationships described above all tested population parameters calculated for the total fish community, including alien species. In order to assess the condition of native fish communities, these analyses were repeated using the proportion of the total species richness, abundance and biomass, which were native fish species.

There were no significant relationships between the proportion of native species ($F_{1,26}$ = 3.54, p = 0.071), the proportion of native individuals ($F_{1,26}$ = 3.93, p = 0.058) or the proportion of native biomass ($F_{1,26}$ = 0.03, p = 0.87) and altitude. However, there were significant differences between the proportion of species (χ^2_3 = 8.72, p = 0.0333) and individuals (χ^2_3 = 9.25, p = 0.0262) that were native between altitude zones, but not the proportion of biomass (χ^2_3 = 6.67, p = 0.0831). These relationships were also consistent for eco-types where there were significant differences between the proportion of native species (χ^2_5 = 11.39, p = 0.0402) and individuals (χ^2_5 = 11.39, p = 0.0442) but not proportion native biomass (χ^2_5 = 8.51, p = 0.1302).

The lowland altitude zone was the only part of the basin with more native than alien species per site. The lowland altitude zone also had a greater proportion of native individuals than the remaining zones (apart from the impoundment site: Woolgarlo). However, in this case, both the lowland distributary and 'reduced flow' regulated lowland eco-types had higher proportions (Figure 3.13).

3.3.5.6. *Proportion recruits*

There were no significant differences between altitude zones (χ^2_3 = 4.46, p = 0.2162) or between functional eco-types (χ^2_5 = 5.29, p = 0.3812) in the proportion of new recruits in the population (Figure 3.15).

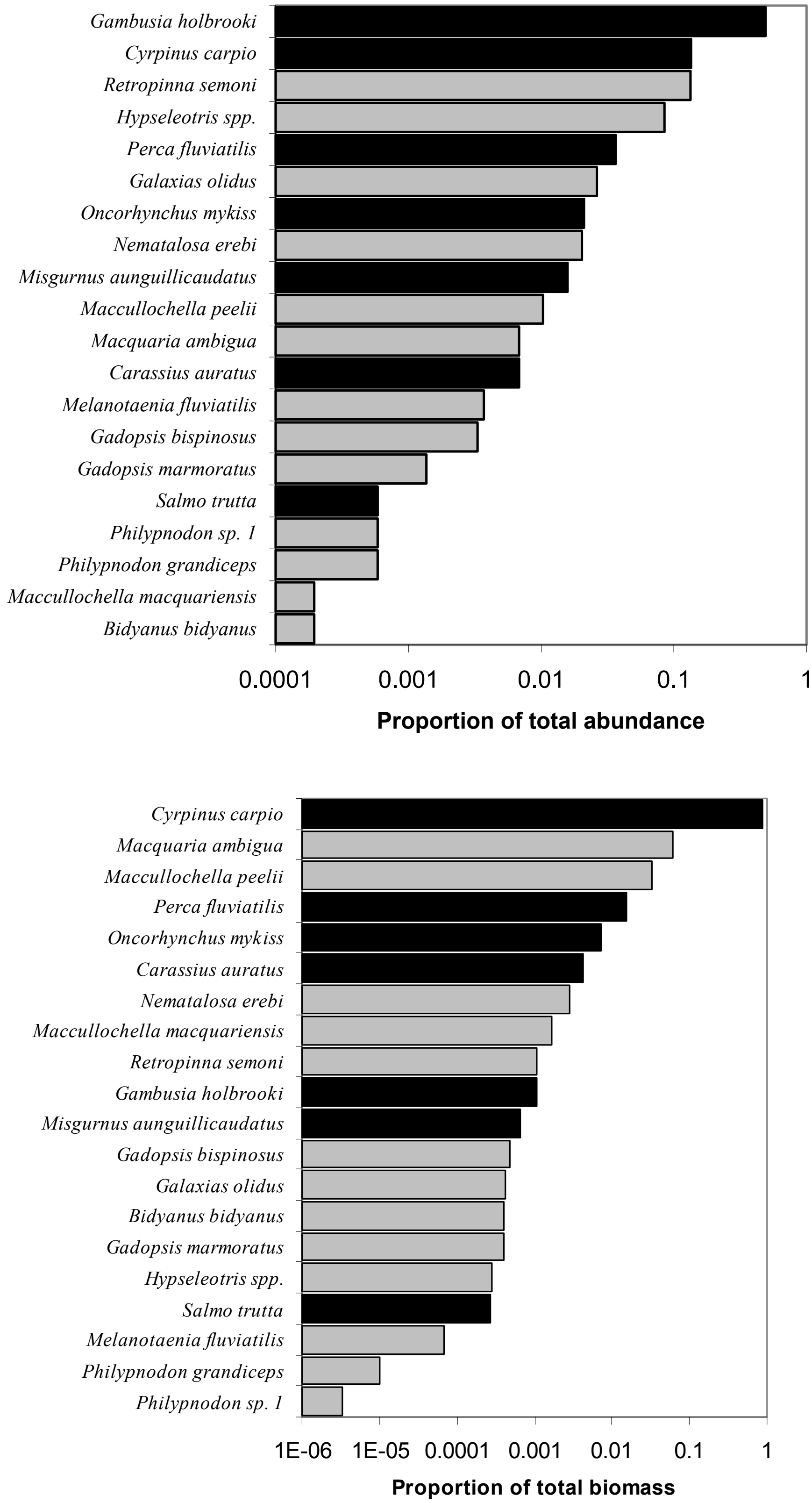


Figure 3.8. Proportions of each species of the total number of individuals and to total biomass ($\log_{10}$ scale) sampled throughout the catchment. Black: Alien species. Grey: Native species.

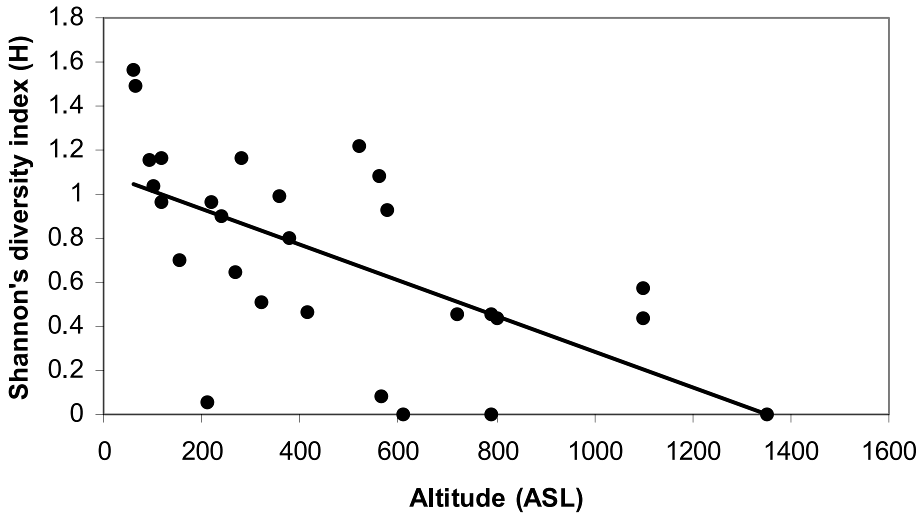


Figure 3.9. Relationship between fish community diversity (*H*) and altitude within the Murrumbidgee catchment. $R^2 = 0.32$.

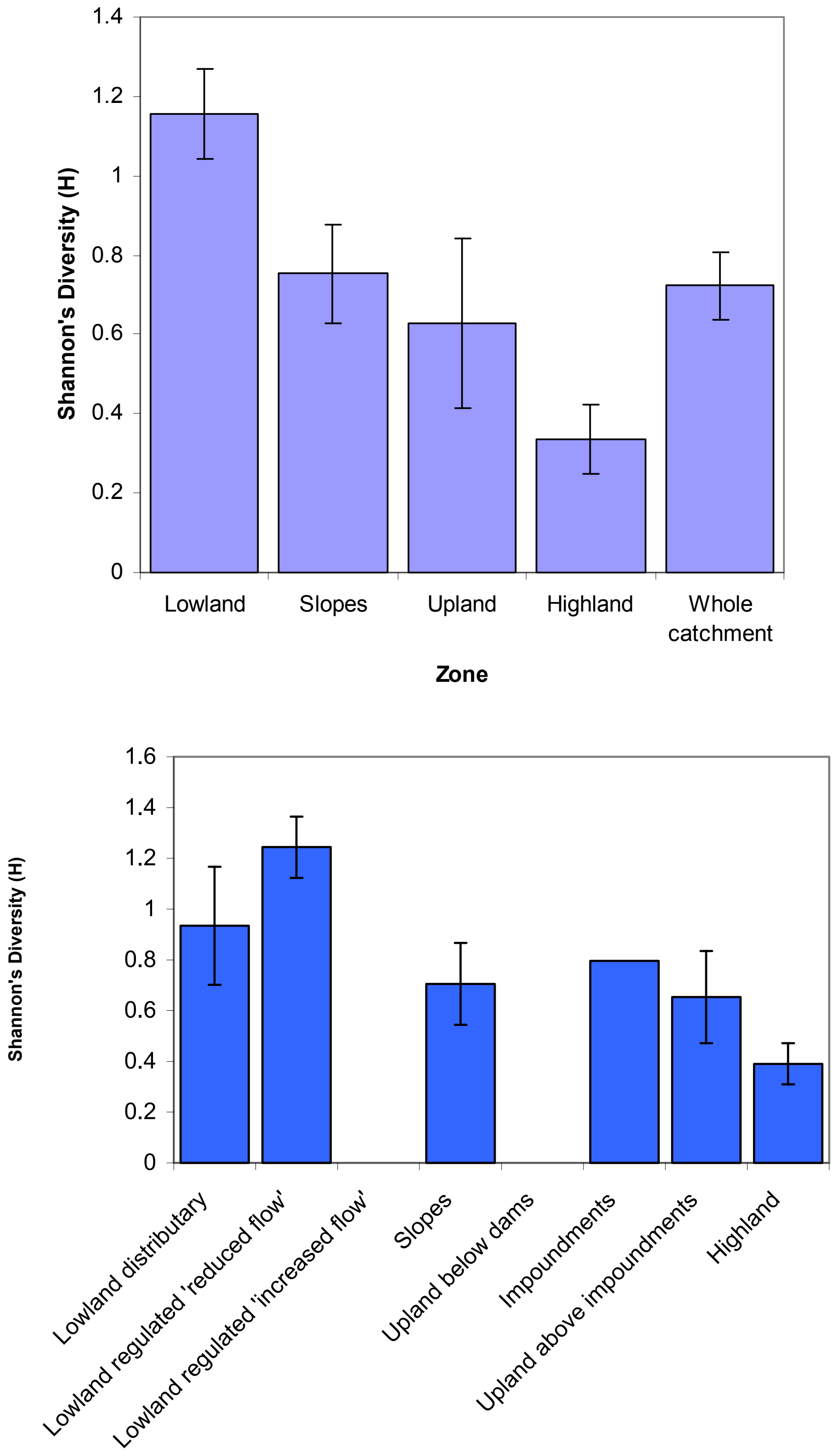


Figure 3.10. Average Shannon's diversity (*H*) at sites in each of the four altitude zones, the total catchment and within functional eco-types. Error bars represent the standard error. No data is presented for 'Regulated lowland 'increased flow'' or 'Upland reaches below the irrigation impoundments' habitats as no randomly selected monitoring sites were located in these eco-types.

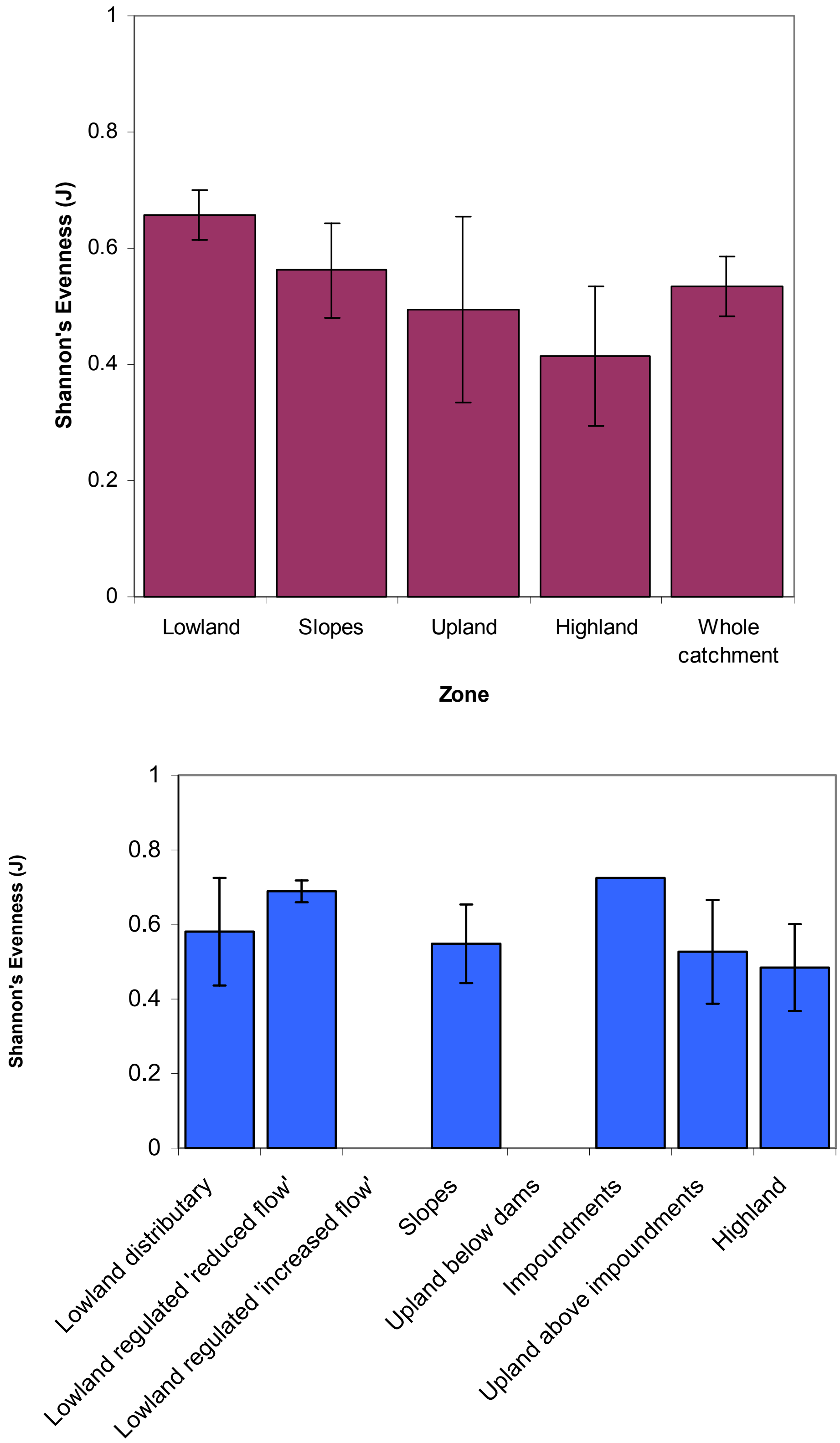


Figure 3.11. Average Shannon's evenness (*J*) at sites in each of the four altitude zones, the total catchment and within functional eco-types. Error bars represent the standard error. No data is presented for 'Regulated lowland 'increased flow'' or 'Upland reaches below the irrigation impoundments' habitats as no randomly selected monitoring sites were located in these eco-types.

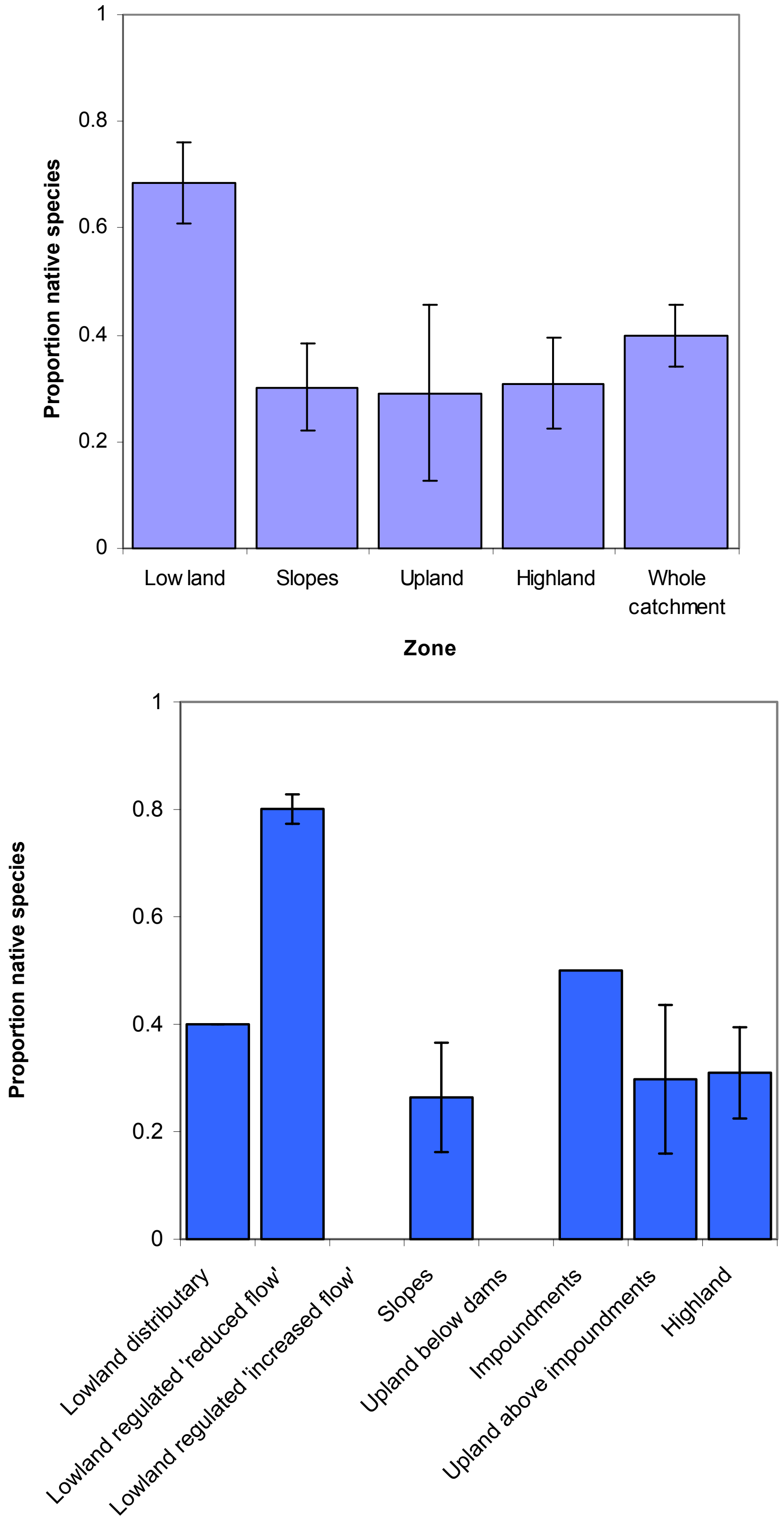


Figure 3.12. Average proportion of species which are native at sites in each of the four altitude zones, the total catchment and within functional eco-types. Error bars represent the standard error. No data is presented for 'Regulated lowland 'increased flow'' or 'Upland reaches below the irrigation impoundments' habitats as no randomly selected monitoring sites were located in these eco-types.

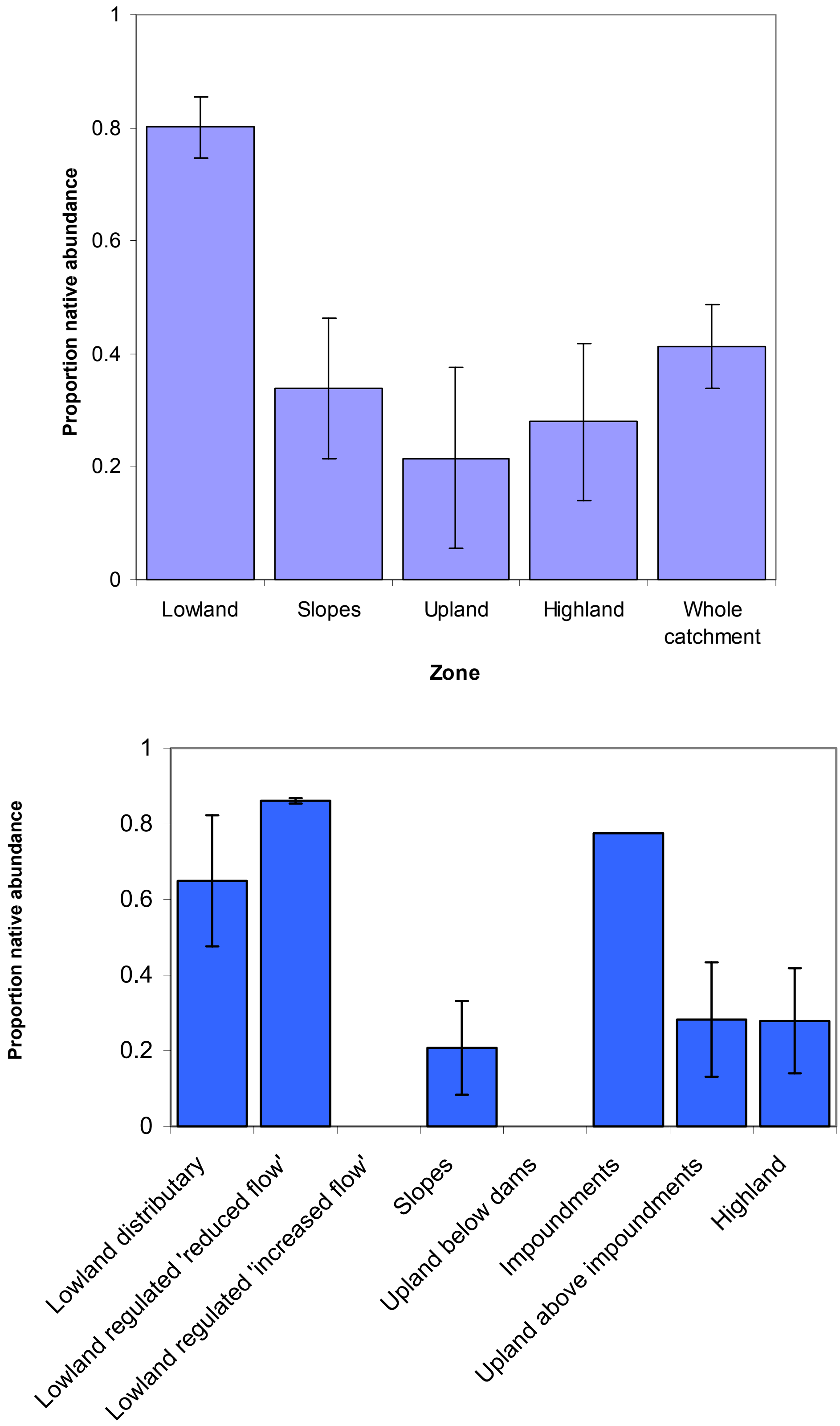


Figure 3.13. Average proportion of total number of individuals which are native at sites in each of the four altitude zones, the total catchment and within functional eco-types. Error bars represent the standard error. No data is presented for 'Regulated lowland 'increased flow'' or 'Upland reaches below the irrigation impoundments' habitats as no randomly selected monitoring sites were located in these eco-types.

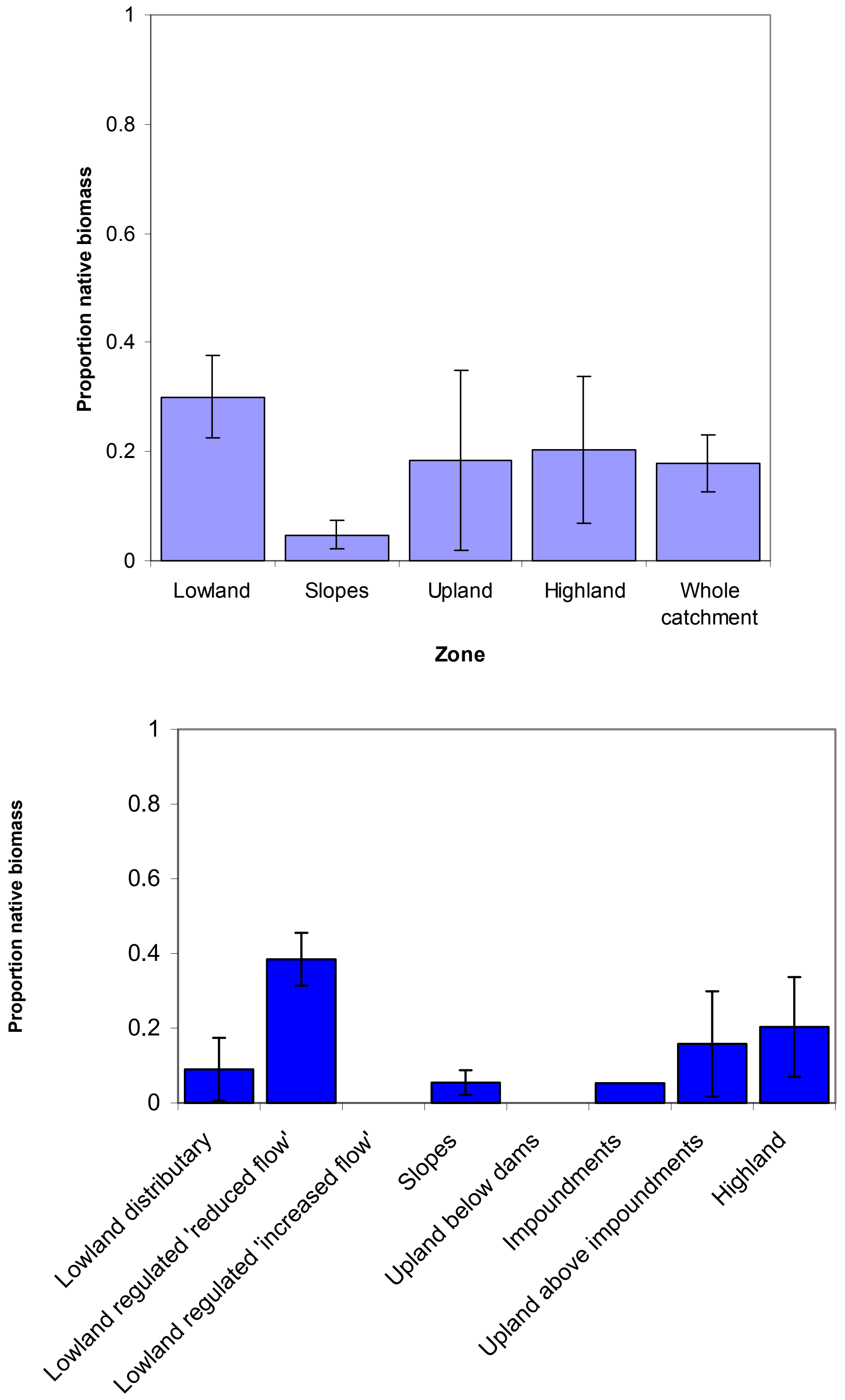


Figure 3.14. Average proportion of total biomass which are native fish at sites in each of the four altitude zones, the total catchment and within functional eco-types. Error bars represent the standard error. No data is presented for 'Regulated lowland 'increased flow'' or 'Upland reaches below the irrigation impoundments' habitats as no randomly selected monitoring sites were located in these eco-types.

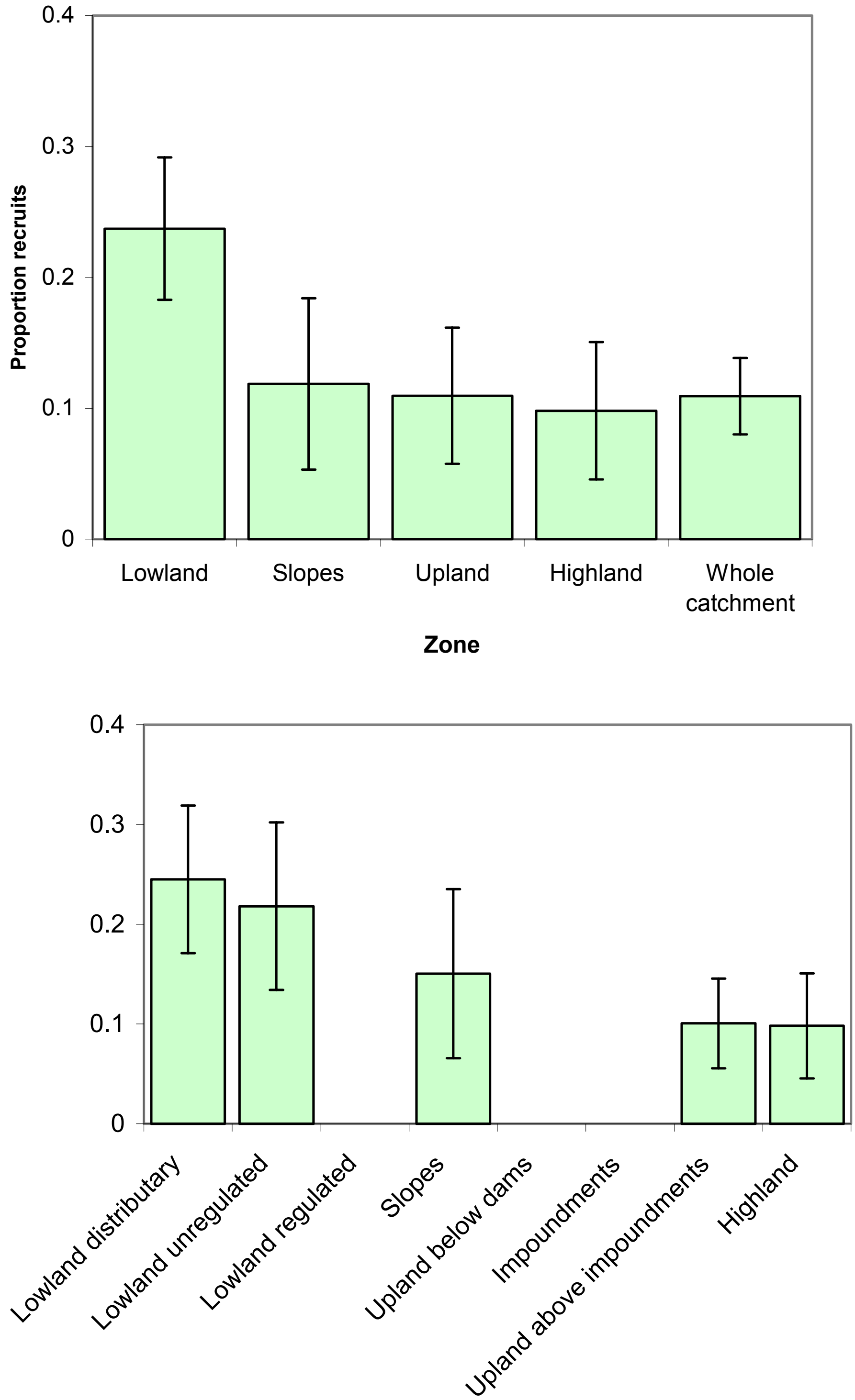


Figure 3.15. Average proportion of the total catch which are new recruits at sites in each of the four altitude zones, the total catchment and within functional eco-types. Error bars represent the standard error. No data is presented for 'Regulated lowland 'increased flow'' or 'Upland reaches below the irrigation impoundments' habitats as no randomly selected monitoring sites were located in these eco-types.

3.3.5.7. *Power analyses*

Power analysis indicated a range of sensitivities across the four altitude zones and among population parameters (Table 3.9). An average of ~50% change in parameters is required in order to have a high probability of detection across the whole catchment. Analyses in the lowlands zone are most sensitive due to the lower variability between samples in this zone. Sensitivity declines in the slopes zone and again in the upland and highland zones.

A change of two species is sufficient to detect a significant change in species richness across all zones (Table 3.9). A change of between 52 and 448 individuals is required to detected a change in abundance (Table 3.9). A change of between 1 and 51 kg is required in order to detect a change in biomass (Table 3.9). Shannon's diversity index and evenness index must change by at least 0.52 and 0.39 respectively to be statistically detectable in all altitude zones (Table 3.9). Changes in all three population parameters based on the proportion of native fish are detectable if the change is greater than 0.40 (Table 3.9). This corresponds to a 19% to 250% improvement on current condition. An increase in the proportion of new recruits of between 15 and 18% is also detectable.

Table 3.9. Minimum detectable change in population parameters in each of the altitude zones. Percentage values reflect the minimum detectable change as a percentage of the benchmark value identified from this study. The power analysis assumed the same sampling strategy described in this benchmarking report with $\alpha = 0.05$ and $\beta = 0.8$.

	Lowland	**Slopes**	**Upland**	**Highland**	**Whole catchment**
Species richness	± 1.6 (28%)	± 2.0 (58%)	± 1.3 (48%)	± 1.1 (61%)	± 1.1 (30%)
Total abundance (individuals)	± 52 (46%)	± 448 (135%)	± 60 (85%)	± 339 (217%)	± 157 (86%)
Total biomass (kg)	± 8.6 (59%)	± 51.5 (112%)	± 20.2 (129%)	± 1.0 (153%)	± 17.4 (83%)
Shannon's *H*	± 0.30 (27%)	± 0.35 (46%)	± 0.52 (95%)	± 0.20 (54%)	± 0.40 (53%)
Shannon's *J*	± 0.11 (18%)	± 0.23 (40%)	± 0.39 (91%)	± 0.29 (62%)	± 0.14 (25%)
Proportion native (species richness)	± 0.20 (31%)	± 0.23 (74%)	± 0.40 (157%)	± 0.22 (77%)	± 0.16 (40%)
Proportion native (abundance)	± 0.14 (19%)	± 0.35 (103%)	± 0.39 (209%)	± 0.37 (140%)	± 0.20 (50%)
Proportion native (biomass)	± 0.20 (70%)	± 0.07 (147%)	± 0.40 (250%)	± 0.35 (184%)	± 0.15 (82%)
Proportion recruits	± 0.15 (64%)	± 0.18 (155%)	± 0.15 (133%)	± 0.15 (150%)	± 0.58 (58%)

3.4. Discussion

Following substantial sampling effort, only 62% of native species and 64% of alien species known to have existed in the Murrumbidgee catchment were sampled in 2004. Although a substantial number of species were not detected, this program adequately sampled the fish community present, as 20 of the 21 taxa sampled had been collected from the initial 28 randomly selected monitoring sites. Despite sampling at an additional 22 targeted sites, only a single additional species, Macquarie perch, was collected (Table 3.2).

It was not unexpected that many native species were not found. The threatened olive perchlet, southern purple-spotted gudgeon and southern pygmy perch had not been recorded in the Murrumbidgee catchment for several decades and Murray hardyhead have not been detected for nine years. The three vagrant species are, by definition, not often present in the catchment and as a result were not included in the historical species list and hence did not contribute to the calculation. Of the alien species not detected, tench has not been recorded in the Murrumbidgee for 24 years, and the other two species, Atlantic salmon and brook charr only exist as stocked, non self-sustaining populations. Currently, Atlantic salmon are only likely to be present in Burrinjuck Dam and brook char are only likely to be present in Dry Dam (near Cabramurra) The non-endemic climbing galaxias have only been recorded very recently (2002) in the upper Tumut River catchment where no monitoring sites were located. The most informative absences from samples were the failure to detect the fly-specked hardyhead, Murray galaxias and freshwater catfish. Fly-specked hardyheads are generally not considered a rare species in the lower Murrumbidgee, with reasonable numbers being detected near Balranald by Baumgartner (2003) and Baumgartner (2004). In contrast, Murray galaxias have not been detected in the Murrumbidgee catchment since 1971 (Table 1.1) and only one freshwater catfish has been sampled by NSW Fisheries since 1994 (Yanco Creek 2000: Baumgartner, unpublished data). Both species are likely to warrant threatened status in the Murrumbidgee catchment. As Macquarie perch were not detected at any of the randomly selected monitoring sites, it also tallies as an absent species for the benchmarking process despite the fact that we found one individual at one of the targetted threatened species sampling sites.

Assuming that the sampling strategy was sufficiently intensive, it appears that the native fish community of the Murrumbidgee catchment has suffered the loss and/or very low abundance of eight of the 21 native taxa known to previously contribute to the Murrumbidgee catchments fish community (it had lost a ninth, trout cod, which were subsequently reintroduced into the Murrumbidgee following release of captive bred individuals). This degradation is also emphasised by the large number of alien fish species present in the catchment (33% of the species richness), their high relative abundance (70.77% of the total number of individuals) and even higher relative biomass (89.84% of the total biomass) at randomly selected monitoring sites. Further, no native species at all were sampled from 7 of the 28 (25%) monitoring sites, whereas alien fishes were only absent from 2 (7%).

Distinct fish community units within the catchment were difficult to detect, largely because the variance between sites increased with increasing altitude, making statistically significant differences difficult to detect. The fish community at sites in the lowlands were very consistent whereas sites at higher altitudes were characterised by various combinations of only a small number of species. Apart from the Cooma site, the remaining sites were separated into high altitude sites where carp were absent (24% of sites) and lower altitude sites were carp were present (73% of sites). The carp-free sites could be further broken down into those dominated by native galaxias (14%) and those dominated by alien trout (10%). Sites with carp were divided into those where native fish were still common or dominant (34%), which were primarily in the lowland areas, and those where native fish were rarer of absent (39%), which were primarily in the slopes and upland zones. This suggests that much of the distinction between sites was driven by the presence and abundance of alien fishes rather than on functional attributes of the habitat, although altitude did impact on species composition with high altitude fish species being separated from lower altitude species. This was also observed by Gehrke and Harris (2000) who recognised a distinct montane fish community dominated by introduced trout, gambusia and mountain galaxiids.

Of the fish community parameters assessed some exhibited significant relationships with altitude which is a primary environmental parameter thought to drive many patterns in fish distribution within catchments (MDBC 2004*a*). Many studies have demonstrated that the usual downstream increase in species richness occurs mostly through addition of new species rather than by replacement of species that occur only in more upstream reaches (Sheldon 1968; Hocutt and Stauffer 1975; Evans and Noble 1979; Lake 1982; Beecher *et al*. 1988; Jones *et al.* 1990; Rahel and Hubert 1991; Paller 1994). However, Gehrke and Harris (2000) and other NSW Fisheries data from the Murrumbidgee catchment suggest that, although species richness does increase rapidly with distance from the source, there is substantial species replacement in the upland and slopes zones. This strongly suggests that fish rehabilitation activities should be concentrated in these two sections of the catchment, although the lowland zone should not be completely ignored in terms of management intervention.

4. STATUS OF INDIVIDUAL SPECIES IN THE MURRUMBIDGEE CATCHMENT IN 2S04

4.1. Introduction

Although assessments of fish community structure are informative for definition of management zones and fish community health, the status of individual components of the fish communities, their species, is also of management interest. For example, if a decline in species richness is observed, it is necessary to identify which species are being lost.

Three aspects of an individual species' status are their abundance within the ecosystem, how widespread or restricted their distribution may be and the level of recruitment within the population. Changes in these three parameters may affect the status of the population. For instance, an increase in the abundance of a species suggests that habitat condition has improved for adults of that species, or an increase in recruitment suggests that suitable spawning cues and rearing habitats are being created. However, the most useful information would be gained from situations were only one of the three parameters changed whilst the other two remained stable. Changes in abundance alone would indicate changes in the habitat condition leading to altered survival of adult fish, changes in recruitment alone would indicate changes in spawning cues and nursery habitats, and changes in distribution alone would indicate dispersal or localised disturbances.

Species could be considered secure only if all three of these factors remained stable or increased. However if any one of these factors declined significantly, that species could be considered at risk.

4.2. Methods

Site selection and sampling followed the protocols and procedures outlined in chapter 2. Only data from the 28 monitoring sites were used to benchmark the current status of fish species in each altitude zone and eco-type. As only a single randomly selected wetland at Glen-Avon Redgum mill was sampled, the data is presented although little can be interpreted from the results. Further replicate sampling of wetlands would be required to make inferences about the condition of fish species in these habitats.

Abundance was calculated as both the proportion of individuals and the proportion of total biomass of the sample. Each of these is presented separately. The distribution of each species was calculated as the proportion of sites at which that species was sampled. Size limits used to estimate the proportion of new recruits for each species were based on either the size at one year or the size at sexual maturity for species that reach sexual maturity at less than one year of age as presented in Table 3.1.

4.3. Results and Discussion

4.3.1. Proportion of catch

The three most numerous species in the catchment were eastern gambusia, carp and, Australian smelt (Table 4.1). However there was substantial variation amongst zones and amongst eco-types (Table 4.1). Eastern gambusia also dominated the single wetland community sampled, making up 72% of the catch (Table 4.1).

Excluding species not sampled at monitoring sites during this survey, the two rarest taxa were silver perch and trout cod (both 0.02% of catch) (Table 4.1). Macquarie perch was the only species added to the species list after sampling an additional 22 targeted threatened species sites. Using the full set of 50 sites sampled (28 random plus 22 targeted), silver perch and Macquarie perch were the two rarest species (both 0.01% of the total catch).

4.3.2. Proportion of biomass

Carp dominated the fish biomass of the catchment, contributing 87% of the total biomass (Table 4.2). Golden perch (6%) and Murray cod (3%) had the second and third highest biomass (Table 4.2). These three large species together contributed 96% of the total fish biomass in the catchment. Eastern gambusia and Australian smelt, which contributed 49% and 13% of abundance, only contributed 0.1% of the total biomass due to their small size. However, in the single wetland sampled, which was largely occupied by small fish, gambusia contributed 60% of the biomass (Table 4.2).

4.3.3. Proportion of sites

The most widespread species was carp occurring at 71% of sites sampled and being found in every zone and eco-type sampled except for wetlands (although they were captured in wetlands associated with targeted threatened species sites) (Table 4.3). The next most widespread species was eastern gambusia occurring at 39% of sites (Table 4.3). However, this species was not sampled from any lowland riverine sites, but was abundant in the lowland wetland. The third most widespread species was Australian smelt occurring at 36% of sites. However, this species was restricted to the lowland and slopes zones (Table 4.3).

The least widespread species were: silver perch, two-spined blackfish, river blackfish, trout cod and dwarf flat-headed gudgeons, each being found at only one site (Table 4.3).

As Macquarie perch were sampled at one targeted site but no randomly selected ones, they can be considered even less widespread than the above species. Other species only sampled at one of the full set of 50 sites sampled (28 random and 22 targeted), and therefore just as restricted in distribution as Macquarie perch were silver perch, two-spined blackfish and dwarf flat-headed gudgeon. In contrast, both trout cod and river blackfish were sampled at several targeted sites and are therefore slightly more widespread.

4.3.4. Proportion recruits

Recruits made up 15% or more of the sampled populations of five fish species: carp (39%), two-spined blackfish (35%), bony herring (30%), Murray cod (21%) and goldfish (15%)(Table 4.4). Carp recruits were sampled in all four altitude zones, with all carp sampled in the highland zone being young-of-year fish. Two-spined blackfish and bony herring were only found in one site and one zone respectively, yet appear to be recruiting populations in those areas. Murray cod recruits were only found in the lowland zones and no recruitment was detected in the distributary streams or within the upland zone. Goldfish recruits were detected in the lowland distributaries and in floodplain wetlands. No recruits were detected for several species: silver perch, river blackfish, mountain galaxias, trout cod, Murray-Darling rainbowfish, flat-headed gudgeons, dwarf flat-headed gudgeons or brown trout.

Table 4.1. Proportion of each species of the total catch within altitude zones, the single wetland site and the whole catchment. Data presented was collected from randomly selected monitoring sites only. The total was calculated for Riverine sites only and excludes the wetland sample.

Altitude zone	**Lowland**	**Slopes**	**Upland**	**Highland**	**Wetland**	**Total**	**Rank (total)**
Bidyanus bidyanus	0.001	0	0	0	0	<0.001	19
Carassius auratus	0.014	0.007	0	0.004	<0.001	0.007	11
Cyprinus carpio	0.166	0.136	0.165	0.096	0	0.135	2
Gadopsis bispinosus	0	0	0	0.015	0	0.003	14
Gadopsis marmoratus	0	0.003	0	0	0	0.001	15
Galaxias olidus	0	0	0.043	0.098	0	0.026	6
Gambusia holbrooki	0	0.598	0.282	0.699	0.799	0.492	1
Hypseleotris spp.	0.009	0.157	0.029	0	0.193	0.085	4
Macquaria ambigua	0.027	0.004	0.004	0	0	0.007	11
Maccullochella macquariensis	0	<0.001	0	0	0	<0.001	19
Maccullochella peelii	0.062	0	0.002	0	0	0.010	10
Melanotaenia fluviatilis	0.023	0	0	0	0	0.004	13
Misgurnus anguillicaudatus	0	0.005	0.141	0	0	0.016	9
Nematalosa erebi	0.123	0	0	0	0	0.020	8
Oncorhynchus mykiss	0	0.002	0.004	0.087	0	0.021	7
Perca fluviatilis	0.009	0.006	0.331	0	0	0.036	5
Philypnodon grandiceps	0.002	<0.001	0	0	0	0.001	16
Philypnodon sp. 1	0	0.001	0	0	0	0.001	16
Retropinna semoni	*0.563*	0.080	0	0	0.007	0.134	3
Salmo trutta	0	<0.001	0	0.002	0	0.001	16

Table 4.2. Proportion of each species of the total biomass within altitude zones, the single wetland site and the whole catchment. Data presented was collected from randomly selected monitoring sites only. The total was calculated for riverine sites only and excludes the wetland sample.

Altitude zone	**Lowland**	**Slopes**	**Upland**	**Highland**	**Wetland**	**Total**	**Rank (total)**
Bidyanus bidyanus	0.002	0	0	0	0	<0.001	14
Carassius auratus	0.002	0.004	0	0.182	0.128	0.004	6
Cyprinus carpio	0.665	0.942	0.880	0.115	0	0.870	1
Gadopsis bispinosus	0	0	0	0.059	0	<0.001	12
Gadopsis marmoratus	0	0.001	0	0	0	<0.001	15
Galaxias olidus	0	0	0.001	0.038	0	<0.001	13
Gambusia holbrooki	0	0.001	<0.001	0.033	0.599	0.001	10
Hypseleotris spp.	<0.001	<0.001	<0.001	0	0.255	<0.001	16
Macquaria ambigua	0.158	0.040	0.030	0	0	0.061	2
Maccullochella macquariensis	0	0.003	0	0	0	0.002	8
Maccullochella peelii	0.154	0	0.015	0	0	0.033	3
Melanotaenia fluviatilis	<0.001	0	0	0	0	<0.001	18
Misgurnus anguillicaudatus	0	<0.001	0.003	0	0	0.001	11
Nematalosa erebi	0.015	0	0	0	0	0.003	7
Oncorhynchus mykiss	0	0.004	0.002	0.565	0	0.007	5
Perca fluviatilis	<0.001	0.004	0.068	0	0	0.015	4
Philypnodon grandiceps	<0.001	<0.001	0	0	0	<0.001	19
Philypnodon sp. 1	0	<0.001	0	0	0	<0.001	20
Retropinna semoni	0.003	0.001	0	0	0.018	0.001	9
Salmo trutta	0	<0.001	0	0.008	0	<0.001	17

Table 4.3. Proportion of sites within altitude zones, the single wetland site and the whole catchment at which each species was sampled. Data presented was collected from randomly selected monitoring sites only. The total was calculated for riverine sites only and excludes the wetland sample.

Altitude zone	**Lowland**	**Slopes**	**Upland**	**Highland**	**Wetland**	**Total**	**Rank (total)**
Bidyanus bidyanus	0.143	0	0	0	0	0.036	16
Carassius auratus	0.429	0.125	0	0.143	1	0.179	8
Cyprinus carpio	1	1	0.667	0.143	0	0.714	1
Gadopsis bispinosus	0	0	0	0.143	0	0.036	16
Gadopsis marmoratus	0	0.125	0	0	0	0.036	16
Galaxias olidus	0	0	0.167	0.571	0	0.179	8
Gambusia holbrooki	0	0.625	0.667	0.286	1	0.393	2
Hypseleotris spp.	0.429	0.375	0.167	0	1	0.25	5
Macquaria ambigua	0.571	0.25	0.167	0	0	0.25	5
Maccullochella macquariensis	0	0.125	0	0	0	0.036	16
Maccullochella peelii	0.857	0	0.167	0	0	0.25	5
Melanotaenia fluviatilis	0.286	0	0	0	0	0.071	13
Misgurnus anguillicaudatus	0	0.125	0.167	0	0	0.071	13
Nematalosa erebi	0.714	0	0	0	0	0.179	8
Oncorhynchus mykiss	0	0.125	0.167	0.286	0	0.143	11
Perca fluviatilis	0.286	0.375	0.667	0	0	0.321	4
Philypnodon grandiceps	0.143	0.125	0	0	0	0.071	13
Philypnodon sp. 1	0	0.125	0	0	0	0.036	16
Retropinna semoni	*1*	0.375	0	0	1	0.357	3
Salmo trutta	0	0.125	0	0.286	0	0.107	12

Table 4.4. Proportion of fish populations sampled that are assumed to be new recruits (young-of-year or sub-adults for species maturing in < 1 year) within altitude zones, the single wetland site and the whole catchment at which each species was sampled. Data presented was collected from randomly selected monitoring sites only. The total was calculated for riverine sites only and excludes the wetland samples.

Altitude zone	Lowland	Slopes	Upland	Highland	Wetland	Total	Rank (total)
Bidyanus bidyanus	0					0	13
Carassius auratus	0.25	0		0	0.5	0.15	5
Cyprinus carpio	0.404	0.3	0.413	1		0.394	1
Gadopsis bispinosus				0.35		0.35	2
Gadopsis marmoratus		0				0	13
Galaxias olidus			0	0		0	13
Gambusia holbrooki		0.01	0.023	0.11	0.03	0.033	12
Hypseleotris spp.	0.333	0	0		0.05	0.143	6
Macquaria ambigua	0.125	0	0			0.071	10
Maccullochella macquariensis		0				0	13
Maccullochella peelii	0.243		0			0.209	4
Melanotaenia fluviatilis	0					0	13
Misgurnus anguillicaudatus		0	0.17			0.085	8
Nematalosa erebi	0.3					0.3	3
Oncorhynchus mykiss		0	0	0.125		0.063	11
Perca fluviatilis	0.125	0	0.135			0.088	7
Philypnodon grandiceps	0	0				0	13
Philypnodon sp. 1		0				0	13
Retropinna semoni	*0.119*	0			0	0.083	9
Salmo trutta		0		0		0	13

5. TARGETED ASSESSMENT OF POPULATIONS OF THREATENED FISH SPECIES WITHIN THE MURRUMBIDGEE

5.1. Introduction

Although a process of random site selection is essential in order to make basin-wide or zone-wide statements about the status of fish communities and populations, randomisation is inadequate for monitoring the status of threatened species. This is because populations of threatened species are by definition rare, and usually only occur as discrete isolated populations. Through chance, selecting a moderate number of sampling sites in very large catchments such as the Murrumbidgee is likely to miss many or most isolated threatened species populations. As a result, the targeted sampling of known threatened species populations is required to assess changes in their status through time. However, as these samples are not randomly selected, the results obtained cannot be used to infer population status at larger spatial scales. The results from targeted sampling are location specific.

Eighteen species or populations of fish, aquatic invertebrates or marine plants are listed under the *Fisheries Management Act 1994* as threatened species. Of these seven (39%) are found, or were historically found, in the Murrumbidgee catchment. These are the trout cod and Murray hardyhead which are listed as endangered species, the western populations of olive perchlet and southern purple-spotted gudgeon which are listed as endangered populations and the silver perch, Macquarie perch and Southern pygmy perch which are listed as vulnerable. Further, the entire ecological community of the lower Murray River system, which includes the Murrumbidgee below Burrinjuck Dam and the Tumut River below Blowering Dam, as well as all their tributaries, has been listed as an endangered ecological community.

The threatened status of most of the species and populations listed in the Murrumbidgee varies between the NSW, ACT and Commonwealth legislation. Further, the two-spinned blackfish is listed as vulnerable in the ACT but not in NSW, and Murray cod are listed as vulnerable nationally but not within either NSW or the ACT. Only those species listed under the *NSW Fisheries Management Act 1994* were targeted by the surveys described in this report.

5.2. Methods

5.2.1. *Site selection and sampling procedure*

The process of selecting targeted threatened species sites for each species and the sampling procedure are described in chapter 2. Twenty-two targeted sites were sampled. Of these 21 were riverine sites and one site, Bringagee, was a wetland. Of three wetlands within 2.5km of a riverine sites (targeted threatened species sites) only the wetland adjacent to the site downstream of Berembed Weir contained water. Hence only two targeted wetlands were sampled.

5.2.2. Data analysis

The most fundamental estimate of status determined for each species was the proportion of sites sampled where species historically existed at which the species still occurs. However it is important to remember that a single snap-shot sample has a moderate probability of ‘missing’ some species, particularly those that are rare. Consequently, these data are not intended to document the existence of all remnant populations. Only to give an indication of the reduction in distribution of each species. A greater sampling effort with replication of sampling is required to provide are more conclusive result.

For those species that were detected during sampling, the number of individuals that were sampled, and the proportion of recruits at each site are reported.

To assess potential interactions threatened taxa and other fish species, the fish community at sites where species still occurred was compared to the fish community at sites no longer occupied using multivariate analysis undertaken using PRIMER 5.1.2 (Plymouth Marine Laboratory). The species under consideration was omitted from the data-set prior to analysis. Similarity matrices were created using the Bray-Curtis similarity index (Bray and Curtis 1957) using un-standardised abundance data. Data was fourth root transformed to equalise the contribution of rare and common taxa. ANOSIM (ANalysis Of SIMilarities) (Clarke 1993) was used to test for differences in fish community between sites were each species still occurred or had disappeared. Permutation tests to estimate the probability of the observed results used 5000 randomisations.

5.3. Results

5.3.1. Trout cod – Endangered (FM Act 1994)

Australian Museum records report trout cod (Figure 5.1) from 10 locations within the Murrumbidgee catchment prior to their local extinction; the Murrumbidgee River at Wagga Wagga (Lat: 35.12, Long: 147.37) in 1882, near Yass (Lat: 34.93; Long: 148.92) in 1885, the upper Murrumbidgee (Lat : 36, Long: 149) in 1906, 1908 and 1919, in the vicinity of the Burrinjuck Dam site (Lat: 35, Long: 149) in 1910, the lower end of the Murrumbidgee (Lat: 34: Long: 143) in 1920, near Narrandera (Lat: 34.75, Long: 146.55) in 1920 and 1969, agricultural canals near Yanco (Lat: 34.6, Long: 146.42) in 1932, Angle Crossing (Lat: 35.58, Long: 149.12) and Casuarina Sands in the ACT (Lat: 35.67, Long: 148.83) in 1970, Tharwa (Lat: 35.52, Long: 149.07) in the ACT in 1976. The museum also records a specimen from Narrandera in 1993 which is likely to have originated from the stocking program. Lintermans (2000*a*) reported the capture of several individuals in the Gigerline Gorge by anglers in the mid to late 1970’s. NSW Fisheries freshwater records report trout cod from the original Murrumbidgee population at Tharwa (Lat: 35.52, Long: 149.07) in 1976 (Llewellyn, 1983- same as museum specimen), and samples from stocked populations in the Cooma Weir-pool from 1990 – 1994 (Faragher *et al.*, 1993), Murrell’s Crossing in 1992, 1994 (Faragher *et al.* 1993) and 1998 (unpublished), Bendora Dam in 1993 (unpublished), Narrandera in 1991 and 1994 (unpublished), Wantabadgery in 2000 (unpublished), Lamont’s Beach in 2000 and 2001 (unpublished) and Buckingbong Station in 2002 (MDBC 2004*a*). The NSW fisheries freshwater stocking database also indicates the trout cod have been released at 12 locations in the catchment; Yanco, Narrandera, Collingullie, Wantabadgery, Gundagai, Glendale, Angle Crossing, Murrell’s Crossing, Cooma Weirpool, Adaminaby, Talbingo Dam and Bendora Dam.

Figure 5.1. The endangered trout cod (*Maccullochella macquariensis*). Photo: Nicole McKirdy.

Given the many reported capture locations in the Murrumbidgee only a sub-sample were chosen as monitoring sites. Targeted sites were Lamont's Beach, Narrandera boat-ramp, downstream of Berembed Weir, Berry Jerry Station, Pomingalarna, Wantabadgery, Gundagai, Angle Crossing, Murrell's Crossing and the Cooma weir-pool (Figure 5.2). Randomly selected monitoring sites at Lobb's Hole, Glendale, Bolaro and Yass were also locations where trout cod have been stocked or recorded in the past (Figure 5.2).

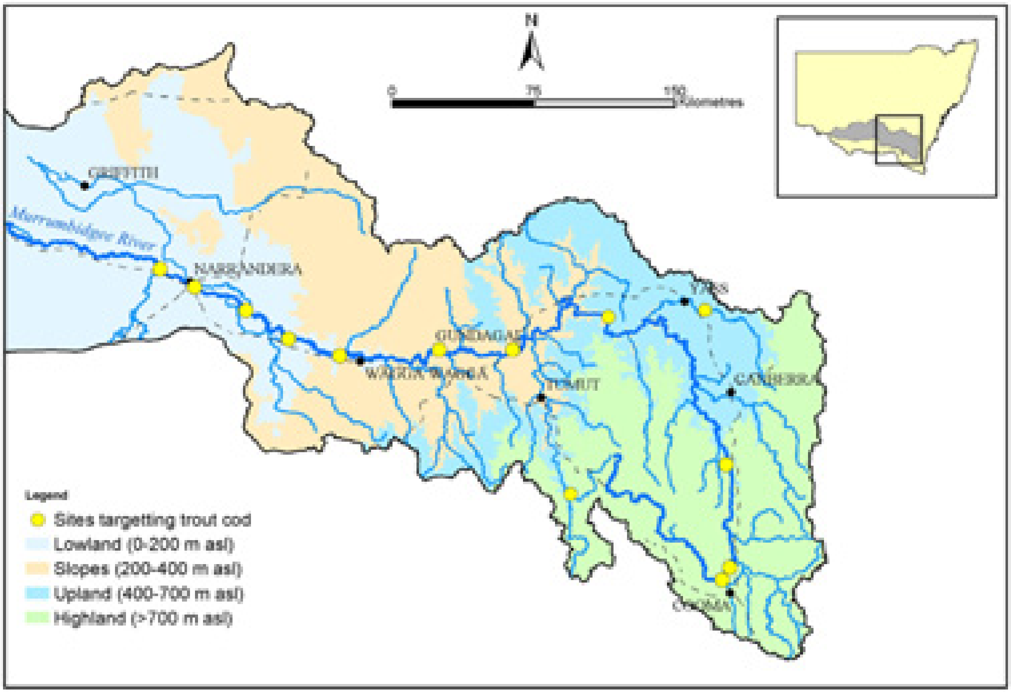


Figure 5.2. Sites sampled to monitor trout cod within the Murrumbidgee catchment.

Trout cod were sampled at seven of the 14 sites targeted, representing 50% of the sample of sites where it had previously existed. The existence of this species in the catchment is a direct result of the stocking program initiated in the Murrumbidgee in 1988, the last wild bred individual having been recorded in 1976 (Llewellyn 1983). Trout cod were targeted at all but one of the twelve stocking locations. The twelfth stocking location, Bendora Dam in the ACT, was not sampled, but a self-sustaining population of trout cod is believed to exist in that impoundment (Lintermans pers. com). Trout cod existed at all of the stocking locations in the lower part of the catchment (downstream of Burrinjuck Dam) (Lamont's Beach, Narrandera boat ramp, Berry Jerry Station, Wantabadgery, Gundagai, and Glendale) but only one stocking site in the upper catchment (Angle Crossing) which had been stocked in the previous two years (Table 5.1).

There was no significant difference between the co-occurring fish community at these sites and the fish community that occurred at sites where trout cod were not detected (ANOSIM $R = 0.163$, $p = 0.066$). However the difference approached significance and a SIMPER analysis suggests the presence of trout cod was most closely associated with an abundance of Australian smelt and golden perch, and a lower abundance of carp. Whether these associations are driven by shared habitat preferences or through direct interactions between species is unknown.

Table 5.1. Sites where trout cod were sampled, the number collected, their catch per unit effort (CPUE of electrofishing- fish per hour), the stocking history at that site and the proportion of the sample which were new recruits (less than 150 mm).

Site name	Number caught	CPUE	Stocking history (number of fingerlings and years stocked)	Proportion of new recruits
Lamont's Beach	3	3.67	53,500 between 1998 –2001	0
Narrandera Boat ramp	7	7.37	85,000 between 1996 –2000	0
Berry Jerry Station	4	5.00	59,300 between 1993 – 2001	0
Wantabadgery	4	4.13	69,500 between 1994 – 2000	0
Gundagai	1	1.30	18,500 in 1997	0
Glendale	1	1.22	35,000 between 1997-1999	0
Angle Crossing	5	7.32	62,000 between 1995-2003	0.80

Young of the year (YOY) trout cod were only collected at Angle Crossing (Table 5.1). This suggests that recruitment of the trout cod populations was limited in the 2003 breeding season. Further, there is a high probability that the all five fish collected at Angle Crossing arose from the stockings which occurred at this site in 2002 and 2003, and were not wild recruited fish (Table 5.1). This is of substantial concern given that the recovery of this endangered species is dependant on the natural recruitment and self-sustainability of the reintroduced populations.

In order to enable demonstration of natural recruitment, trout cod stocking in the lower catchment was discontinued in 2001. Due to the absence of stocking, any fish sampled in the lower Murrumbidgee found to be less than three years of age (as of the 2004 sampling for this project) can be considered wild recruits. At Narrandera, one of the seven fish was likely to be less than three years of age (as it was < 330 mm in length (sexual maturity reached from 3 years of age and at length from 330 mm (Ingram and Rimmer 1992)). At Berry Jerry Station near the Collingullie stocking site, one of the three individuals measured (one was only observed) was also likely to be less than three years old. At Wantabadgery, two of the four fish were likely to be less than three years old. And at Lamont's Beach, two of the three individuals collected were likely to be less than three years of age. In contrast, the single individual collected at Glendale was a mature fish (426 mm) that could potentially have a hatchery origin and the single individual observed at Gundagai was also a large adult fish likely to have been stocked.

Therefore, although no recruitment from the 2003 season was detected, natural recruitment over the previous two to three years appears to have occurred at a number of sites. Otolith analysis (screening for hatchery chemical batch marks and accurate ageing) of these potential wild recruits will be undertaken to provide conclusive evidence that these fish are in fact wild in origin.

Pending confirmation of this evidence, the stocking program in the lower Murrumbidgee appears to have been successful at establishing a recruiting population of trout cod in that section of the river. Demonstration of natural recruitment in at least two populations will provide the evidence warranting consideration of the down-listing of trout cod in NSW (NSW FSC, pers. com. 2004).

5.3.2. Murray hardyhead – Endangered (FM Act 1994)

An Australian Museum record reports Murray hardyhead (Figure 5.3) in Yanco Creek near Narrandera (Lat: 34.867, Long: 146.3) in 1910. A single individual was caught during the NSW Rivers Survey in 1995 at Rocky Waterholes on Bundidgery Creek (Harris and Gehrke 1997). And Llewellyn also collected Murray hardyhead from Willow Dam between 1965 and 1970, from a wetland in the Narrandera town common in 1967, from Lake Talbot in 1968 and from Roach's regulator further downstream in the irrigation system in 1970 (Llewellyn 1979).

Figure 5.3. The endangered Murray hardyhead (*Craterocephalus fluviatilis*). Photo: Gunther Schmida

A targeted site at Willow Dam and the monitoring sites at Columbo Creek and Rocky Waterholes acted as suitable sites to survey for the former known populations (Figure 5.4). The targeted site at Tilpee was also sampled as it represented a previously unsampled area of suitable habitat for this species (Figure 5.4).

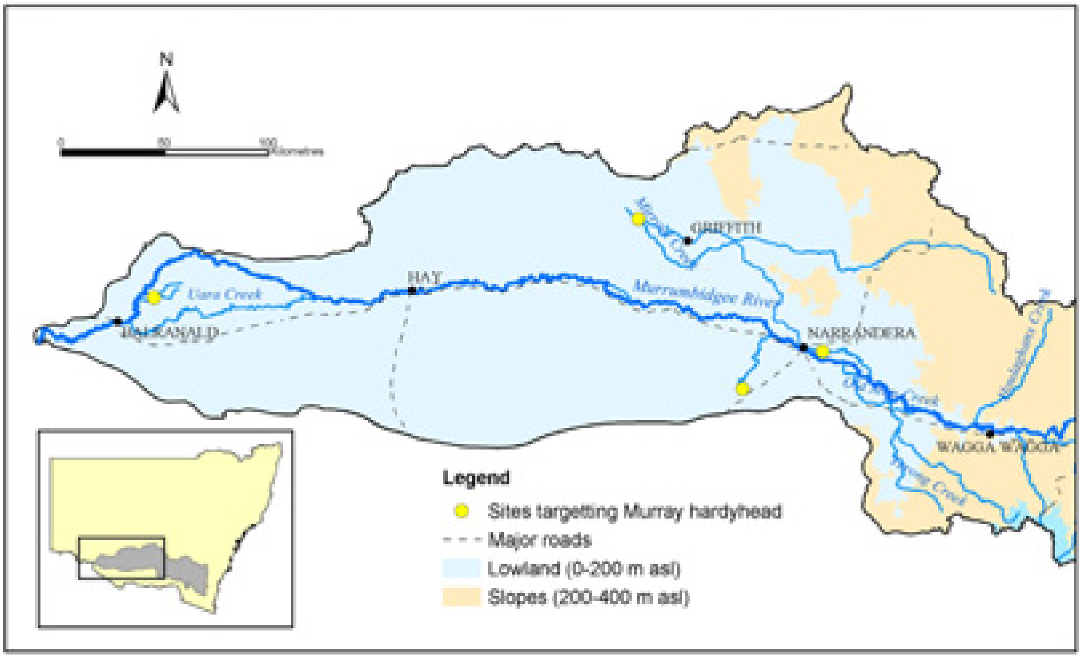


Figure 5.4. Sites sampled to monitor Murray hardyhead within the Murrumbidgee catchment.

Populations of the endangered Murray hardyhead were not detected at the sample of three locations where they had previously occurred in the Murrumbidgee catchment. It is highly likely that this species is locally extinct.

5.3.3. Olive perchlet – Endangered (western population) (FM Act 1994)

Australian Museum records report the collection of olive perchlet (Figure 5.5) from two locations in the Murrumbidgee catchment, both in 1910. These were near Yanco (Lat: 34.6, Long: 146.417) and Columbo Creek north of Urana (Lat: 35.167, Long: 146.117). Llewellyn also collected olive perchlet from Willow Dam between 1965 to 1970 (Llewellyn: unpublished data).

The targeted sample at Willow Dam, the monitoring site on Columbo Creek acted as suitable survey sites for the former known populations (Figure 5.6). A targeted site at Tilpee was also sampled as it represented a previously unsampled area of suitable habitat (Figure 5.6).

Populations of the endangered olive perchlet were not detected at the sample of locations where they had previously occurred in the Murrumbidgee catchment. It is highly likely that this species is locally extinct.

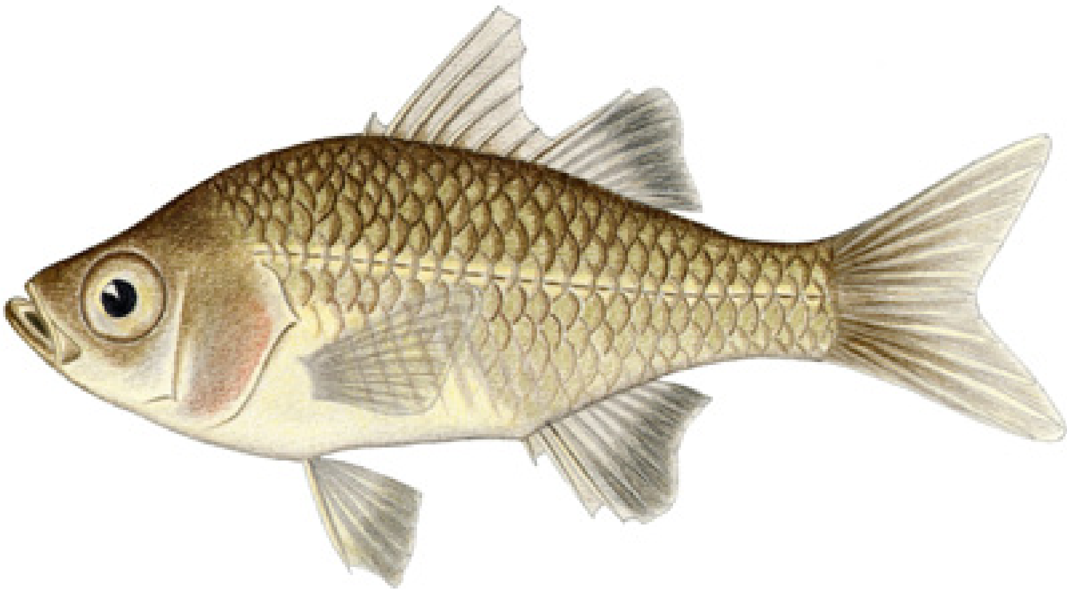


Figure 5.5. The endangered olive perchlet (*Ambassis agassizii*). Drawing: Jack Hannan.

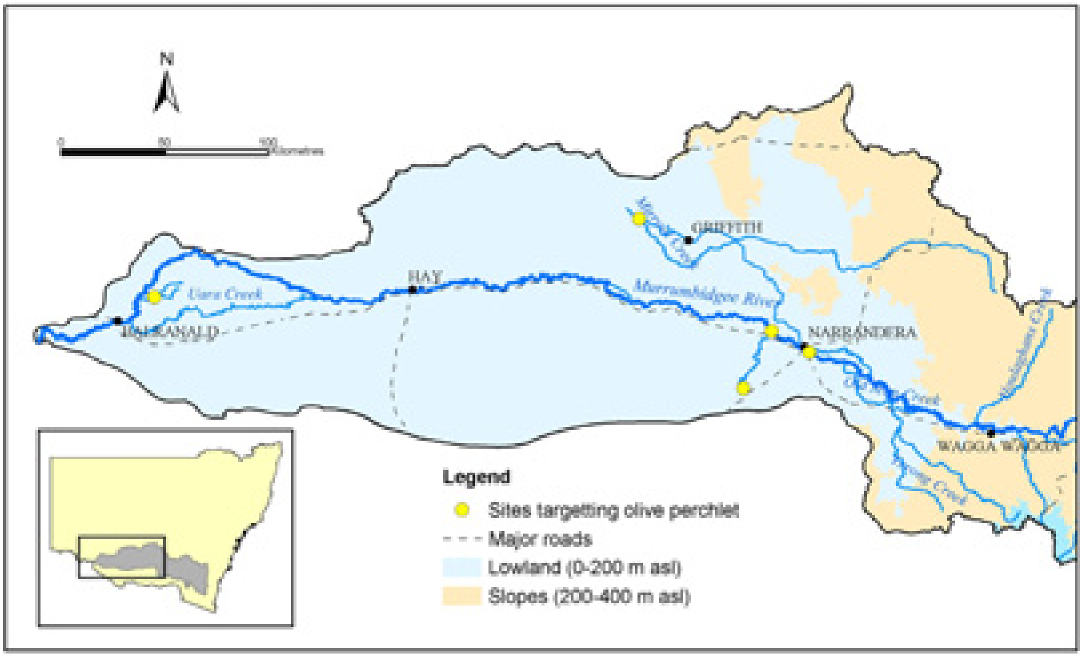


Figure 5.6. Sites sampled to monitor olive perchlet within the Murrumbidgee catchment.

5.3.4. Southern purple–spotted gudgeon – Endangered (western population) (FM Act 1994)

An Australian Museum record reports southern purple-spotted gudgeon (Figure 5.7) from an irrigation canal north of Bringagee Creek (Lat: 35.45, Long: 145.70) in 1910. Similarly, Langtry reported the existence of this species at Bringagee in 1949 – 50 (Cadwallader 1977). Llewellyn collected southern purple spotted gudgeon from Willow Dam between 1967 and 1968 (Llewellyn: unpublished data).

Figure 5.7. The endangered Southern purple-spotted gudgeon (*Mogurnda adspersa*). Photo: Gunther Schmida.

Targeted sites at Willow Dam and Bringagee were surveyed for the former known populations. An additional targeted site at Tilpee represented a previously unsampled area of suitable lowland habitat for this species. A further five previously unsampled sites in tributaries of the slopes zone were also surveyed, as this region most closely resembles the habitats of the remnant populations in the northern part of the Murray-Darling Basin (Figure 5.8). These were: Red Hill and Bona Vista on Adjungbilly Creek, and a single site in Brungle, Gilmore and Adelong Creeks.

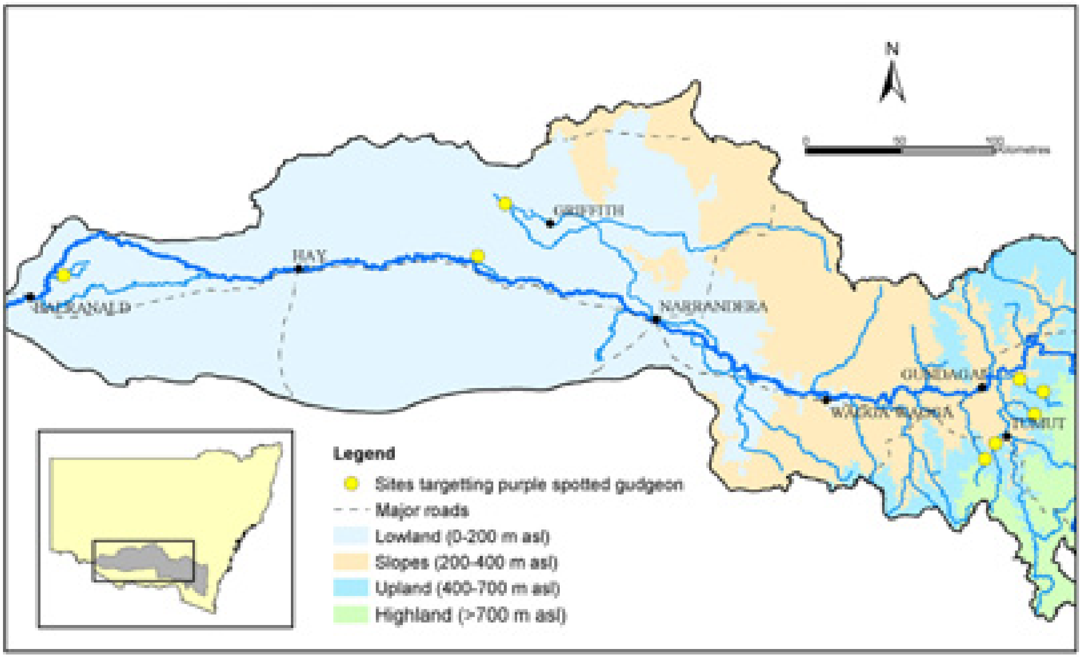


Figure 5.8. Sites sampled to monitor southern purple-spotted gudgeon within the Murrumbidgee catchment.

Populations of the endangered southern purple-spotted gudgeon were not detected at the sample of locations where they had previously occurred in the Murrumbidgee catchment. It is highly likely that this species is locally extinct.

5.3.5. Silver perch – Vulnerable (FM Act 1994)

Australian Museum records reports silver perch (Figure 5.9) from six locations within the Murrumbidgee catchment; the upper Murrumbidgee (Lat: 36, Long, 149) in 1908, the Murrumbidgee at Grong Grong (Lat: 34.73, Long: 146.78) in 1910, Balranald (Lat: 39.63, Long: 143.57) in 1959, Narrandera (Lat: 34.75, Long: 146.55) in 1963 and 1969, two sites in Burrinjuck Dam (Lat: 34.00, Long: 148.67 and Lat: 34.98, Long: 148.62) in 1969 and a further site (Lat: 35.00, Long: 148.57) in 1976, the Cotter River (Lat: 35.32, Long: 148.93) in 1969, and a second site at Narrandera (Lat: 34.6, Long: 146.57) in 1981. NSW Fisheries freshwater sampling data records report Silver perch from; Burrinjuck Dam (Lat: 35.00, Long: 148.58) in 1976 (Llewellyn 1983) and 1985/86 (Burchmore *et al.* 1988), Willow Isles on the lower Murrumbidgee in 1998, 2003 and 2004 (Gilligan, unpublished data and Baumgartner 2003, 2004), Balranald in 2003 and 2004 (Baumgartner 2003, 2004), Yanco Creek in 2001 (Baumgartner, unpublished), at Glendale in 2002 (MDBC 2004*a*), below Yanco Weir in 2002 (Baumgartner, unpublished) and near Narrandera in 2003 (Gilligan, unpublished data). The NSW Fisheries freshwater stocking database indicates the silver perch have been released into 19 locations in the catchment, mostly into dams and impoundments. Of the records above, only the 1999 report of silver perch in Googong Dam could have been the result of fish stocking. Within the ACT, Lintermans (2000*a*) reports silver perch as far upstream as the Kambah pools.

Figure 5.9. The vulnerable silver perch (*Bidyanus bidyanus*). Photo: Gunther Schmida.

Given the many reported capture locations in the Murrumbidgee only a sub-sample were chosen as monitoring sites. Targeted sites were the Murrumbidgee River at Lamont's Beach and the Narrandera boat-ramp, Dale's Point within Burrinjuck Dam and the upper Murrumbidgee at Murrell's Crossing (Figure 5.10). Randomly selected monitoring sites at Willow Isles, Glen Avon – Redgum mill, Columbo, Glendale, Woolgarlo and Willow tree Waterhole are sites (or are reasonably close to sites) where the species has been reported in the past (Figure 5.10).

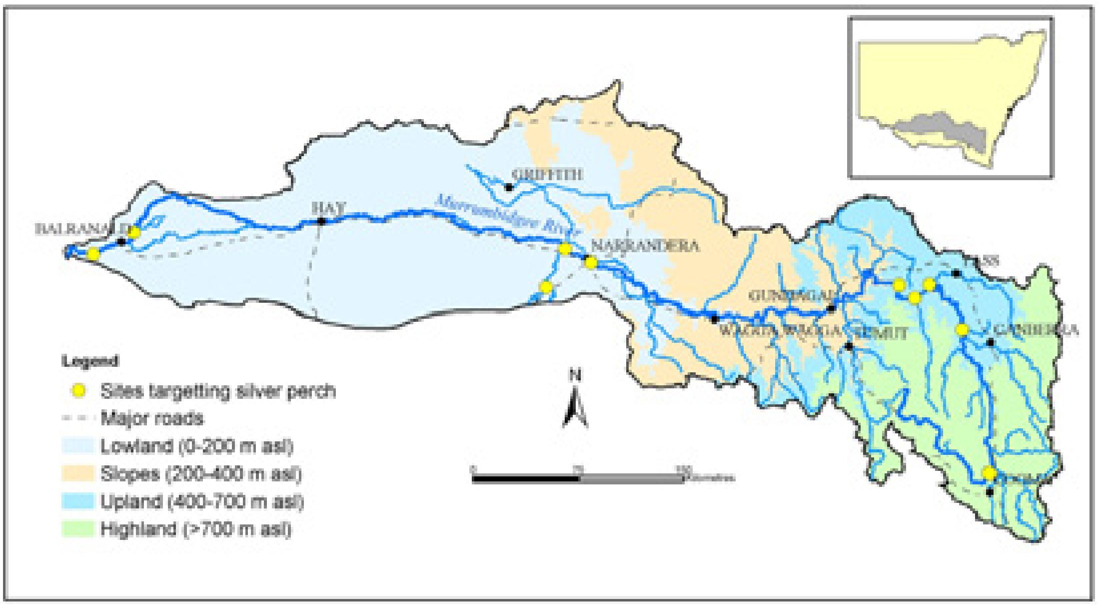


Figure 5.10. Sites sampled to monitor silver perch within the Murrumbidgee catchment.

Silver perch were only collected at Willow Isles, which corresponds to 10% of the sample of locations where they formerly existed. This result suggests that the threatened status of silver species in the Murrumbidgee is more serious than inferred from its vulnerable classification under state wide legislation. Reconsideration of endangered status may be warranted.

The single silver perch was sampled at a relative abundance of 1.07 individuals per hour. There was no significant difference between the co-occurring fish community at this site and the fish communities present at sites where silver perch were no detected (ANOSIM $R = -0.148$, $p = 0.600$) suggesting that factors other than interactions with other species may be responsible for the loss of silver perch populations. However given that there was only a single replicate site where the species was present, the power of this statistical test is extremely weak. Therefore, it cannot be suggested that interactions with other species did not contributed to population decline.

The individual sampled at Willow Isles was 255mm in length. This individual was also not likely to be sexually mature.

5.3.6. *Macquarie perch – Vulnerable (FM Act 1994)*

Australian Museum records report Macquarie perch (Figure 5.11) from five locations within the Murrumbidgee catchment; near Yass (Lat: 34.83, Long 148.917) in 1885, in the vicinity of the Burrinjuck Dam site (before construction started) (Lat: 35.00, Long: 148.583) and near Yanco (Lat: 34.6, Long: 146.42) in 1910, Narrandera (Lat: 34.75, Long: 146.533) in 1964, three sites within Burrinjuck Dam (Lat: 35.00, Long: 148.667, Lat: 35.000, Long: 148.57, and Lat: 35.000, Long: 148:58) in 1969, 1976 and 1985 and the Cotter River (Lat: 35.00, Long: 148.667) in 1969. NSW Fisheries freshwater sampling data records report Macquarie perch from; Burrinjuck Dam (Lat: 35.00, Long: 148.58) in 1976 (Llewellyn 1983) and 1985/86 (Burchmore *et al.*, 1988), Cooma Weir-pool in 1990, 1991, 1993 1994 (Faragher *et al.*, 1993), Killarney (upper Murrumbidgee) (Lat: 35.90, Long: 148.79) in 1991 (Faragher *et al.*, 1993), Murrell's Crossing near Cooma in 1992-94 (Faragher *et al.*, 1993), 1998 and 2003 (Gilligan, unpublished), Coodravale on the Goodradigbee River in 1995 (Harris and Gehrke 1997), 1999 (Gilligan, unpublished) and 2002 (MDBC 2004a), Dromore on the Numeralla River in 2003 (Gilligan, unpublished) and in Adjungbilly Creek in 2005 (Gilligan, unpublished data). NSW Fishfiles records also report Macquarie perch at sites in the upper Murrumbidgee in 1998 (Lat: 35.69, Long: 149.13, Lat: 35.98, Long: 148.89, Lat: 35.86, Long: 148.8, Lat: 36.08, Long: 149.13, Lat: 36.01, Long: 149.12, Lat: 36.11, Long: 149.11, Lat: 36.13, Long: 149.10), in 1999 (Lat: 36.13, Long: 149.00) and in 2001 (Lat: 35.35, Long: 149.23). The NSW Fisheries freshwater stocking database reports the release of Macquarie perch into the Batlow River and Burrinjuck Dam in 1988 and into Talbingo Dam in 1995. Within the ACT, Lintermans (2000*a*) reports Macquarie perch in four rivers; the Cotter river between Cotter Dam and Vanity's Crossing, the lower end of the Molonglo River, the Paddy's River and the entire ACT length of the Murrumbidgee (Lintermans 2000*a*). Lastly, following decline of the Queanbeyan River population after construction of Googong Dam, 57 individuals were moved from the impoundment into the Queanbeyan River upstream of Curley's Falls (Lintermans 2002).

Figure 5.11. Murray-Darling form of the vulnerable Macquarie perch (*Macquaria australasica*). Photo: Gunther Schmida.

Given the many reported locations of past Macquarie perch populations in the Murrumbidgee, only a sub-sample were chosen as monitoring sites. Targeted sites were the ACT EW Hole on the Queanbeyan River, Dale's Point within Burrinjuck Dam, Dromore on the Numeralla River, Angle Crossing, Murrell's Crossing and Cooma weir-pool in the upper Murrumbidgee and the Narrandera boat-ramp. Randomly selected monitoring sites at; Coodravale on the Goodradigbee River, Woolgarlo within Burrinjuck Dam, Bolaro in the upper Murrumbidgee, Lobb's Hole in the upper reaches of Talbingo Dam, Willow tree Waterhole on the Murrumbidgee just downstream of the ACT, Coppin's Crossing on the Molonglo River, the Yass River at Yass and below Burrinjuck Dam at Glendale are sites (or are reasonably close to sites) where the species has been reported in the past (Figure 5.12).

Macquarie perch were only found at one site, Cooma Weir-pool, corresponding to 7% of the sample of sites were this species previously existed. This result suggests that the threatened status of Macquarie perch in the Murrumbidgee is more serious than inferred from its vulnerable classification under state legislation. Reconsideration of endangered status may be warranted. However it must be remembered that this snap-shot sampling provides only tentative results and cannot be used to prove the absence of Macquarie perch from other targeted sites. For instance, although we did not find Macquarie perch at Bolaro, Murrell's Crossing or ACT EW hole, recent sampling for other projects suggests that recruiting populations do exist at those locations. Further, targeted sampling for this project did not cover all historical habitats. Therefore, these results only provide a indication of the reduction in distribution and do not infer the absence of Macquarie perch from other locations in the catchment.

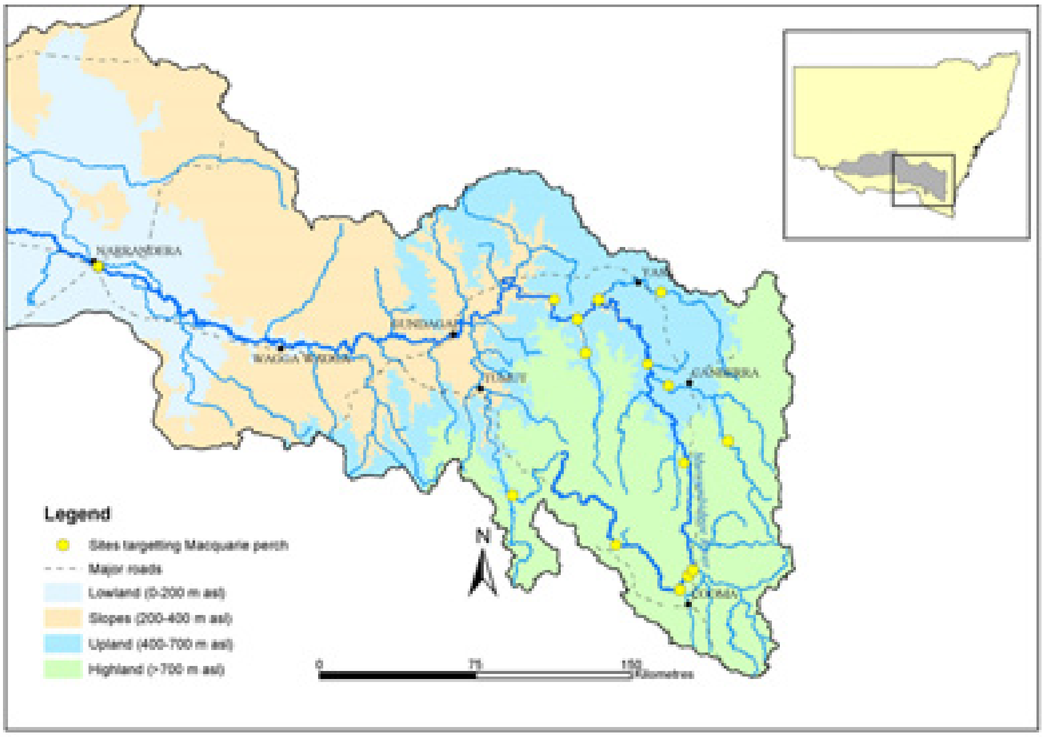


Figure 5.12. Sites sampled to monitor Macquarie perch within the Murrumbidgee catchment.

The single Macquarie perch captured was sampled in the Cooma Weir-pool at a relative abundance of 0.87 individuals per hour of electrofishing. Like silver perch, there was no significant difference between the co-occurring fish community at this single site and the fish community present at sites where Macquarie perch had disappeared (ANOSIM R = -0.242, p = 0.786). However, given a similar substantial lack of statistical power, this analysis only provides a extremely tentative indication that factors other than interactions with other species are responsible for the loss of populations. It cannot be suggested that interactions with other species did not contributed to population decline.

The individual sampled at Cooma Weir-pool was not sexually mature, being only 146 mm in length. It is likely to be two years of age (Battaglene 1988).

5.3.7. Southern pygmy perch – Vulnerable (FM Act 1994)

Australian Museum records report Southern pygmy perch (Figure 5.13) at six locations within the Murrumbidgee catchment: Columbo Creek (Lat: 34.92, Long: 146.28) in 1914, Bringagee (Lat: 35.45, Long: 145.7) in 1918, in Mirool Creek near Barren Box Swamp (Lat: 34.18, Long: 145.83) and in Barren Box Swamp (Lat: 34.15, Long: 145.83) in 1967, Willow Dam (Lat: 34.2, Long, 145.83) in 1968, and in the Tumut River at Tumut (Lat: 36.1, Long: 148.2) in 1976. Llewellyn also collected Southern pygmy perch from Willow Dam (same as museum records), Lake Wyangan (Lat: 34.23, Long: 146.02), an irrigation canal at Yanco (Lat: 34.62, Long: 146.42), Lake Talbot (Lat: 34.75, Long: 146.57), billabongs off Poison Waterholes Creek (Lat: 34.77, Long: 146.66) and lagoons within the Narrandera town common (Lat: 34.77, Long: 146.58) between 1966 and 1968 (Llewellyn 1974).

Figure 5.13. The vulnerable Southern pygmy perch (*Nannoperca australis*). Photo: Kris Pitman.

Targeted sites at Willow Dam and the Narrandera boat-ramp were sampled to survey former known populations of this species. A further two sites at Tilpee and Bango represented previously unsampled areas of suitable habitat for this species (Figure 5.14). The Bango site is similar to and in close proximity to the remnant population of this species known to exist in the neighbouring

Lachlan catchment. Randomly selected monitoring sites at Columbo, Readymix and Rocky Waterholes were also close to locations were southern pygmy perch have been recorded in the past.

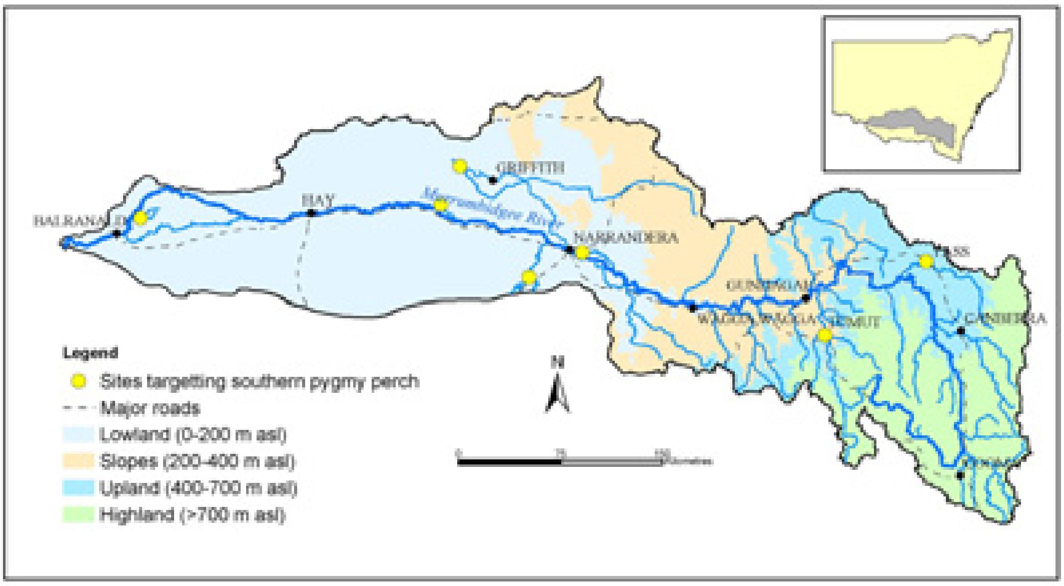


Figure 5.14. Sites sampled to monitor southern pygmy perch within the Murrumbidgee catchment.

Populations of the vulnerable southern pygmy perch were not detected at locations where they had previously occurred in the Murrumbidgee catchment. It is highly likely that this species is locally extinct. The vulnerable status of this species requires urgent reconsideration given its likely extinction in the Murrumbidgee and very restricted range in the Lachlan and Murray catchments (Gilligan, unpublished data).

5.4. Discussion

Only three of the seven listed threatened species were detected. Populations of the endangered Murray hardyhead, olive perchlet, southern purple-spotted gudgeon and vulnerable southern pygmy perch were not detected at locations where they had previously occurred in the Murrumbidgee catchment and it is probable that these four species are locally extinct. Two of the remaining three threatened species, Macquarie perch and silver perch were found at only one site each, with only single individuals of each species collected. Both species are listed as vulnerable taxa. These results suggest that the status of both may require reconsideration and endangered status may be warranted. This also applies to southern pygmy perch which are only listed as vulnerable, yet are probably extinct in the Murrumbidgee catchment. However data collected from targeted threatened sites were only single samples, and therefore do not conclusively prove absence from a site. However at a minimum, the data can be used to infer a very low abundance.

Given the apparent success of the reintroduction program for trout cod, similar programs may be considered for the four other threatened taxa which are at likely to be extinct in the Murrumbidgee. However in order to be effective, it is necessary to ensure that the threatening processes that lead to the extinction of the species in the first place are eliminated or controlled. River regulation, fish stocking, degradation of riparian vegetation, salinisation, agricultural practices, cold water pollution, predation by redfin, predation by trout, competition with goldfish and gambusia, loss of aquatic vegetation, floodplain alienation and seasonal flow reversal have variously been identified as threats to Murray hardyheads, olive perchlets, southern purple spotted gudgeons and southern pygmy perch (Shipway 1949; Cadwallader 1979; Ivanstoff and Crowley 1996; Kuiter *et al.* 1996; Lugg 2000; Morris *et al.* 2001).

Murray hardyhead were considered common in wetlands and waterways around Narrandera and at Willow Dam near Barren Box swamp up until 1970 (Llewellyn pers. com.). Since 1970, there has only been a single report of the species in the Murrumbidgee from 1995 (Harris and Gehrke 1997), which was the last individual recorded in the catchment . Similarly Llewellyn (pers. com.) considered populations of olive perchlet, southern purple-spotted gudgeon and southern pygmy perch secure in several locations around Narrandera and at Willow Dam following sampling between 1965 and 1970. None of these species have subsequently been recorded anywhere in the catchment and are also likely to be locally extinct. The coincidental invasion of the catchment by Boolarra strain carp in 1972 is highly likely to be the principal cause, or at least a major factor in the extinction of these species in the catchment. Despite the fact that many factors would have impacted on these four taxa, the invasion of carp is most closely related to the point in time when populations of these species changed from being relatively common to disappearing from the catchment. As a result, localised carp control, in addition to rehabilitation and adequate management in suitable wetland systems are likely to provide suitable habitat for each of these species in the Murrumbidgee.

However a process of habitat rehabilitation and carp control, followed by reliance on recolonisation by immigration from neighbouring catchments is not a viable option for recovery as these species are also likely to be rare or extinct in all adjacent catchments. As a result, no level of river rehabilitation or improvements in catchment management will result in the return of these species in the Murrumbidgee. A captive breeding and reintroduction program is the only viable alternative.

A reintroduction program was initiated in 2004 for the southern purple spotted gudgeon, with 400 hatchery reared fish released at two sites in the Murrumbidgee catchment in April 2004, ‘Red Hill’ and ‘Bona Vista’, both on Adjungbilly Creek. Reintroduction into an upland stream was preferred over reintroduction into lowland wetlands for two reasons. Firstly, the upland habitats in the Murrumbidgee most closely resembled the habitats of the remnant source populations in the north of the state. And secondly, there are fewer threatening processes affecting unregulated upland streams than impact upon lowland wetlands. Despite the suitable habitat conditions in Adjungbilly Creek, the existence of both trout and carp in the system may prevent establishment of the reintroduced population. The same problems may be encountered during potential reintroductions of southern pygmy perch in upland streams, as predation by trout on pygmy perch species is known to be substantial (Shipway 1949; Cadwallader 1979; Kuiter *et al.* 1996). Therefore, establishment of trout free waters in upland areas may be a necessity for recovery of these two species in the Murrumbidgee. Upland reintroductions are not suitable for either Murray hardyhead or olive perchlet, which are both lowland species. For these taxa, improved wetland management and carp exclusion are likely to be the best means of providing suitable habitats for reintroduction programs for all four species in lowland regions.

Although Macquarie perch are still present in the catchment, their distribution is significantly reduced with populations having disappeared from many tributaries reaches of the catchment. Macquarie perch populations had begun to decline in the Murray-Darling Basin by the 1960’s (Bishop and Tilzey, 1978). By 1982, populations of Macquarie perch in the Canberra region were small and localised (Pratt, 1979). These populations declined further between 1980 and 1985 (Lintermans 2000*a*). There are several potential causes for the observed declines. Land clearing in upper catchments resulted in siltation of deep holes and associated changes in benthic fauna degrading habitat condition in many streams (Cadwallader 1978; Cadwallader 1982). The construction of dams obstructed fish passage, inundated spawning habitats (as occurred following the construction of Googong Dam) and resulted in thermal pollution downstream (Lintermans

2000*a*). Carp invaded the upper catchment in the late 70's (Lintermans 2000*a*). Numbers of brown trout and rainbow trout stocked into the Murrumbidgee catchment increased significantly throughout the 1980's (NSWF 2003) with several known Macquarie perch populations stocked with trout (NSWF 2003). Trout compete with Macquarie perch for food and are known to prey on juveniles (Butcher 1945), with resultant declines in areas heavily stocked with trout (Cadwallader and Rogan 1977).The stocking of large numbers of Atlantic salmon into Burrinjuck Dam in the 1980's coincided with the decline of Macquarie perch in that impoundment (NSWF 2003). Lastly, the colonisation of the upper Murrumbidgee by redfin perch in the 1980's also coincides with declines of Macquarie perch (Lintermans 2000*a*). Redfin perch may have preyed on juvenile Macquarie perch, competed with adults or transmitted the EHN virus which is lethal to Macquarie perch (Lintermans 2000*a*).

In order to prevent the further decline of Macquarie perch in the Murrumbidgee and enable recovery of Macquarie perch populations, each of these threats need control or remediation. This would require the control of erosion in upland catchments, the recovery of deep pools through dredging silt burdens in streams, the limitation or exclusion of trout stocking within streams containing Macquarie perch populations, the control of carp and redfin perch, and the exclusion of these alien species from habitats they have not yet invaded.

Until recovery has progressed to the point where Macquarie perch populations have spread throughout the upper catchment, each small and isolated remnant population will remain at risk of genetic deterioration through inbreeding. In order to prevent further decline of remnant populations in the short term, translocations of disease free individuals between populations provides the best means of preventing genetic deterioration. Instances where this has been successful in recovering declining populations of threatened populations are the North American Greater prairie chicken (Westemeier *et al.* 1998), the Florida panther (Jansen and Logan 2002) and Swedish adder (Madsen *et al.* 2004). The development of hatchery production techniques for this species should also be considered a high priority.

Silver perch declined in the lower Murrumbidgee in the early 1960's (see chapter 7) although Llewellyn still considered them widespread and fairly common in 1983 (Llewellyn 1983). In the Murray River, the species declined by 93% between 1940 and 1990 (Mallen-Cooper 1993). In the upper Murrumbidgee, Lintermans (2000*a*) reports declines in the 70's and 80's. A range of threatening processes have been suggested including river regulation, thermal pollution, barriers to fish passage, interactions with carp redfin and gambusia, de-snagging, loss of riparian vegetation and aquatic plants, salinisation, parasites and disease, degraded water quality, algal blooms, pollution, sedimentation, commercial and recreational over-harvest, inappropriate stocking, escape of aquaculture stocks and trophic alterations (Lintermans 2000*a*, Lugg 2000, Clunies and Koehn 2001).

Consideration of all available data suggests a very strong relationship between the decline of silver perch in the Murrumbidgee catchment and the cumulative number of weirs constructed in the system. This may have threatened silver perch populations directly through the obstruction of fish passage, or may have resulted from the river regulation practices that were facilitated by their construction, with a relationship also apparent for the decline of silver perch and the volume of water extracted from the river. These very strong relationships suggest that the construction of fishways on weirs and the implementation of suitable environmental flows may result in the recovery of silver perch in the Murrumbidgee. However the impact of carp, which proliferated in the Murrumbidgee after silver perch populations had already begun to decline, could potentially impact on recovery of silver perch even if fish passage and environmental flows are provided.

Two species of Murrumbidgee fishes are listed as threatened by other jurisdictions but not under the NSW Fisheries Management ACT 1994. Insufficient data has been collected for two-spinned blackfish populations in NSW waters in order to make any recommendations of status. Extant populations are known from several waterways in the upper catchment areas of the Murrumbidgee in NSW; the Goobarragandra River (MDBC 2004a), Jounama Creek, Mountain Creek, Murrumbidgee River upstream of Yaouk and the Goodradigbee River (Lintermans 2000*a*). The species was collected from only a single site in this survey (one of the 28 randomised monitoring sites), Cotter Flats in the ACT, where 17 individuals were collected at a rate of 20.82 fish per hour of electrofishing. This population had the second highest level of recruitment of any species in the catchment with 35% of individuals estimated as less than one year of age.

In contrast, substantial data has been collected for Murray cod populations in the Murrumbidgee. Murray cod were captured at 12 sites (seven randomised monitoring sites and five targeted sites). A total of 65 individuals were sampled at an average of 5.48 fish per hour at these 12 sites. Almost all Murray cod were captured in the lowland zone. None were sampled in the slopes zone and only two were sampled in the upland zone. The maximum catch at any one site was 35 individuals captured at Wyreema near Hay. Murray cod had the 2^{nd} highest total biomass of any species in the catchment and were the sixth most abundant native fish species overall. Substantial numbers of recruits were collected, with 21% of individuals being less than one year of age.

A further two Murrumbidgee fish species not listed as threatened under NSW legislation, freshwater catfish (Figure 5.15) and flat-headed galaxias (Figure 5.16), were not sampled at any of the sites surveyed. Flat-headed galaxias has not been sampled from the Murrumbidgee catchment since 1971 were they were formerly common around Narrandera and in Willow Dam. Freshwater catfish have not been scientifically sampled from the Murrumbidgee since 2000, however recreational fishers occasionally report captures of large freshwater catfish from Yanco and Columbo Creeks. They were formerly common in the river downstream of Wagga Wagga (Lake 1971) and particularly abundant in Barren Box swamp (Reid *et al.* 1997; Lugg 2000). These species are likely to warrant endangered status in the Murrumbidgee catchment with the flat-headed galaxias likely to be locally extinct.

Figure 5.15. The freshwater catfish (*Tandanus tandanus*). Although not listed as a threatened species, is very rare in the Murrumbidgee catchment. Photo: Gunther Schmida.

Flat-headed galaxias populations require the same recovery management as for Murray hardyhead and olive perchlets, as they are also a lowland wetland species. The threatening processes for catfish include; river regulation, thermal pollution, de-snagging, interactions with redfin and carp, alien species, loss of riparian and aquatic vegetation, degraded water quality, diseases and parasites, inappropriate fish stocking, salinisation, and over-harvest (Lugg 2000). However the primary cause of population declines is not clear although competition with carp and their disturbance of catfish nests are likely to be a primary factor. Given that carp densities are now likely to be at the lowest levels since invasion of the catchment in 1972 (see chapter 7) stocking of freshwater catfish in the Murrumbidgee may aid in the recovery of this species.

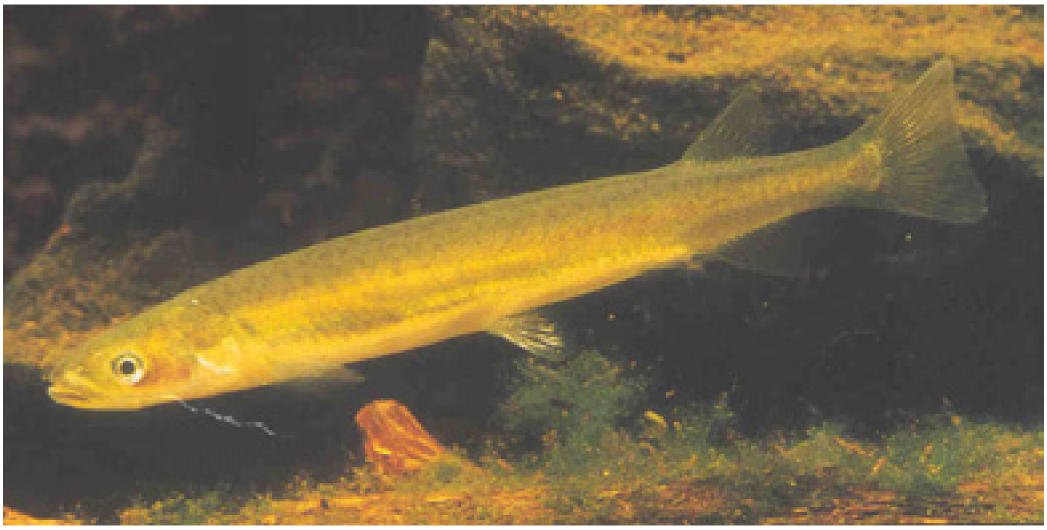


Figure 5.16. The flat-headed galaxias (*Galaxias rostratus*). Although not listed as a threatened species, it was last observed in the Murrumbidgee catchment in 1971 and is likely to be locally extinct. Photo: Gunther Schmida.

6. TRENDS IN FISH COMMUNITIES AND FISH SPECIES IN THE MURRUMBIDGEE CATCHMENT FROM 1994 – 2004: ANALYSIS OF STANDARDISED ELECTROFISHING DATA

6.1. Introduction

Ongoing sampling using a consistent standardised sampling methodology, which targets all members of the fish community (as far as is possible), is the most robust method of assessing changes in fish community structure and the status of individual species through time (Brown 1992, Rutzoa *et al.* 1994, ACT Government 1998, Lintermans 2000*a*). Long term and regular surveys also enable early detection of the introduction and spread of new pest species such as the release of various aquarium fish into Australian rivers (Lintermans 2000*a*).

In 1976, Llewellyn undertook the first broad-scale survey of fish populations throughout NSW, including 15 Sites in the Murrumbidgee catchment (Llewellyn 1983). This was followed in 1979 by the development of a long term river monitoring program in the ACT which itself was preceded by the Canberra Lakes Monitoring Program initiated in 1970 (Linetrmans 2000*a*). The methods used in Llewellyn's 1976 broad scale survey were not standardised at all sites and therefore the data are not suitable for quantitative comparison. The same applies to museum records for individual species. In contrast, the NSW Rivers Survey developed a standardised electrofishing protocol (Harris and Gehrke 1997), which has been used consistently for a majority of NSW Fisheries research programs since 1994, including the IMEF project, and was also adopted by the ACT fish monitoring surveys.

Coincident with the development of this fish monitoring program, the Murray-Darling Basin Commission developed and tested a basin-wide monitoring program for river health across the Murray-Darling Basin (MDBC 2004). Although the fish sampling protocol developed for the Sustainable Rivers Audit program varies slightly from that used initially in NSW, the electrofishing procedures are consistent with the original NSW protocol. Therefore electrofishing data collected within NSW since 1994 will continue to provide a means of quantitatively assessing changes in fish populations through time.

This chapter uses meta-analysis techniques to analyse trends for individual species and fish community parameters across sites where long-term standardised electrofishing data are available.

6.2. Methods

6.2.1. Data

To qualify for inclusion in these analyses, individual sites must have been sampled on at least four occasions. Data from fourteen sites was available: Willow Isles (19 samples: between 1994 - 2004), Cookoothama (7: 1998 - 2004), Lamont's Beach (4: 2000 - 2004), Rocky Waterhole (7: 1994 - 2004), Buckingbong Station (4: 2000 - 2002), Wantabadgery (4: 2000 - 2004), Readymix (7: 1994 - 2004), Glendale (11: 1994 - 2004), Coodravale (9: 1994 - 2004), Yass (7: 1994 - 2004), Murrell's Crossing (5: 1998 - 2004), Cooma (5: 1994 - 2004), Cappawidgee (7: 1994 - 2004) and Benbullen (7: 1994 - 2004). All these sites were re-sampled in 2004 as part of this survey, with coordinates provided in Table 2.1 and Table 2.2 (except for Buckingbong Station (Latitude = 34.8051, Longitude = 146.6556, Altitude = 145 m)).

Sampling procedures for all pre-SRA samples are described in Harris and Gehrke (1997). The sampling procedures for the SRA program are described in chapter 2 of this report. Calculations used for estimation of fish community parameters are described in chapter 3.

6.2.2. Data analysis

Only data collected using electrofishing was included in these analyses and these were standardised to catch-per-unit-effort (CPUE), calculated as number of individuals sampled per hour (real time), including both captured and observed individuals. For a majority of tests, data were not normally distributed. Therefore, non-parametric Spearman's rank correlations (Sokal and Rohlf 1995) were used to correlate CPUE with sampling date.

Correlations were undertaken for each species at each site and the correlation coefficients and sample sizes (number of sampling events at each site) were entered into Comprehensive Meta-Analysis version 2 (Biostat). Data was meta-analysed for each species using a random effects model with each correlation weighted by the number of samples collected. When significant heterogeneity was observed (Q statistic) within a catchment-wide test, data were re-analysed at the zone level.

6.3. Results

6.3.1. Fish community parameters

Species richness at the 14 sites has increased significantly since 1994 ($r = 0.360$, $p = 0.006$) and the trend was consistent throughout the catchment ($Q_{13} = 12.993$, $p = 4483$). A positive trend for total abundance of fish per site almost reached significance ($p = 0.054$) as did a negative trend in total biomass ($p = 0.059$) (Table 6.1). There were no significant trends for Shannon's diversity, proportion of native species (species richness) or proportion native biomass (Table 6.1). Trends in proportion native abundance were heterogeneous throughout the catchment ($Q_{12} = 32.973$, $p = 0.001$). When re-analysed at the level of zone, the highland zone had a significant negative trend in the proportion of native abundance ($r = -0.71 \pm 0.36$, $p = 0.013$). However trends in the slopes zone still showed significant heterogeneity between sites ($Q_3 = 15.233$, $p = 0.002$). Both Coodravale and Glendale sites showed a consistent ($Q_2 = 0.130$, $p = 0.937$) and significant positive trend in proportion native abundance ($r = 0.65 \pm 0.26$, $p = 0.003$) whereas the third slopes zone site, Readymix, showed a significant negative trend ($r = -0.89$, $p = 0.007$).

Table 6.1. Meta-analysis output of trends in the fish community parameters across long-term monitoring sites (14) in the Murrumbidgee catchment. Data analysed were the Fisher's *Z* transformed Spearman's rank correlations for each parameter at each site. Data presented are the mean ± standard error Fisher's *Z*, the *z*-score is the statistic used to test significance of the trend using a standard *p* value of α = 0.05. *Q* (degrees of freedom) tests for heterogeneity across samples within the meta-analysis. If significant heterogeneity was detected, data were re-analysed at the level of zone. Consistent trends are highlighted in grey. When significant heterogeneity was detected, and the data re-analysed at the level of zone, those analyses are surrounded by a box.

	Fisher's Z ± SE	***z*-score**	***p* value**	**Q (df)**	***p* value**
Species richness	0.377 ± 0.138	2.737	0.006	12.993 (13)	> 0.1
Total abundance	0.422 ± 0.219	1.924	0.054	13.180 (13)	> 0.1
Total biomass	-0.529 ± 0.137	-1.885	0.059	12.775 (13)	> 0.1
Shannon's *H*	0.122 ± 0.149	0.821	0.412	12.010 (12)	> 0.1
Shannon's *J*	-0.131 ± 0.155	-0.846	0.397	11.685 (12)	> 0.1
Proportion native (species richness)	0.067 ± 0.170	0.397	0.692	12.333 (13)	> 0.5
Proportion native (abundance)	-0.16 ± 0.24	-0.659	0.510	32.973 (12)	0.001
Lowland	0.21 ± 0.20	1.065	0.287	3.872 (4)	0.424
Slopes	0.15 ± 0.62	0.243	0.808	15.233 (3)	0.002
Slopes (minus Readymix)	0.65 ± 0.26	2.972	0.003	0.130 (2)	0.937
Readymix	-0.89		0.007		
Upland	-0.36		0.359		
Highland	-0.71 ± 0.36	-2.487	0.013	2.379 (2)	0.304
Proportion native (biomass)	0.060 ± 0.159	0.379	0.705	11.975 (13)	> 0.5

6.3.2. Individual species

The only native species showing a significant trend over the last decade are the carp-gudgeons (Table 6.2). Carp-gudgeons have increased in abundance since 1994 ($r = 0.53 \pm 0.17$, $p = 0.0006$) and the trend is consistent across all five sites where carp-gudgeons have been sampled ($Q_4 = 1.164$, $p = 0.884$). Of the remaining 13 native species for which analyses were possible (sampled at least one of the long-term monitoring sites), eight species showed positive (but non-significant) increases and five species showed negative (but non-significant) decreases in abundance (Table 6.2).

Two alien species showed significant trends over the last decade (Table 6.2). Redfin perch have increased in abundance since 1994 ($r = 0.37 \pm 0.15$, $p = 0.011$) and the trend is consistent across all seven sites where redfin perch have been sampled ($Q_6 = 4.960$, $p = 0.549$). In contrast, trends in the abundance of carp have been heterogeneous throughout the catchment ($Q_{11} = 23.028$, $p = 0.018$). When re-analysed at the level of zone, a significant decline in carp abundance was detected in the slopes zone ($r = -0.48 \pm 0.23$, $p = 0.022$) and a significant increase in carp abundance was detected in the highland zone ($r = 0.90 \pm 0.41$, $p = 0.0003$).

Table 6.2. Meta-analysis output of trends in the abundance of each species across long-term monitoring sites in the Murrumbidgee catchment. Raw data were the Spearman's rank correlation for each species at each site (where they had been collected at least once). Data presented were the mean ± standard deviation of all correlations for each species, the *z*-score is the statistic used to test significance of the trend using a standard p value of $\alpha = 0.05$. *Q* (degrees of freedom) tests for heterogeneity across samples within the meta-analysis. If significant heterogeneity was detected, data were re-analysed at the level of zone. Consistent trends are highlighted in grey. When significant heterogeneity was detected, and the data re-analysed at the level of zone, those analyses are surrounded by a box.

Species	Fisher's Z ± SE	*z*-score	*p* value	Q (df)	*p* value
Native species					
Bidyanus bidyanus	0.19 ± 0.20	0.958	0.338	0.624 (1)	0.429
Craterocephalus fluviatilis	-0.20		0.605		
Craterocephalus stercusmuscarum	0.35 ± 0.22	1.627	0.104	0.122 (1)	0.726
Gadopsis marmoratus	0.11 ± 0.71	0.153	0.878	0.278 (1)	0.598
Galaxias olidus	-0.14 ± 0.25	-0.546	0.585	1.797 (4)	0.773
Hypseleotris spp.	0.53 ± 0.17	3.428	0.0006	1.164 (4)	0.884
Maccullochella macquariensis	0.19 ± 0.37	0.516	0.606	5.111 (4)	0.276
Maccullochella peelii	0.31 ± 0.21	0.153	0.126	4.359 (4)	0.360
Macquaria ambigua	-0.13 ± 0.19	-0.658	0.510	9.477 (7)	0.220
Macquaria australasica	-0.19 ± 0.35	-0.551	0.582	0.219 (1)	0.640
Melanotaenia fluviatilis	0.39 ± 0.22	1.861	0.063	0.088 (1)	0.767
Nematalosa erebi	-0.17 ± 0.22	-0.775	0.438	0.806 (1)	0.369
Philypnodon grandiceps	0.39		0.085		
Retropinna semoni	0.23 ± 0.21	1.143	0.253	12.207 (8)	0.142
Alien species					
Carassius auratus	0.15 ± 0.17	0.880	0.379	1.799 (5)	0.876
Cyrpinus carpio	-0.05 ± 0.22	-0.208	0.835	23.028 (11)	0.018
Lowland	-0.32 ± 0.20	-1.698	0.089	2.236 (4)	0.692
Slopes	-0.48 ± 0.23	-2.287	0.022	0.588 (3)	0.899
Upland	0.18 ± 0.5	0.361	0.718	0.000 (0)	1.000
Highland	0.90 ± 0.41	3.662	0.0003	0.002 (1)	0.969
Gambusia holbrooki	0.45 ± 0.29	1.679	0.093	1.412 (2)	0.493
Oncorhynchus mykiss	0.18 ± 0.25	0.749	0.454	9.932 (6)	0.128
Perca fluviatilis	0.37 ± 0.15	2.534	0.011	4.960 (6)	0.549
Salmo trutta	-0.12 ± 0.34	-0.364	0.716	8.514 (4)	0.074

6.4. Discussion

Analysis of data collected from the Murrumbidgee catchment over the last 10 years indicates several significant changes.

The number of species sampled at sites has increased consistently throughout the catchment. This is counter to the local extinction of several threatened species. The observed relationship could result from either the continued spread of alien species, which is a negative effect, or the recovery and spread of rarer native species over the last decade, which is a positive change. Total abundance and total biomass have also changed consistently throughout the catchment yet the relationships were not quite statistically significant. The total number of individuals has increased whilst the total biomass has declined. The biomass relationship is the most meaningful as it suggests that the carrying capacity of streams has declined over the last 10 years.

Although alien fish species dominate much of the catchment in terms of the proportion of species, individuals and biomass at sites, no significant trends were detected in the proportion of alien species richness or proportion of alien biomass. This is indicative of some level of stability in the system and suggesting that alien species may have reached equilibrium within fish communities. This was not the case for the proportion of individuals at sites that were native species. In this case, there was significant heterogeneity across the basin, with some zones experiencing a significant increase and others a significant decline. The highland zone experienced a significant decline in the proportion of native individuals per site. This relationship probably resulted from a non-significant decline in the abundance of native mountain galaxias and counteracting non-significant increases in the abundance of alien goldfish, gambusia and rainbow trout and significant increases in the abundance of alien redfin perch and carp in the highland zone. Sites in the slopes zone exhibited further heterogeneity, with both Coodravale and Glendale experiencing increases in the proportion of native individuals whilst the proportion of native individuals has declined at the Readymix site in the Tumut River. This result is difficult to interpret as Glendale and Readymix are located below Burrinjuck Dam and Blowering Dam respectively and should be most similar, both being exposed to severe river regulation and thermal pollution. Whilst Coodravale is on the unregulated Goodradigbee River upstream of Burrinjuck Dam. It is unclear why changes at Glendale should be consistent with those at Coodravale, rather than the physically more similar site at Readymix. No significant trends in the proportion of native individuals were observed in the lowland or upland zones.

Only three species showed clear trends in abundance over the last 10 years. Carp-gudgeons were the only native species whose population size has changed with a consistent increase throughout the catchment. Of the remaining 13 native species assessed, eight had increased and five had declined, but the trends were not significant. The declining species were fly-specked hardyhead, mountain galaxias, golden perch, Macquarie perch and bony herring.

The alien species which had exhibited significant trends were redfin perch and carp. Redfin perch have increased in abundance consistently throughout the basin. However the abundance of carp has varied among zones. Carp have declined in the lowland zone, however the trend is just non-significant. Similarly, a decline in carp abundance has been observed in the slopes zone, but this trend is statistically significant. In contrast, carp abundance has increased in the upland and highland zones, although the trend is only significant in the highland zone. The decline in carp in the lowland and slopes zone is consistent with the observations of recreational fishers who have increasingly claimed a decline in carp numbers in these areas.

7. TRENDS IN THE HARVEST OF FISH SPECIES FROM THE MURRUMBIDGEE CATCHMENT BETWEEN 1955 – 2001: THE INLAND COMMERCIAL FISHERY

7.1. Introduction

The commercial fishery had received heavy criticism for its perceived role in depleting the Murrumbidgee River of its native fish (Brown 1992). Throughout the Murray-Darling Basin overfishing has been identified as a cause of decline for trout cod (Douglas *et al.* 1994), Macquarie perch (Cadwallader 1978), Murray cod (Rowland 1989; Jackson *et al.* 1993), silver perch (Clunie and Koehn 2001) and blackfish (Roughley 1953). As a result of declining catches, the NSW inland commercial fishery for native finfish closed in September 2001.

Whether commercial over-fishing can be implicated in the decline of fish populations or not, the data provided by commercial fishermen provides the most extensive long-term data set available. Further, the very extensive period of data collection corresponds with the appearance of numerous threatening processes and enables a detailed assessment of the response of fish communities to temporal changes in river management and a wide variety of flow events. As a result, this dataset lends itself to assessment of the causes of decline of individual species and the potential responses of various fish species to implementation of environmental flows.

Details of the inland fishery in NSW had been recorded since 1880, but a large number of records were destroyed. Only those from 1955 until the closure of the inland commercial fishery in September 2001 are available for the Murrumbidgee fisheries: The Murrumbidgee River, Lake Yanga and Barren Box Swamp. Brown (1992) has previously analysed the commercial catch data from the Murrumbidgee catchment from 1955 to 1978. Subsequently, Reid *et al.* (1997) collated fishery records which exist from 1883 onwards (although coverage and accuracy of the data were poor until compulsory fishers' returns were introduced in 1947) for all of NSW up until the 1994/95 season. This report completes the data-set for the Murrumbidgee catchment up until the closure of the native fishery in 2001.

7.2. Data analysis

Since 1947, monthly returns of catches indicating weight of each species taken have been recorded. However, a significant shortcoming of the commercial fishery database is that records of fishing effort are only available as 'months fished'. Detailed effort data (days fished), was not routinely recorded until 1979. As a result, variation in catch could result from variation in fishing effort amongst years. Data on the number of fishing days undertaken in each of the Murrumbidgee fisheries remained relatively stable between 1984 and 1995 (Reid *et al.* 1997). However, over the longer term, Reid *et al.* (1997) reported that the fishery (entire NSW fishery) was at its peak of about 290 licensed fishers in 1953 and declined gradually until 1968, where it increased to a peak again in 1973, had declined to 40 licensed fishers by 1995 and finally closed in 2001 (Fig. 4 in Reid *et al.* 1997). Fishing methods changed very little over the life of the fishery and therefore contribute little to changes in the catch through time (Reid *et al.* 1997).

Data of the Murrumbidgee commercial fishery (Lake Yanga, Barren Box Swamp, and Murrumbidgee River – but not Murrumbidgee Riverina which is within the Benanee catchment, not the Murrumbidgee catchment) were extracted from Appendix 2(b) of Reid *et al.* (1997). Remaining data from 1996 to the close of the fishery in 2001 is unpublished and was accessed directly from the NSW Fisheries Com-catch database. Data from all three commercial fishing zones within the catchment were combined for analysis.

A recognised flaw in the commercial fishery data, as pointed out by Reid *et al.* (1997), is the lack of detailed effort data prior to 1984. Data could be adjusted to the catch per month fished from 1955, or to number of days fished from 1984. However, to enable inclusion of all available data, the catch figures were not standardised by any effort information and should therefore be interpreted with caution.

Commercial catch data required a square-root transformation to normalise the data. Annual discharge data from the Hay gauging station was also normalised by square-root transformation. A correlation matrix was created using Pearson's correlation coefficient to assess relationships between the commercial catch of each species across years. Data for freshwater catfish and silver perch following the voluntary fishing closure were omitted (post 1993). Data for bony herring were omitted prior to their reappearance in 1984 and data for tench were omitted following their disappearance in 1981. Correlations were also undertaken to assess the relationship of commercial catch for each species and annual flow. These analyses were undertaken for flows in the year of harvest, one year prior to harvest, two years prior to harvest, three years prior to harvest and 4 years prior to harvest in order to identify any lag periods in response of the commercial catch to flow. A lag would be expected given that several species took several years to grow to harvestable size following a recruitment event induced by flow conditions.

7.3. Results and Discussion

7.3.1. Bony Herring

Bony herring were not recorded in commercial catches until 1984 when they were first recorded in the Murrumbidgee catch, and particularly the Lake Yanga fishery (Figure 7.1). This pattern is unlikely to be the result of a lack of accurate recording prior to 1984, as in 1949/50, Langtry reported that "bony herring were rarely taken", that the species was considered to have declined and was " now almost extinct after having been present in great numbers in the early 1900's" and "last seen in large numbers in 1927 in lagoons" (Cadwallader 1977). The reasons for the initial decline, almost complete disappearance and then sudden recovery in the 1980's are unclear but do not appear to be related to annual flow or river regulation. Further, the initial decline pre-dates the introduction of carp, redfin and gambusia.

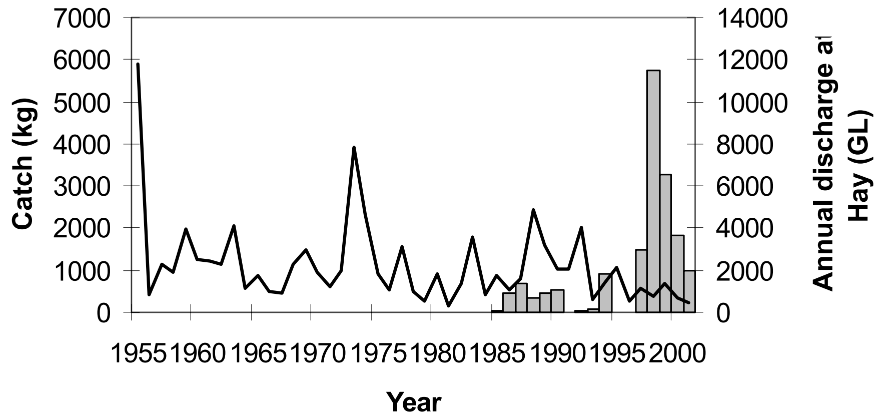


Figure 7.1. Commercial catch data for bony herring in the Murrumbidgee catchment (bars) superimposed on the annual discharge at Hay.

7.3.2. Carp

Small catches of carp (possibly goldfish or the localised population of Yanco strain carp) were recorded prior to the initial colonisation of the Murrumbidgee by invasive Boolarra strain carp in 1973 (Figure 7.2). This invasion coincided with the large floods that occurred that year. Carp populations increased rapidly until 1980 then declined through until 1984-85 (Figure 7.2). Since 1985, the carp population in the Murrumbidgee appears to have stabilised at an equilibrium density that appears to fluctuate over a four to five year cycle (Figure 7.2). The peaks in carp catch in 1988 and 1992 correspond to high flows in those years however the most recent peak in 1997 does not correspond with a high annual flow (Figure 7.2). Lastly, in the final two years of the commercial fishery, carp numbers where the lowest they had been since the original colonisation event in 1973 (Figure 7.2).

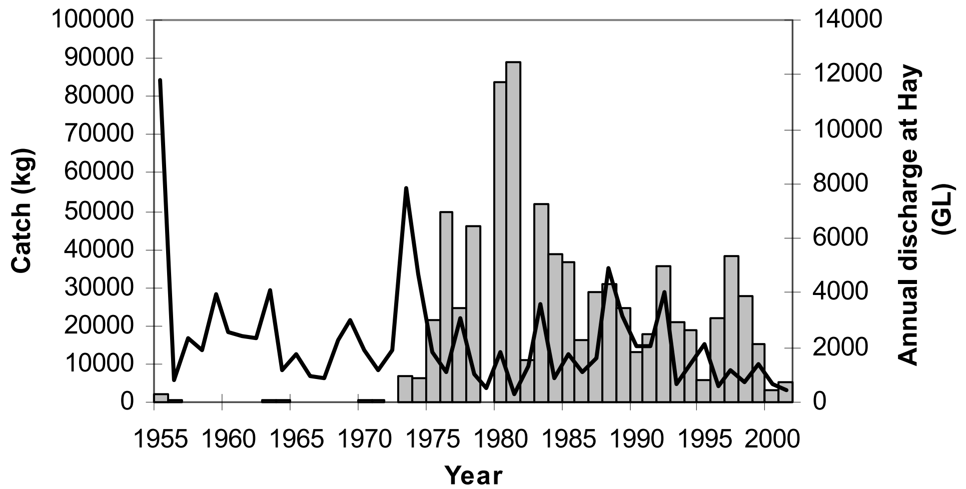


Figure 7.2. Commercial catch data for carp in the Murrumbidgee catchment (bars) superimposed on the annual discharge at Hay.

7.3.3. Freshwater catfish

Freshwater catfish catches appear to have been moderate throughout the 1960's and increased to 10 tonnes following the high flow years of 1973 - 74 (Figure 7.3). The catfish catch then declined, yet remained viable throughout the carp 'explosion' period of the 1980's before disappearing from the riverine catch ten years later in 1983. The Barren Box Swamp catfish fishery continued from the 1984 to early 1991 before also collapsing in this wetland system. The observed ten year overlap between the invasion of carp and the decline of catfish suggests a more complex relationship between these two species. Rather than carp competing directly with adult catfish resulting in their exclusion, a hypothesis of carp preventing catfish recruitment through disturbance of catfish nest or preying directly on catfish eggs is proposed. Under this hypothesis, adult catfish would persist for several years before the population would collapse through lack of recruitment, as was observed in the Murrumbidgee. Commercial fishers implemented a voluntary ban on the harvest of freshwater catfish in 1993 (Reid *et al.* 1997).

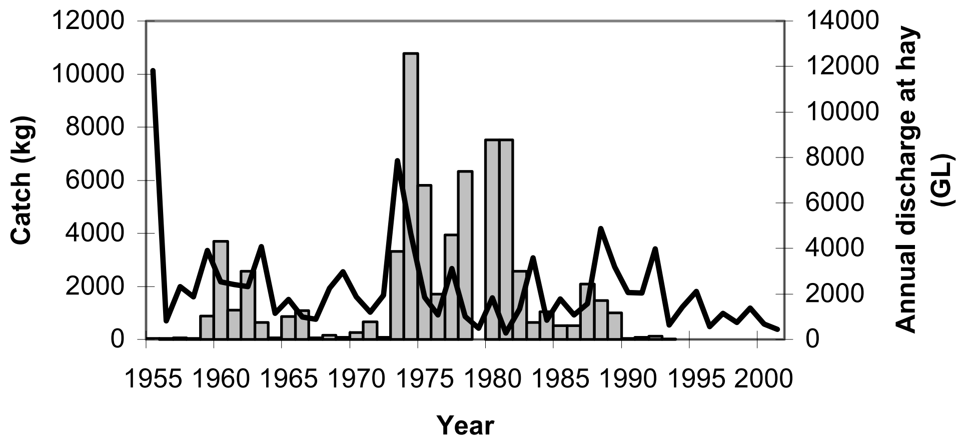


Figure 7.3. Commercial catch data for freshwater catfish in the Murrumbidgee catchment (bars) superimposed on the annual discharge at Hay.

7.3.4. Murray cod

Murray cod catches were the highest on record (10.6 tonnes) in the first year of catch recording in the Murrumbidgee (Figure 7.4). Catches declines through the late 50's and early 60's as was the trend for the entire Murray cod fishery within NSW (Reid *et al.* 1997). Murray cod catches remained very low through the late 60's and early 70's, but unlike the rest of the fishery, Murray cod catches began to increase in the early 70's and continued to do so until the late 80's. In contrast, the NSW Murray cod fishery for the balance of the state remained stable at the depleted level (Reid *et al.* 1997). Catches declined again through the early to mid 90's (Figure 7.4). However by 1998, the commercial catch of Murray cod approached 1955 levels (10.5 tonnes) and remained high for 3 years (Figure 7.4). The catch declined slightly in the final year of the commercial fishery, but was still the ninth best year of the previous 47 years of commercial catch data records.

The commercial catch of Murray cod was not significantly correlated with the annual discharge during the year of harvest. For example, Murray cod catches did not increase following the period of high annual flows in 1973 and 1974 (Figure 7.4). In contrast, a significant negative correlation was detected, with Murray cod catches increasing three years after a year of low annual discharge (r = -0.33, $p < 0.05$). The three year lag may represent the time it takes for young Murray cod to reach a size were they are vulnerable to commercial fishing gear. This result supports the low-flow hypothesis of Humphries *et al.* (1999) and Humphries and Lake (2000). This hypothesis suggests that cod recruitment is most successful under conditions of low flow. If correct, this hypothesis would explain the recent increase in Murray cod populations (Figure 7.4 and Table 6.2) under the drought conditions which have prevailed for the past few years. This relationship has important implications for environmental flow management and further detailed assessment is required. Particularly as this relationship is the frequently proposed suggestion that Murray cod recruitment success increases following large flow events (Rowland 1989; Rowland 1998).

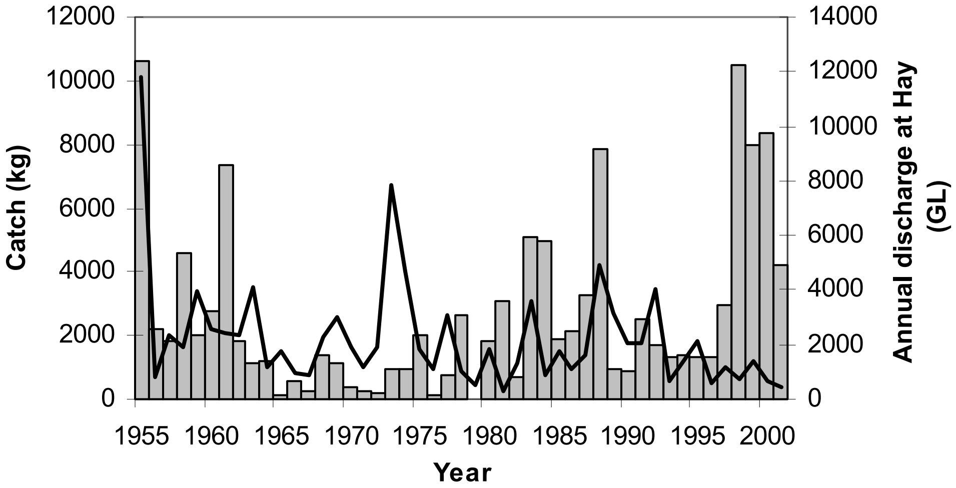


Figure 7.4. Commercial catch data for Murray cod in the Murrumbidgee catchment (bars) superimposed on the annual discharge at Hay.

7.3.5. Freshwater eels/Short headed lamprey

One of the more interesting records from the Murrumbidgee commercial fishery were reports of an influx of what were recorded as freshwater eels during the high flow years between 1972 and 74 (Figure 7.5). The Murray-Darling Basin is outside the normal distribution of freshwater eels, which are catadromous (obligatory spawning migration to the ocean) and generally restricted to coastal rivers (McDowall 1996). However, freshwater eels are known to undertake overland movements between waterbodies and have been found in the headwaters of several Murray-Darling Basin catchments (including the Murrumbidgee), presumably having moved between the headwater streams of the coastal and inland rivers along the ridge of the Great Dividing Range. Although individual freshwater eels are found on an irregular basis around Canberra (Lintermans 2000*a*) and as far downstream as Lake Wyangan (Llewellyn pers. comm.), it is doubtful whether the influx in the commercial catches in the Murrumbidgee were in fact eels.

Mr Henry Davies, a commercial fisherman in the Murrumbidgee fishery during the early 1970's, was able to confirm that these catches were not freshwater eels, but were in fact a species of lamprey. Lamprey also require a marine stage in their life-cycle (McDowall 1996). However unlike eels, lamprey are anadromous and migrate upstream from the ocean as adults to spawn in freshwaters. An unidentified environmental cue must have attracted adult lamprey from the southern ocean into the Murray-Darling River system during this short period. This hypothesis is supported by the simultaneous influx of 'freshwater eel' in the Lachlan, Darling and Murray fisheries (Reid *et al.* 1997: Appendix 2(b)).

There are two species of lamprey known to inhabit the South Australian coastline, the short-headed lamprey and the pouched lamprey (McDowall 1996). Specimens collected from the Murrumbidgee River at Narrandera in 1968, and preserved by Llewellyn, were the short-headed species. Therefore, it is assumed that this is the species caught by the commercial fishers in the 70's.

Interestingly, no museum samples, or reports of lampreys in the Murrumbidgee exist prior to the specimens of Llewellyn, or the commercial catch data. And subsequent to 1974, no official reports of lampreys have been collected apart from two angler reports. It is hypothesised that the occurrence of a substantial number of lamprey in the Murrumbidgee was dependant on the high flow conditions in 1973 and 1974. This is supported by a significant correlation between lamprey catches and annual discharge ($r = 0.39$, $p < 0.05$). However the absence of lamprey in catches in the high flow event in 1955 do not support this hypothesis (Figure 7.5). It is possible that data for this species may not have been recorded in the early fishery.

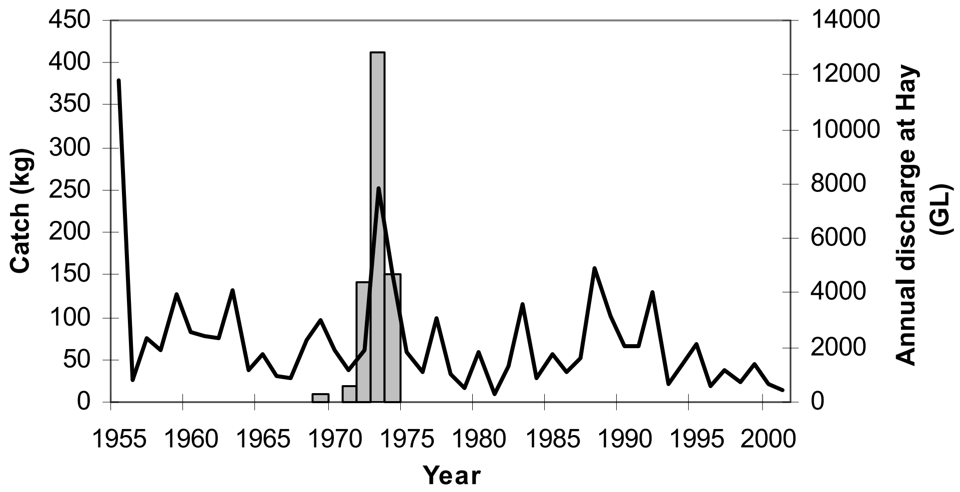


Figure 7.5. Commercial catch data for eels/lamprey in the Murrumbidgee catchment (bars) superimposed on the annual discharge at Hay.

7.3.6. Golden perch

The pattern within the commercial catch data for golden perch is very similar to that of the Murray cod fishery ($r = 0.72$, $p < 0.0001$) although the tonnages taken were around twice as high (Figure 7.6). The highest catch recorded was during the first year of data collection in 1955 (Figure 7.6). The catch declined during the 60's and was very low during the late 60's and early 70's before increasing again in the late 70's through to the late 80's (Figure 7.6). The catch declined slightly during the early 90's but increased again during the late 90's to become the second highest commercial catch for this species in the final year of the fishery in 2001(Figure 7.6). Like Murray cod, golden perch did not show any significant correlation with annual discharge in the year of harvest or with up to 4 years lag-time.

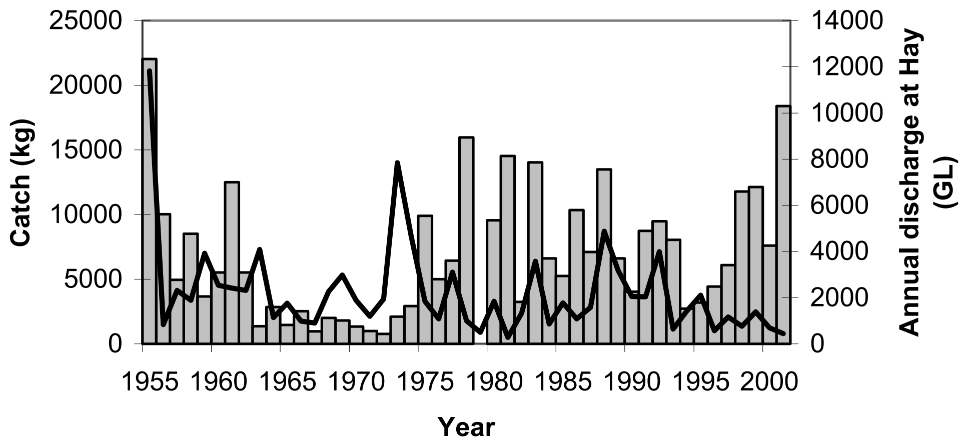


Figure 7.6. Commercial catch data for golden perch in the Murrumbidgee catchment (bars) superimposed on the annual discharge at Hay.

7.3.7. Macquarie perch

The commercial catch of Macquarie perch was small in comparison to other perch and cod species (Figure 7.7). Apart from a small harvest in the late 50's, most of the commercial catch was taken in the late 70's and 80's (Figure 7.7). The last commercial harvest from the Murrumbidgee was in 1988 (Figure 7.7). Macquarie perch showed a significant negative correlation with annual discharge, with catch increasing 2 years after periods of low annual discharge (r = -0.38, p < 0.01).

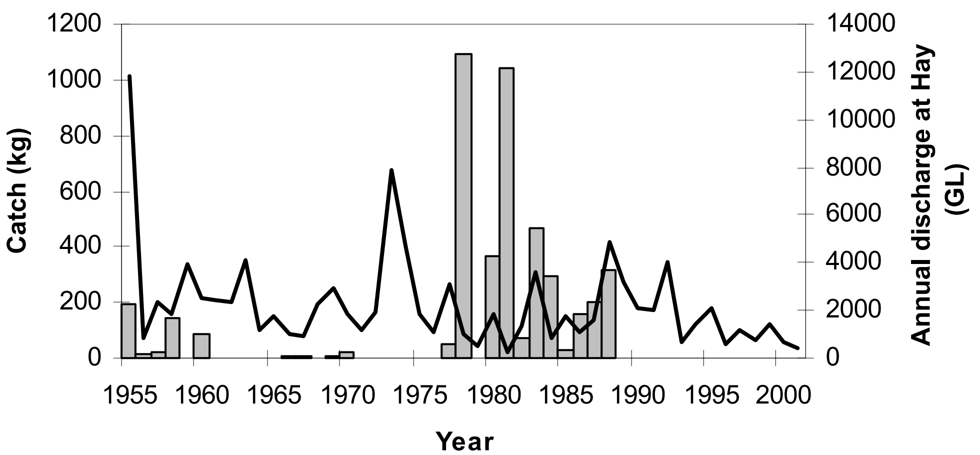


Figure 7.7. Commercial catch data for Macquarie perch in the Murrumbidgee (bars) catchment superimposed on the annual discharge at Hay.

7.3.8. Redfin perch

Redfin perch colonised the lower Murrumbidgee in the 1940's and supported a moderate commercial harvest in most years (Figure 7.8). Redfin catches were highest during the late 80's (Figure 7.8). Redfin populations appear to fluctuate on a roughly nine to ten year cycle that is partially influenced by annual flow (Figure 7.8). However the flow relationship is not significant during the year of harvest but is delayed by one year ($r = 0.35$, $p < 0.024$). The commercial catch was greatest in the 80's and early 90's and declined to low levels during the late 90's (Figure 7.8).

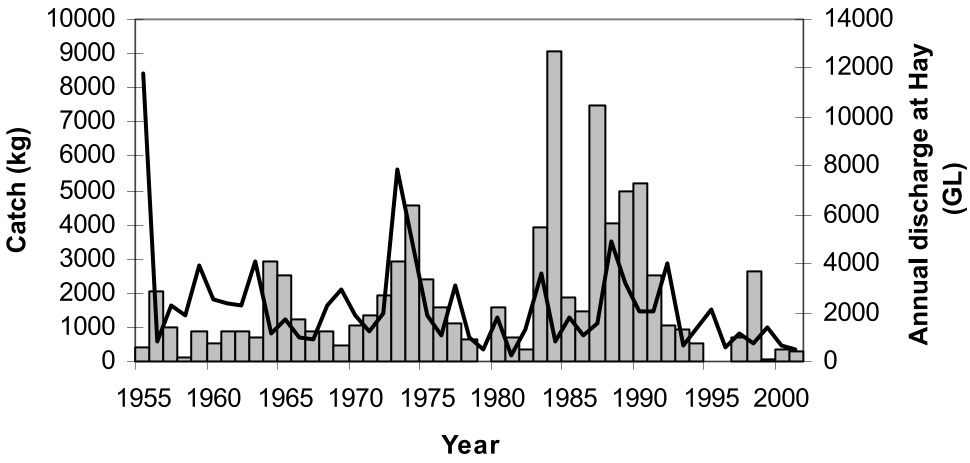


Figure 7.8. Commercial catch data for redfin perch in the Murrumbidgee catchment (bars) superimposed on the annual discharge at Hay.

7.3.9. Silver perch

Like the Murray cod and golden perch fishery, the annual harvest of the silver perch fishery was highest in 1955, the first year or data recording (Figure 7.9). The catch declined through the late 50's and was low by the 60's. However in contrast to Murray cod and golden perch, populations of silver perch did not recover in the late 70's and 80's (Figure 7.9). Catches remained low through to 1993 when commercial fishers implemented a voluntary ban on harvest (Reid *et al.* 1997). The catch of silver perch was significantly correlated with the annual discharge (measured at Hay) within the year of harvest ($r = 0.39$, $p = 0.015$). Which supports statements that the species was most effectively harvested during the migration of large schools as a response to flow events (Cadwallader 1977).

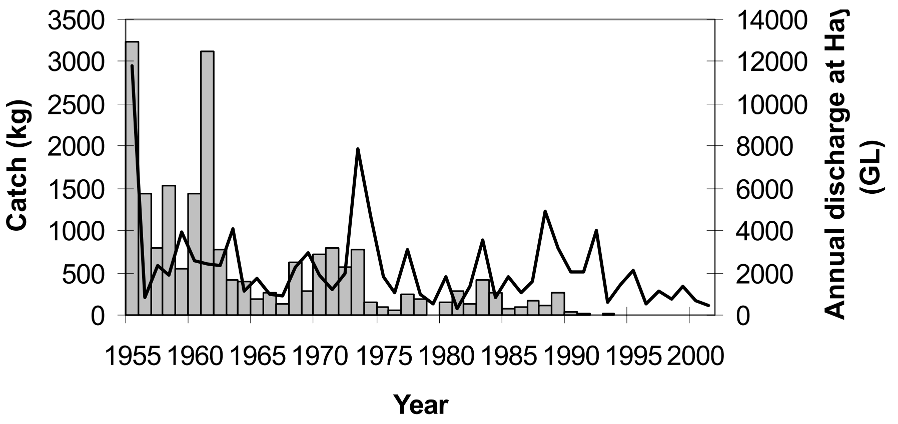


Figure 7.9. Commercial catch data for silver perch in the Murrumbidgee catchment (bars) superimposed on the annual discharge at Hay.

7.3.10. Tench

Tench were largely harvested from Lake Yanga, with smaller numbers coming from the Murrumbidgee River. The catch was at its highest in 1972 and crashed as soon as Boolarra strain of carp colonised the catchment (Figures 7.2 and 7.10). The commercial catch in 1980 was the last report of tench in the Murrumbidgee catchment.

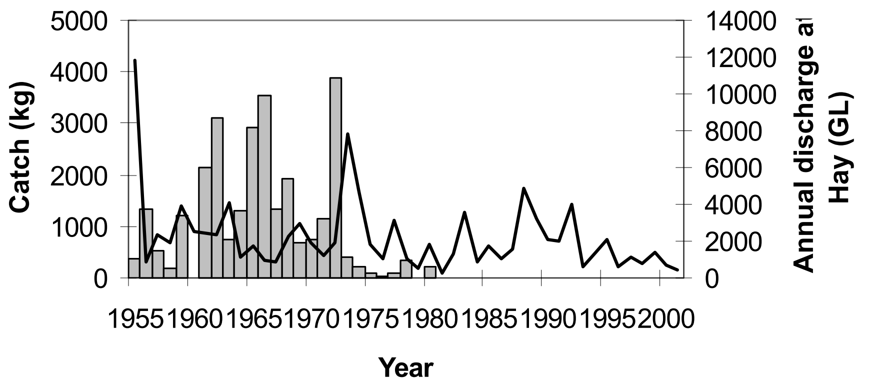


Figure 7.10. Commercial catch data for tench in the Murrumbidgee catchment (bars) superimposed on the annual discharge at Hay.

8. FISH STOCKING IN THE MURRUMBIDGEE CATCHMENT: 1968 -2004

8.1. Introduction

Fish stocking includes both the translocation of fish from one area into another as well as the hatchery production and release of captive bred fish. It is typically undertaken with the intent of either improving recreational fishing opportunities or for the conservation of endangered populations (NSWF 2003).

Despite much debate among fisheries managers and scientists, stocking fish is considered by the public as an important tool in achieving sustainable recreational fisheries (NSWF 2003). The history of trout stocking in NSW dates back to as early as 1877 (NSWF 2003). Newly established trout populations flourished between 1900 and 1930's when growth rates began to decline due to increased densities and limited food. Management of stocking activities was assumed by the NSW government in 1960 (NSWF 2003). Native fish breeding programs did not begin until 1961 with the opening of the Narrandera Fisheries Centre.

This chapter compiles all stocking records from the Murrumbidgee catchment (NSW portion only) since 1968.

8.2. Data analysis

Stocking data was accessed from the NSW fish stocking database. This database contains data from all stocking activities undertaken in the Murrumbidgee catchment since 1968. It does not contain data regarding salmonid stocking activities prior to 1968, early translocation of native species, the deliberate liberation of alien species such as goldfish and redfin, or the illegal introduction of aquarium fishes.

Stocking data was correlated with year to test the significance of trends in the umber of individuals of each species stocked using Pearson's product-moment correlation.

8.3. Results and Discussion

Seven native species and four alien salmonids have been, or continue to be stocked as part of either harvest stocking programs to promote recreational fishing or conservation stocking programs to aid the recovery of threatened species.

8.3.1. Golden perch

Golden perch is the most stocked fish in the Murrumbidgee catchment with 4,623,938 fingerlings having been released (Figure 8.1). The first recorded stocking of golden perch was of 2,000 individuals in 1960. However regular stocking of large numbers of fingerlings did not begin until 1976. The number of fingerlings released has increased significantly since that time ($r = 0.68$, $p < 0.0001$) (Figure 8.3).

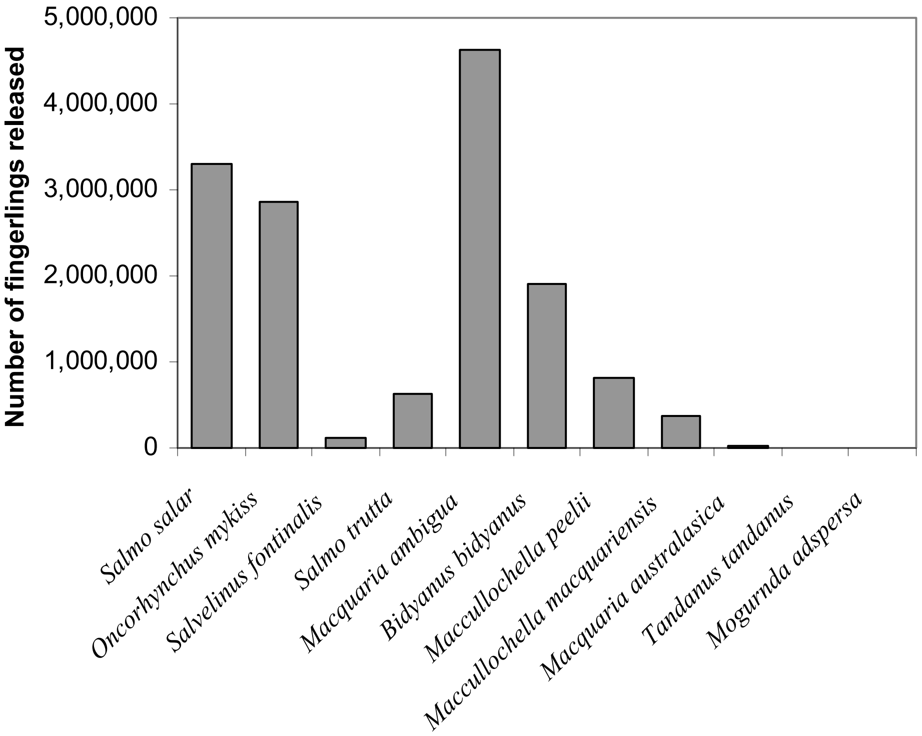


Figure 8.1. Number of fingerlings of each species stocked into the Murrumbidgee catchment since record keeping began in1968.

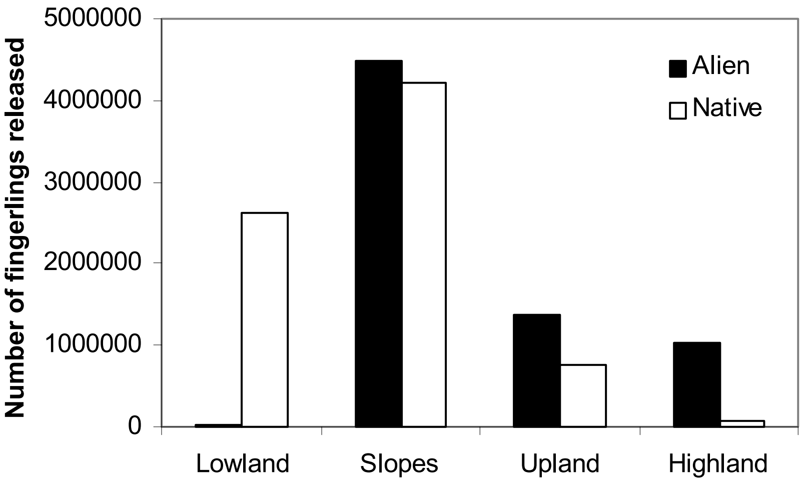


Figure 8.2 The number of fingerlings of alien trout species and native fish species into each of the altitude zones in the Murrumbidgee catchment.

Golden perch have been released at 30 sites, with 68% of individuals being released into dams. The slopes zone received 56% of the fingerlings, the lowland zone received 37%, the upland zone, the upland zone received 7% and the highland zone 0.2%.

The increasing commercial catches of golden perch in the Murrumbidgee from the mid 1970's corresponds with the initiation of stocking this species. Therefore, it is possible that stocking had a positive affect on population of this species.

Table 8.1. Streams and Dams in the Murrumbidgee catchment stocked with golden perch.

Stream name	Nearby Town	Dam name	Nearby town
Murrumbidgee River	Alfredtown	Ariah Park Lake	Ariah Park
Murrumbidgee River	Balranald	Captains Flat Dam	Captains Flat
Murrumbidgee River	Berembed Weir	Lake Wyangan	Griffith
Murrumbidgee River	Carrathool	Yanco Reserve	Leeton
Murrumbidgee River	Currawarna	Lake Talbot	Narrandera
Murrumbidgee River	Grong Grong	Gillenbah Lagoon	Narrandera
Morleys Creek	Gundagai	Googong Dam	Queanbeyan
Murrumbidgee River	Hay	Jounama Pondage	Talbingo
Bundidgery Creek	Narrandera	Centenary Lake	Temora
Murrumbidgee River	Narrandera	Blowering Dam	Tumut
Umbango Creek	Tarcutta	Forest Dam 1 & 2	Tumut
Murrumbidgee River	Wagga Wagga	Bowmans Lagoon	Wagga Wagga
Murrumbidgee River	Between Wagga Wagga and Burrinjuck	Lake Albert	Wagga Wagga
Murrumbidgee River	Yanco	Wagga Lagoon	Wagga Wagga
Murrumbidgee River	Yass	Burrinjuck Dam	Yass

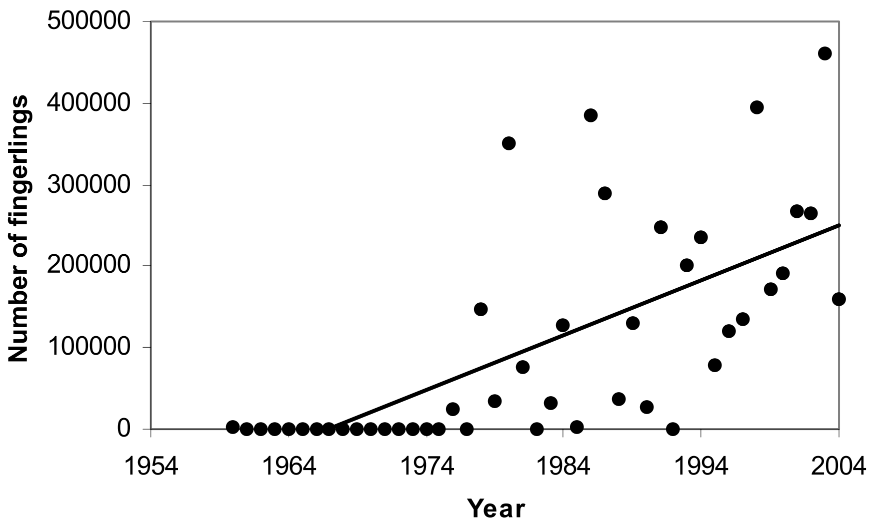


Figure 8.3. Number of golden perch fingerlings released in the Murrumbidgee catchment. R^2 = 0.46.

8.3.2. *Atlantic salmon*

Atlantic salmon is the second most stocked fish in the Murrumbidgee catchment with 3,297,670 fingerlings having been released (Figure 8.1). Atlantic salmon stocking began in 1980 and the last stocking in the Murrumbidgee was in 2002. The number of fingerlings released has declined significantly ($r = 0.5$, $p = 0.011$) (Figure 8.4).

Atlantic salmon were originally stocked into three impoundments in the Murrumbidgee catchment; Talbingo Dam, Jounama Pondage and Burrinjuck Dam (including the Goodradigbee River and Micalong Creeks). However no salmon have been released into Talbingo or Jounama since 1982. Given their short life spans and the fact that Atlantic salmon do not form self-sustaining populations in impoundments, stocks have most certainly disappeared from these two waterbodies. Therefore, the only waterway were Atlantic salmon could be expected to occur within the Murrumbidgee catchment is within Burrinjuck Dam. However even within this impoundment, population sizes are very low, as neither of the two sites sampled in the dam, Dale's Point or Woolgarlo detected any individuals of this species.

The slopes zone received 83% of the Atlantic salmon fingerlings with the upland zone receiving the remaining 17%. This species does not form self-sustaining populations in NSW.

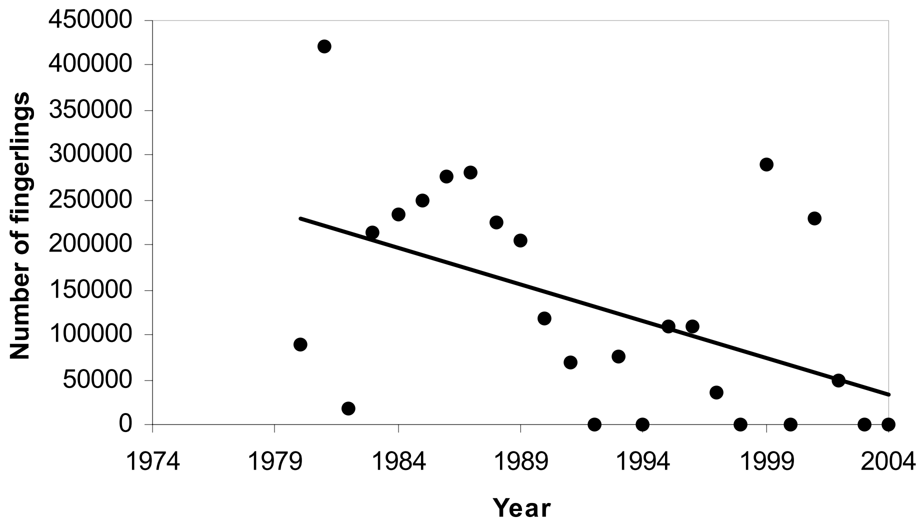


Figure 8.4. Number of Atlantic salmon fingerlings released in the Murrumbidgee catchment. $R^2 = 0.25$.

8.3.3. Rainbow trout

Rainbow trout is the third most stocked fish in the Murrumbidgee catchment with 2,871,410 fingerlings having been released since 1968 (Figure 8.1). However rainbow trout were first introduced into NSW in 1894 (McKay 1984) and are known to have been released in the upper Murrumbidgee in the 1890's (Lintermans 2000*a*). Since record keeping began in 1968, the number of rainbow trout fingerlings stocked in the Murrumbidgee has increased significantly ($r = 0.59$, $p = 0.0001$) (Figure 8.5).

Rainbow trout have been stocked into 57 sites with 65% of fingerlings being released into dams and impoundments. The slopes zone received 51% of rainbow trout fingerlings, the uplands received 25% and the highlands has received 24%. No rainbow trout have been released into the lowland zone since at least 1968.

Given their long history of release, it at first appears that rainbow trout stocking could not have resulted in the distinct declines of Macquarie perch in the upper catchment observed between 1979 and 1985 as reported by Lintermans (2000*a*). However 1980 was the first year when very large numbers of rainbow trout were released (Figure 8.5). Therefore, increases in the stocking rate of rainbow trout, more than any other factor, coincide with the decline of the threatened Macquarie perch in the upper Murrumbidgee.

Widespread stocking of rainbow trout also limits the prospects of reintroducing southern purple spotted gudgeons and southern pygmy perch into the upland areas of the Murrumbidgee catchment. Additionally, Tilzey (1976), Cadwallader (1979), Lintermans and Rutzou (1990), Raadik (1995) and Lintermans (2000*a*) have documented substantial negative impacts of rainbow trout on native galaxiid populations. Lastly, Gillespie (2001) and Gillespie and Hero (1999) have documented negative impacts of rainbow trout on endangered Booroolong frogs.

Table 8.2. Streams and Dams in the Murrumbidgee catchment stocked with rainbow trout.

Stream name	Nearby Town	Dam name	Nearby town
Morrass River	Adaminaby	Batlow Dam	Batlow
Boundary Creek	Adaminaby	Tumut No. 2	Cabramurra
Goorudee Rivulet	Adaminaby	Tumut Pond	Cabramurra
Murrumbidgee River	Adaminaby	Three Mile Dam	Kiandra
Sams Creek	Adaminaby	Lake Williams	Nimmitabel
Adelong Creek	Adelong	Googong Dam	Queanbeyan
Queanbeyan River	Anembo	Jounama Pondage	Talbingo
Buddong Creek	Batlow	Talbingo Dam	Talbingo
Yaven Yaven Creek	Batlow	Blowering Dam	Tumut
Bago Creek	Batlow	Burrinjuck Dam	Yass
Reedy Creek	Batlow		
Cooleman Creek	Brindabella		
Bull Flat Creek	Brindabella		
McPherson' Creek	Burrinjuck		
Ballnafad Creek	Captains Flat		
Rock Flat Creek	Carlaminda		
Cooma Creek	Cooma		
Cowra Creek	Cooma		
Big Badja River	Cooma		
Leather Barrel Creek	Cooma		
Numeralla River	Cooma		
Peppers Creek	Cooma		
Roberts Creek	Jerangle		
Sherlock Creek	Jerangle		
Cave Creek	Kiandra		
Nanima Creek	Murrumbateman		
Greenlands Creek	Nimmitabel		
Kybeyan River	Nimmitabel		
Kydra Creek	Nimmitabel		
Nimmitabel River	Nimmitabel		
Punchbowl or Winifred Creek	Nimmitabel		
Tom Groggin Creek	Nimmitabel		
Celeys Creek	Peakview		
Molonglo River	Queanbeyan		
Tinderry Creek	Queanbeyan		
Mill Creek	Talbingo		
Tarcutta Creek	Tumbarumba		
Burra Creek	Tumbarumba		
Long Creek	Tumbarumba		
Emu Creek	Tumut		
Gilmore Creek	Tumut		
Tumut River	Tumut		
Carey Creek	Wee Jasper		
Dinnertime Creek	Wee Jasper		
Goodradigbee River	Wee Jasper		
Micalong Creek	Wee Jasper		
Yass River	Yass		

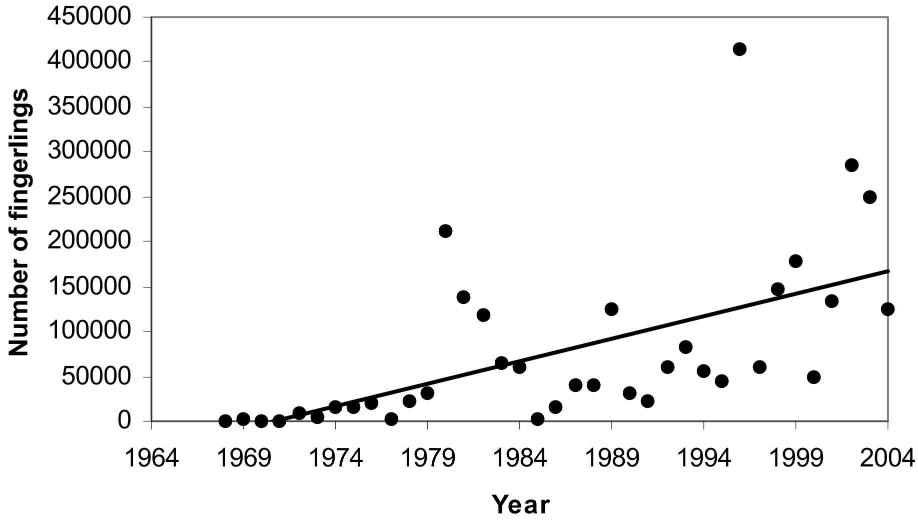


Figure 8.5. Number of rainbow trout fingerlings released in the Murrumbidgee catchment. R^2 = 0.35.

8.3.4. Silver perch

1,896,920 silver perch have been released into the Murrumbidgee catchment for harvest stocking, making it the fourth most stocked species in the catchment (Figure 8.1). Like golden perch, the first stocking occurred in 1960, but regular large-scale stocking did not begin until 1981. Since that time, the number of silver perch fingerlings released has increased significantly ($r = 0.62$, $p < 0.0001$) (Figure 8.6).

Silver perch have been stocked at 17 sites, with 79% of fingerlings being released into dams and impoundments. The slopes zone received 56% of silver perch fingerlings, the lowlands zone has received 28%, the upland zone 16% and the highland zone 0.3%.

Despite substantial numbers of hatchery produced fingerlings being released in the Murrumbidgee catchment, this species remains extremely rare. Despite sampling across the entire catchment, only one individual was captured from one site in the lower Murrumbidgee River. Therefore it is apparent that stocking of this species is not providing a viable recreational fishery or leading to increased numbers of this species in the ecosystem.

Table 8.3. Streams and Dams in the Murrumbidgee catchment stocked with silver perch.

Stream name	Nearby Town	Dam name	Nearby town
Murrumbidgee River		Captains Flat Dam	Captains Flat
Bundidgery Creek	Narrandera	Cootamundra Lagoon	Cootamundra
		Lake Wyangan	Griffith
		Bethungra Dam	Junee
		Yanco Reserve	Leeton
		Googong Dam	Queanbeyan
		Jounama Pondage	Talbingo
		Centenary Lake	Temora
		Blowering Dam	Tumut
		Bowmans Lagoon	Wagga Wagga
		Lake Albert	Wagga Wagga
		Wagga Lagoon	Wagga Wagga
		Burrinjuck Dam	Yass
		Railway Dam	Yass
		Chinaman's Dam	Young

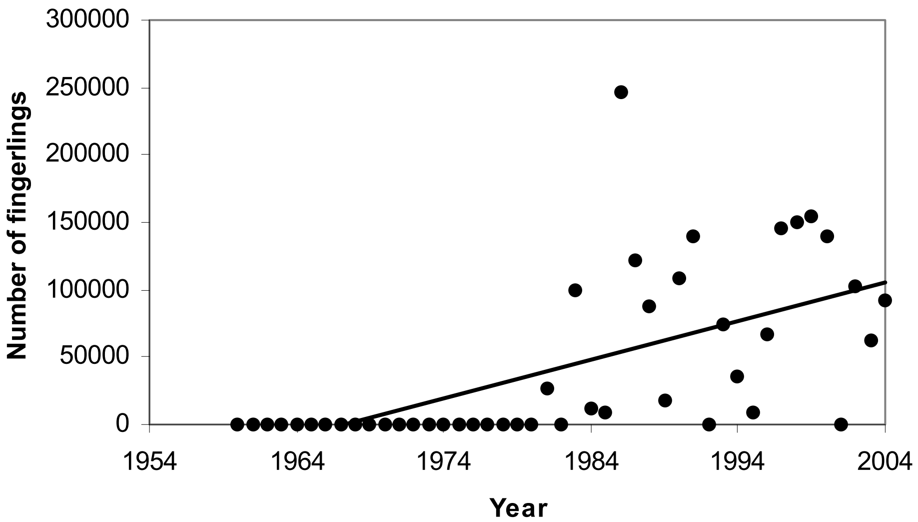


Figure 8.6. Number of silver perch fingerlings released in the Murrumbidgee catchment. R^2 = 0.38.

8.3.5. Murray cod

Murray cod stocking began in 1988 and a total of 822,161 fingerlings have been released in the Murrumbidgee catchment. The number of Murray cod released has increased significantly since 1988 ($r = 0.76$, $p = 0.0004$) (Figure 8.7).

Murray cod have been stocked at 25 sites, with 80% of fingerlings being released into dams and impoundments. The slopes zone received 58% of Murray cod fingerlings, the lowlands zone has received 30%, the upland zone 10% and the highland zone 2%.

Recent anecdotal recreational fisher reports of the recovery of Murray cod populations in the Murrumbidgee River (which are supported by the commercial fishery data presented in chapter 7 and partially supported by the electrofishing data presented in chapter 6) could potentially be explained by the significant increase in the level of stocking of this species in the catchment. However, this relationship is likely to be an artefact, given that Murray cod populations began to recover in the 1970's, before Murray cod stocking began, and the commercial harvest was low throughout the 1990's when Murray cod stocking was increasing.

Table 8.4. Streams and Dams in the Murrumbidgee catchment stocked with Murray cod.

Stream name	Nearby Town	Dam name	Nearby town
Murrumbidgee River	Berembed Weir	Captains Flat Dam	Captains Flat
Molonglo River	Captains Flat	Lake Wyangan	Griffith
Morleys Creek	Gundagai	Bethungra Dam	Junee
Bundidgery Creek	Narrandera	Yanco Reserve	Leeton
Tarcutta Creek	Tarcutta	Lake Talbot	Narrandera
Umbango Creek	Tarcutta	Googong Dam	Queanbeyan
Tumut River	Tumut	Jounama Pondage	Talbingo
Beavers Creek	Wagga Wagga	Centenary Lake	Temora
Murrumbidgee River	Yanco	Blowering Dam	Tumut
		Forest Dam 1 & 2	Tumut
		Bowmans Lagoon	Wagga Wagga
		Lake Albert	Wagga Wagga
		Wagga Lagoon	Wagga Wagga
		Burrinjuck Dam	Yass
		Railway Weir	Yass
		Chinaman's Dam	Young

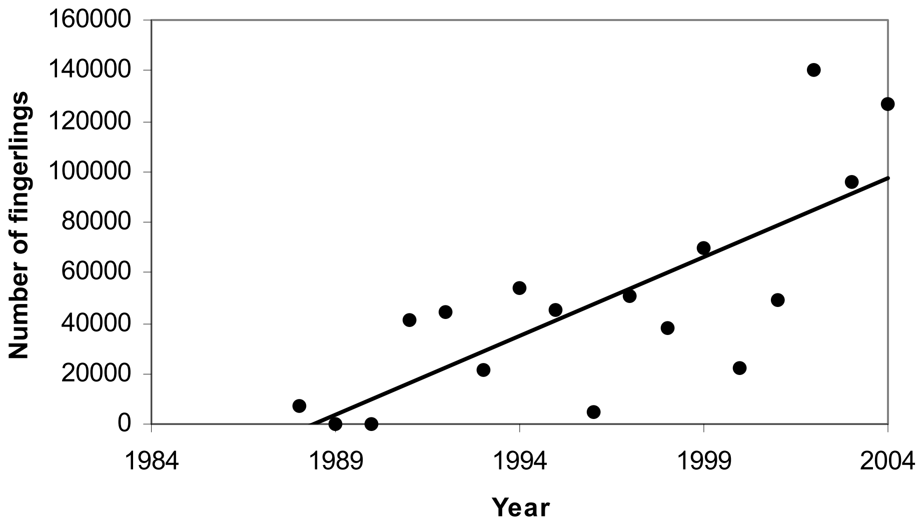


Figure 8.7. Number of Murray cod fingerlings released in the Murrumbidgee catchment. R^2 = 0.58.

8.3.6. *Brown trout*

The next most frequently stocked species is brown trout, with 620,250 fingerlings released since 1968. Brown trout were the first trout introduced to NSW, being introduced in 1888 when 300 or more were received at Queanbeyan and Cooma, and stocked into the Cotter, Queanbeyan, Molonglo, Yass, Naas, Orroral, Little, Bibbenluke and Murrumbidgee Rivers and Ginnindera, Tuggeranong and Jerrabomberra Creeks (Faragher 1986, Lintermans 2000*a*; NSW Fisheries 2003). The number of fingerlings released has increased significantly ($r = 0.55$, $p < 0.0021$) since record keeping began (Figure 8.8).

Since 1968, brown trout have been stocked at 38 sites (Table 8.1), with 71% of fingerlings being released into streams. The highland zone has received the most brown trout stocking, with 50% of fingerlings released in that zone. The slopes zone received 38% of fingerlings while the upland and lowland zone have received 5% each.

Table 8.5. Streams and Dams in the Murrumbidgee catchment stocked with brown trout.

Stream name	Nearby Town	Dam name	Nearby town
Goorudee Rivulet	Adaminaby	Tumut Pondage	Cabramurra
Sams Creek	Adaminaby	Three Mile Dam	Kiandra
Yaouk Creek	Adaminaby	Lake Williams	Nimmitabel
Adelong Creek	Adelong	Googong Dam	Queanbeyan
Buddong Creek	Batlow	Jounama Pondage	Talbingo
Yaven Yaven Creek	Batlow	Blowering Dam	Tumut
Bago Creek	Batlow		
Hindmarsh Creek	Batlow		
Reedy Creek	Batlow		
Goodradigbee River	Brindabella		
Rock Flat Creek	Carlaminda		
Murrumbidgee River	Cooma		
Cooma Creek	Cooma		
Cowra Creek	Cooma		
Alum Creek	Cooma		
Big Badja River	Cooma		
Kybeyan River	Cooma		
Numeralla River	Cooma		
Peppers Creek	Cooma		
Queanbeyan River	Jerangle		
Sherlock Creek	Jerangle		
Bundidgery Creek	Narrandera		
Kydra Creek	Nimmitabel		
Punch Bowl or Winifred Creek	Nimmitabel		
Tom Groggins Creek	Nimmitabel		
Molonglo River	Queanbeyan		
Yandyguinula Creek	Queanbeyan		
Adjungbilly Creek	Tumut		
Gilmore Creek	Tumut		
Goobarragandra River	Tumut		
Tumut River	Tumut		
Murrumbidgee River	Between Wagga Wagga and Burrinjuck		

Like rainbow trout, brown trout stocking is believed to result in the decline of native fish and frogs (Butcher 1967; Weatherly and Lake 1967; Arthington 1991; Crowl *et al.* 1992; Cadwallader 1996; Gillespie and Hero 1999). However, brown trout are considered to be an even greater threat (NSWF 2003). As a result brown trout are no longer released into waters known to contain Macquarie perch, which are the Murrumbidgee River upstream of Cooma, the Queanbeyan River upstream of Googong Dam and the Goodradigbee River (NSWF 2003). Further, due to the threat posed to endangered Booroolong frogs, salmonid stocking has been discontinued within Native Dog Creek; Bombowlee Creek and Brungle Creek (NSWF 2003). However despite the presence of Booroolong frogs, the release of salmonids continues in the Goobarragandra River and Gilmore Creek following consultation with the NSW NPWS (including an 8 part test by NPWS) (NSWF 2003).

Widespread stocking of brown trout limits the prospects of reintroducing southern purple spotted gudgeons, southern pygmy perch and trout cod (Faragher *et al.* 1993) into the upland areas of the Murrumbidgee catchment. Native mountain galaxias are also known to decline or disappear in the presence of brown trout in streams (Fletcher 1979; Cadwallader 1979; Jackson and Williams 1980; Jackson and Davies 1983; Sanger and Fulton 1991; Townsend and Crowl 1991; McIntosh *et al.* 1992). The stocking program for brown trout provides further difficulties for the conservation of native fish in that 71% of brown trout fingerlings are released into streams rather than impoundments.

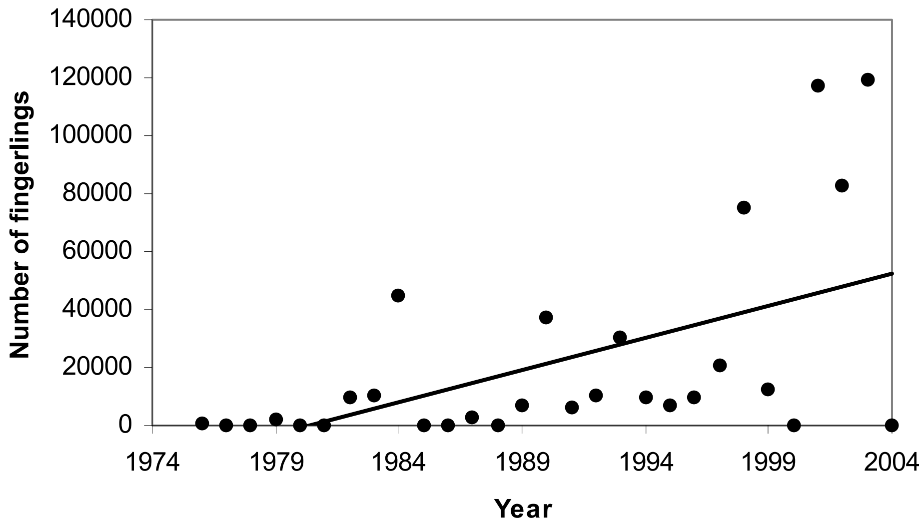


Figure 8.8. Number of brown trout fingerlings released in the Murrumbidgee catchment. R^2 = 0.30.

8.3.7. *Trout cod*

Like Murray cod stocking, trout cod conservation stocking began in 1988 and a total of 379,940 fingerlings have been reintroduced into the Murrumbidgee catchment. The last wild trout cod had been recorded in the upper Murrumbidgee at Tharwa in the mid 1970's (Lintermans 2000*a*). Trout cod fingerlings have been reintroduced at twelve locations within the catchment, with 94% being stocked into rivers. Most fingerlings have been released in the lowland zone (44%), with 28% being released in the slopes zone, 17% in the upland zone and 11% in the highland zone.

This conservation stocking program has been very successful having established populations in several locations within the lower catchment below Burrinjuck Dam (see chapter 5). The stocking program is planned to concentrate efforts in the upper catchment to re-establish populations there over the next few breeding seasons.

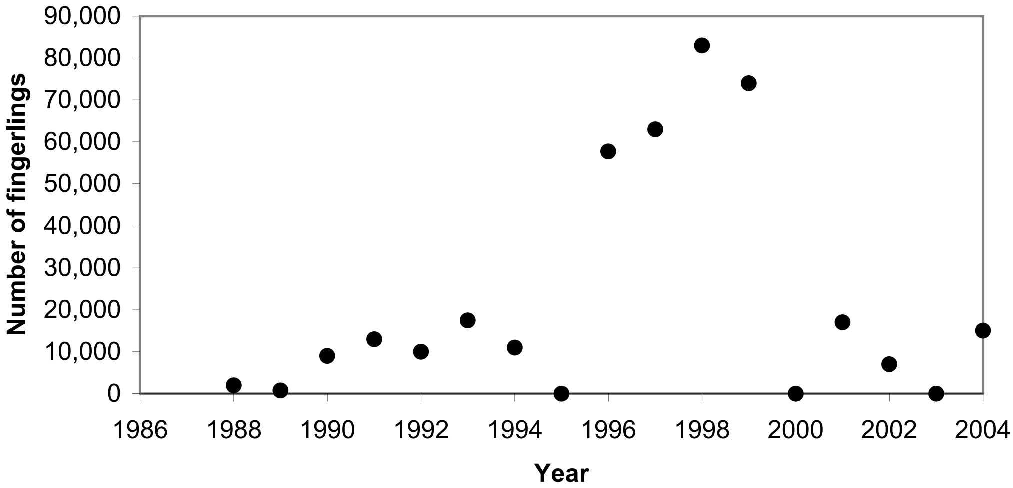


Figure 8.9. Number of trout cod fingerlings released in the Murrumbidgee catchment. R^2 = 0.04.

8.3.8. *Brook trout*

Brook trout are the least stocked of the eight on-going stocking programs with 122,810 individuals stocked in the Murrumbidgee catchment between 1971 and 2001. Most (78%) are stocked directly into streams (the Queanbeyan and Yarrangobilly Rivers) with lower numbers being released into Dry Dam, Tantangara Dam and Jounama Pondage. However all brook trout stocking in the Murrumbidgee since 1997 have been released into Dry Dam. Further, the number of brook trout stocked has decreased significantly (r = 0.36, p = 0.0345) over time (Figure 8.10).

Most 71% brook trout had been released into the upland zone, with 21% being released in the highland zone and 8% in the slopes zone. This species does not form self sustaining populations in the Murrumbidgee and is therefore a lower risk to native fish than are the rainbow and brown trout.

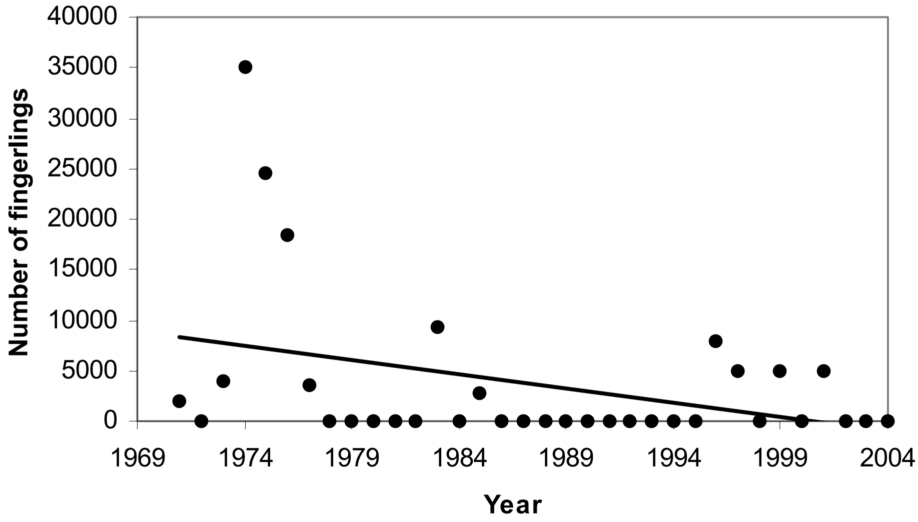


Figure 8.10. Number of brook trout fingerlings released in the Murrumbidgee catchment. R^2 = 0.13.

8.3.9. Macquarie perch, freshwater catfish and southern purple-spotted gudgeon

The remaining three native species have been stocked into the Murrumbidgee on a small number of occasions, at a small number of sites and with only small numbers of individuals. Macquarie perch reared at the Narrandera Fisheries Centre have been stocked into the Batlow River (1,300) and Burrinjuck Dam (2,000) in 1988 (Lintermans (2000*a*) suggests that the Yass River at Gundaroo and not Burrinjuck Dam was the release location for 2,000 fish in 1988), and into Talbingo Dam (10,000) in 1995. This species would benefit substantially from a conservation stocking program. However due to the lack of development of hatchery production protocols, potential for hatchery production is this species is limited to spawning and rearing running ripe fish harvested from the wild. Husbandry techniques have not yet been developed which enable adult fish to undergo gonad maturation in captivity.

Freshwater catfish were stocked into Burrinjuck Dam (400) in 1963 and into Yanco Creek (500) in 1995. Like Macquarie perch, this species also requires a carefully managed conservation stocking program in the Murrumbidgee catchment. Unlike Macquarie perch, this species is easily produced under hatchery conditions. However fecundity is low and therefore available hatchery facilities limit potential for production of sufficient numbers of fish. However it appears that even small numbers of stocked fish are able to establish, with the stocking of 500 fish in Yanco Creek in 1995 resulting in the existence of the only known catfish population in the catchment.

Lastly, the threatened purple-spotted gudgeon reared at Narrandera Fisheries Centre were stocked at two sites in Adjungbilly Creek (400) in 2004 in an effort to re-introduce this species to the catchment. Follow up surveys two weeks after release resampled a number of individuals. However further surveys failed to detect any individuals at either stocking location. A third round of surveys are planned in order to assess the survival and establishment of this species at these release sites. The outcomes of these surveys will determine whether further hatchery reared fish will be released at these sites, or whether alternative stocking locations are sought.

9. GENERAL DISCUSSION AND RECOMMENDATIONS

This report presents the results of the most detailed assessment of fish species and communities ever undertaken across the entire Murrumbidgee catchment. The randomised sampling design ensures that the results collected can be inferred across all reaches of the catchment. The analyses presented here serve three purposes:

- To benchmark the current status of fish species and fish communities.
- To determine trends in fish species and communities up until 2004 based on pre-existing data.
- To provide data-sets suitable for undertaking analysis of the relative impacts of a broad range of processes.

The fish community of the Murrumbidgee catchment (as it existed in 2004) is severely degraded. Eight of the 21 native species which previously existed in the catchment are either locally extinct or survive at very low abundances. In addition to the loss of native species, there is a proportionally high number of alien fish species present (33% of the species richness) that dominate the catchment in terms of the number of individuals (70.77% of the total number of individuals) and even more-so the proportion of total biomass (89.84% of the total biomass). Further, no native species at all were sampled from 7 of the 28 (25%) sites, whereas alien fishes were only absent from 2 (7%).

Assessment of fish communities at finer spatial scales identified some significant differences between lowland areas (< 200 m altitude), slopes areas (201-400m altitude), upland areas (401m – 700 m altitude) and highland areas (>700m altitude). Lowland areas were the least degraded, with the fish community having a higher proportion of native species and native individuals than the other three zones. However, biomass was still heavily dominated by alien species, principally carp. The remaining three zones were largely similar, with more alien species, individuals and biomass at most sites. Few wetlands were sampled, yet these were also dominated by alien fish.

Carp, eastern gambusia and redfin perch were three of the most widespread and abundant species in the catchment. Carp made up 87% of the total biomass of all fish sampled, with redfin contributing 1.5% and gambusia 0.1%. Increased incidence of blue-green algae blooms, declining native fish populations, increased turbidity, damage to stream banks and loss of aquatic vegetation have all been attributed to carp (Crivelli 1983; Faragher and Harris 1994; Koehn *et al.* 2000; Schiller and Harris 2001). However, the extent to which carp are the cause of major disturbances in freshwater ecosystems and to what extent they are a response to disturbance remains a topic of debate (Harris and Gehrke 1997). Irrespective of whether they are a cause of degradation or a response to human-induced degradation, the fact that they utilise 87% of the available fish resources within the catchment's rivers identifies them as the single largest feature of the current poor state of the catchment's fish community and also the single largest factor preventing recovery to a more natural state. This is supported by the coincidental decline and disappearance of many species following the invasion of Boolarra strain carp in the Murrumbidgee catchment in 1973. Although they do not have as high a biomass as carp, the abundance and widespread distribution of redfin perch and eastern gambusia also may have significant impacts on native fish communities. Redfin perch spawn several months earlier than native fishes (McDowall 1996). As a result, predatory redfin perch juveniles are abundant during the breeding seasons of many native fishes. This has been hypothesised to expose the larvae and juveniles of native species to an increased level of predation pressure, with recruitment being much lower in the presence of this species (Rowland pers. com.). Further, redfin perch carry the EHN virus which is lethal to several species of native fish. The decline of both Murray cod (Rowland pers. com.), Macquarie perch (Lintermans 2000*a*) and fish communities in general (Cadwallader 1978) are thought to be partially caused by the invasion of redfin perch. Although eastern gambusia are very small, they are very abundant, making up 49% of individuals in the Murrumbidgee catchment. They have been implicated in the decline of several small native fishes and numerous frog species (Lloyd 1990, McKay *et al.* 2001). Together these species made up 66% of individuals in the catchment. Any reduction in numbers of these three species is likely to result in a substantial recovery of extant populations of native fish.

Of the native species, only Australian smelt and carp-gudgeons made up more than 5% of the catch with 13% and 8% respectively. Australian smelt along with carp-gudgeons, Murray cod and golden perch were the most widespread native species, being sampled at 36%, 25%, 25% and 25% of sites across the catchment respectively. Golden perch and Murray cod made up 6% and 3% of the biomass respectively, making them the 2nd and 3rd most important species in terms of ecosystem resources. However, compared to the data for carp, redfin perch and gambusia, the values for these most secure of native species are all very low.

Analysis of trends over the ten years from 1994-2004 suggests very little change in population structure, with the only significant changes being an increase in species richness (the number of native and alien species) sampled at sites across the whole basin, a significant increase in the proportion of native individuals at some slopes zone sites, but a significant decline in the proportion of native individuals at other sites in the slopes zone, and a uniform decline in the proportion of native individuals in the highland zone. These results suggest that in general, most alien populations have reached an equilibrium within the environment over much of the catchment apart from the slopes zone which is still in a state of flux and in the highland zone where populations of alien species have increased in abundance while native mountain galaxias have been declining. Although species richness was detected to increase across the basin, the only significant change detected which suggested recovery of a native species was for carp-gudgeons which have increased in abundance. The only other species showing a uniform increase in abundance across the catchment was the alien redfin perch. Carp populations have also changed over the last 10 years, with carp populations declining significantly in the slopes zone yet increasing significantly in the highlands.

9.1. Recommendations

Without substantial intervention, the status of fish species and communities in the Murrumbidgee will not improve. Following the recommendations of the Murray-Darling Basin Commissions Native Fish Strategy (NFS) (MDBC 2003), it is recommended to rehabilitate fish communities in the Murrumbidgee. The goal of the NFS is to rehabilitate native fish back to 60% of their pre-European levels within 50 years (MDBC 2003). This 60% level includes both abundance and range (MDBC 2003). The goal does not include species diversity, where the goal of the NFS is that no species shall become extinct in the next 50 years (MDBC 2003). Given MDBC claims of current fish populations being at 10% of pre-European levels (MDBC 2003), this goal constitutes a six-fold increase in native fish populations.

The NFS has identified 13 objectives:

1. Repair and protect key components of aquatic and riparian habitats.
2. Rehabilitate and protect the natural functioning of wetlands and floodplain habitats.
3. Improve key aspects of water quality that affect native fish.
4. Modify flow regulation practices.
5. Provide adequate passage for native fish.
6. Devise and implement recovery plans for threatened native fish species.
7. Create and implement management plans for other native fish species and communities.
8. Control and manage alien fish species.
9. Protect native fish from threats of disease and parasites.

10. Manage fisheries in a sustainable manner.
11. Protect native fish from the adverse effects of translocation and stocking.
12. Ensure native fish populations are not threatened from aquaculture.
13. Ensure community and partner ownership and support for native fish management.

Several of these objectives can be achieved through utilisation of CMA resources. These include rehabilitation of instream and riparian vegetation, rehabilitation of wetlands, eliminating thermal pollution, improving environmental flow management, reinstating fish passage at a number of key barriers, contributing to the control of alien species and finally ensuring community ownership and support.

9.1.1. Aquatic habitat rehabilitation

Key components of aquatic and riparian habitat include home sites, spawning sites, shade, shelter from excessive velocities, shelter from predators, feeding sites and a variety of water depths. Further, each species may utilise a range of habitats at different life stages. Riverine habitats have been degraded by riparian clearing, de-snagging, loss of wetlands, alienation of the floodplain, bank erosion and sedimentation (Cadwallader 1978, Rowland 1989, Cadwallader and Lawrence 1990, Ebsary 1992, Faragher and Harris 1994, Finlayson *et al.* 1994, Abernethy and Rutherford 1999, Kearney *et al.* 1999, Treadwell *et al.* 1999, Lugg 2000, MDBC 2004*a*). Within the Murrumbidgee catchment, 98% of river length assessed had significantly modified environmental features, 61% of which was moderately modified and 37% substantially modified (Norris *et al.* 2001). Catchment disturbance and nutrient and sediment loads were the greatest contributors (Norris *et al.* 2001). Environmental condition was most significantly impaired in headwaters, except for the highland reaches draining Kosciusko and Namadgee National Parks (Norris *et al.* 2001). Half of all the stream length assessed across the Murrumbidgee had substantially modified riparian vegetation. Bed load condition is also modified in 50% of the catchment, with 20% being substantially or severely modified (Norris *et al.* 2001). Overall habitat condition, riparian, bed load and connectivity were most significantly modified in the slopes and uplands zones (Norris *et al.* 2001). Rehabilitation of aquatic habitats requires actions such as rehabilitation and protection of riparian zones, re-snagging, erosion control and de-silting.

9.1.2. Wetland restoration

Currently, wetlands are one of NSW most threatened resources (Kingsford 2000, Treadwell 2004). Wetlands play an important role in the functioning of river ecosystems and are critical to several fish species in the Murrumbidgee. Currently, wetland fish communities are dominated by alien fish (Hillman 1987, Gehrke *et al.* 1999, Humphries *et al.* 1999, Chessman 2003). Murray hardyhead, flat-headed galaxias, olive perchlet, southern purple spotted gudgeon and southern pygmy perch, which are dependent on healthy wetland habitats in the lowland reaches, have all been lost in the Murrumbidgee catchment. Wetland condition in the Murrumbidgee has been degraded by a range of factors in different parts of the catchment, including some systems that are permanently inundated and others where the frequency of inundation has declined (Chessman 2003). Permanent inundation is undesirable as flooding of previously dry habitats is a stimulus for productivity of macrophytes and invertebrates (Maher and Carpenter 1984; Briggs and Maher 1985; Casanova and Brock 2000). Reduced inundation frequency is also associated with a reduced biomass and diversity of invertebrates that emerge from dormant eggs in dry wetland soils (Boulton and Lloyd 1992, Jenkins and Boulton, 1998). These invertebrate blooms are essential in driving wetland productivity and a balance between wetting and drying cycles is required in order to maximise the productivity of wetland habitats. Further, Chessman (2003) reported that many wetlands in the Murrumbidgee do not fill at all under the regulated regime (Chessman 2003) and are therefore lost from the aquatic ecosystem altogether. Under the current management regime for river systems, management of 'natural' wetland systems is probably impossible. Wetlands must be micromanaged systems with environmental flows used to ensure wetting (Shield and Good 2001), regulatory structures put in place to manage wetland water levels and drying phases (Kemper and Bills 1980, Nichols and Gilligan 2004), and the use of fish screens on wetland inlets to prevent access by unwanted aliens fish such as carp (Nichols and Gilligan 2004). Although this management regime would ensure adequate wetland health (to the best capacity possible under current river management), it is still insufficient for conservation of wetland fishes, as no refuge is available for wetland fishes during drying phases, and no source of recruits is available following wetting. Therefore, the conservation of wetland fish will require either the coordinated wetting and drying of a number of wetlands in synchrony, with translocation of fish from one wetland to another. Alternatively, a captive propagation system is required, where fish are produced artificially for the 'seeding' of managed wetland once filled.

9.1.3. Eliminating thermal pollution

The release of cold hypolimnetic water from the base of dams, termed thermal pollution, is one of the most significant threatening processes in regulated catchments (Cadwallader 1978, Koehn and O'Connor 1990*a,* Faragher and Harris 1994, Koehn *et al.* 1995, Kearney *et al.* 1999, Lugg 1999, Koehn 2001, Astles *et al.* 2003). Thermal pollution impacts on fish populations by preventing seasonal warming to critical spawning temperatures, temperature shock to eggs and larvae following sudden high volume releases, inhibited activity, growth, and disease resistance, reduced egg and larval survival, and delayed maturity (Burton and Raisin 2001, Koehn 2001, Astles *et al.* 2003,). Lake (1967) recognised problems associated with cold water pollution in the Murrumbidgee as early as 1967 and attributed the absence of catfish upstream from Wagga Wagga to cold water released from Burrinjuck Dam. The Murrumbidgee River is one of the worst affected, with around 400 km of river suffering thermal pollution (Lugg 1999). The outflows from Burrinjuck Dam in January are 7^{o}C cooler than the inflows (Astles 2001). Summer water temperatures below the dam are 12-18^{o}C, but rise rapidly to 18 - 24^{o}C within 60 km (Astles 2001). However inflows from Blowering Dam, which also creates thermal pollution, re-chill the water to 15 – 18^{o}C where it enters the Murrumbidgee (Astles 2001). The combined flow then continues downstream, gradually increase in temperature at a rate of about 3^{o}C per 100 km until stabilising at ~24^{o}C 300 km downstream of Burrinjuck Dam, in the reach between Wagga Wagga and Narrandera (Astles 2001). Fortunately, a number of relatively simple engineering solutions have been proposed (Sherman 2001), the most effective being the installation (and subsequent utilisation) of multi-level off-takes on large Dams. Within the upper catchment, thermal pollution also occurs at a number of dams, notably, Tantangara Dam, Corin Dam on the Cotter river and Googong Dam on the Queanbeyan River. Introduction of the ACT government's environmental flow guidelines in 1999 resulted in surface releases from Googong and review of operation of the existing multi-level off-take on Corin Dam. As a result, thermal pollution arising from these two structures has been, or is in the process of being addressed (Blanch 2001).

9.1.4. Improving environmental flow management

Regulation of flows through controlled release from storages and water extraction have vastly changed the hydrology or river systems, causing widespread degradation (Cadwallader 1978, Bain *et al.* 1988, Mason 1991, Kinsolving and Bain 1993, Weisberg and Burton 1993, Faragher and Harris 1994, Welcomme 1994, McCully 1996, Holmquist *et al.* 1998, Gehrke *et al.* 1999, Kearney *et al.* 1999). The ecological needs of fish communities can run counter to the needs of water users who depend on reliable and predictable water supplies (MDBC 2004). This has been demonstrated specifically by studies within the Murrumbidgee catchment (Finlayson *et al.* 1994, Gehrke *et al.* 1995, Burns *et al.* 2001, Gehrke and Harris 2001). The major aspects of the flow regime modified by river regulation include (Finlayson *et al.* 1994; Maheshwari *et al.* 1995; MRMC 1998):

- Reduced flow downstream of irrigation areas.
- Reversed seasonal flow regime.
- Reduced duration of flow peaks.
- Reduced frequency of flow peaks, particularly small to medium high flow events.

Under current river regulation levels in the Murrumbidgee, 'drought like' flows (defined as 0-5% natural) now occur in 57% of years in the river downstream of Gogeldrie Weir, with median annual flow now 25% of natural, despite the extra inflows from the Snowy River (MDBCMC 1995, MRMC 1998, Lugg 2000). Total river flows were close to 'low development' levels at Wagga Wagga, but only 20% at Balranald (Chessman 2003). Further, the seasonal flow regime has a reversed seasonality throughout the regulated parts of the catchment (Ebsary 1992, Burns *et al.* 2001, Chessman 2003).

In recognition of the threat posed by river regulation, an embargo on new commercial water licences was implemented in 1985 (MRMC 2002). Subsequently, in 1995, the Murray Darling Basin Ministerial Council introduced a cap on the volume of water diverted from the Murray-Darling Basin. The maximum allowable extraction was set at that which occurred under the levels of development which existed in 1993/94. Further MRMC revised this limit to equal the lesser of either the MDBC cap, or the 1999/2000 extraction level. This maximum extraction volume has been reported variously as 2,230 gigalitres (GL) per year (MRMC 2002), 2,890 GL per year (MRMC 2002) and 1,980 GL/year (WSP 2004).

Licensed extraction entitlements for the catchment are 2,754GL (MRMC 2002) which equates to between 63 – 72% of average annual discharge (based on the highest and lowest estimates of average annual discharge from the Murrumbidgee: 3,800 GL (MRMC 1998), 3,830 GL (Shields and Good 2001), 4,320 GL (MRMC 2002) to 4,360 GL per year (MRMC 2004). However, on average, only ~50% of natural flows are diverted with consumptive use being lower than entitlements (Shields and Good 2001; MRMC 2002).

In addition to adoption of the cap, the Murrumbidgee River Management Committee developed and implemented detailed environmental flow rules in 1998 (MRMC 1998). The rules were required to meet the minimum water regime requirements for maintenance of biota and ecosystem processes, whilst at the same time not reducing consumptive water allocations by more than 10% (Shields and Good 2001). The rules developed were:

- Transparency – A minimum flow of 615 ML per day released from Burrinjuck Dam and 560 ML per day released from Blowering Dam (or releases equal to inflows if inflows are below this level).
- Translucency – A release of a proportion of all inflows during non-irrigation season. The proportion released is dependent on inflows and current storage level.

- End of system flows – A minimum flow of 300 ML per day when allocations exceed 80%, or 200 ML per day when irrigation allocations are lower.
- Environmental Contingency Allowance – A 25 GL allocation of water to be used for environmental rehabilitation.

However, these rules were modified in response to concerns regarding impacts on water availability for irrigators in some years, and the impacts of the translucency and transparency rules on the frequency and magnitude of spillway flows (MRMC 2002). The modifications made were:

- A limit on the percentage of inflows to be released under translucency rules.
- Water not released under translucency rules is made available as an environmental contingency allowance (ECA) when allocation exceeds 80%.
- The 25GL ECA is only available when allocation exceeds 60%.
- Allowing the carry-over of the 25GL ECA and borrowing of 25GL from the following years ECA in line with conditions for consumptive users.
- The 25GL provisional storage is only available when allocations exceed 60%.

These revisions were accepted under the Murrumbidgee Water Sharing Plan which came into effect on 1 July 2004 and ceases on 30 June 2014 (DIPNR 2004). The environmental flow rules currently in place are:

- Reserve all water above the plan extraction limit for the environment.
- Protect low flows in the upper reaches (release 560ML per day from Blowering and between 300 – 615 ML per day from Burrinjuck).
- Provide winter flow variability (release a percentage of inflows from Burrinjuck between 22 April and 21 Oct, with the percentage dependent on climate and storage level).
- Implement three types of environmental water allowance.
- Protect end-of-system flows (from 2004-2008 ensure a minimum of 200-300 ML per day past Balranald Weir – from 2008-2014, these flows will be increased to reflect the natural flow pattern).

These environmental flow rules are to be reviewed by 1 Jul 2005 in order to assess their environmental effectiveness (DIPNR 2004). Following review, the rules may be amended but are not to reduce annual extractions by more than 0.5% (DIPNR 2004). Although both Weisberg and Burton (1993) and Travnichek *et al.* (1995) have demonstrated the positive effects of environmental flows on fish communities and river health. The benefits that these specific Murrumbidgee flow rules may impart on fish communities in the Murrumbidgee catchment are totally unknown. Therefore, an assessment of the response of fish communities to the current set of flow rules, and recommendations on possible alterative strategies would aid the rehabilitation of fish communities in the Murrumbidgee.

9.1.5. Reinstating fish passage

Barriers such as dams, weirs and regulators are known to impede the migration of fish and prevent the completion of their lifecycles (Cadwallader 1978, Faragher and Harris 1994, Kearney *et al.* 1999, Thorncraft and Harris 2000). Berembed Weir was the first structure constructed on the Murrumbidgee River in 1910. The number of structures rose rapidly (Figure 9.1), with the last weir in the lowland zone, Hay Weir, being constructed in 1980. However, weir construction continued in the upper reaches, with the last weir on the Murrumbidgee River being constructed at Cooma in 1992, and the last engineered weir in the catchment, Yerrabi Dam on Ginnindera Creek, being constructed in 1993. The total number of registered weirs in the catchment is 90 with 52 of those being engineered structures. The NSW Weirs policy aims to halt and where possible reduce and remove the environmental impact of weirs on streams. The most effective way of achieving this is by the removal of un-utilised structures. Where this is not possible, construction of a well designed fishway allowing passage of all species and size classes of fish in the community is a viable alternative. Currently, functional fishways only exist on two of the 52 structures in the catchment: a fish-lock on Balranald Weir and a rock-ramp fishway on the Cooma Weir. The construction of fishways on remaining barriers, particularly those in the lowland reaches, would result in improved fish communities in the catchment. In addition to large weirs and dams, road crossings on small streams (culverts and causeways) also inhibit fish migration. Use of the national guidelines for waterway crossing design (Fairfull and Witheridge 2003) to reconstruct poorly designed road crossings at key locations within streams would also benefit fish communities in many areas of the catchment. However consideration needs to be made on the distribution of pest species upstream of some barriers. For example, carp populations are absent above Cotter Dam and Googong Dam. Therefore, it is not advisable to construct fishways on these structures. Similarly, trout may be excluded by some road crossings in upland streams. These areas should be maintained as trout-free for the benefit on the existing native fish communities in these streams.

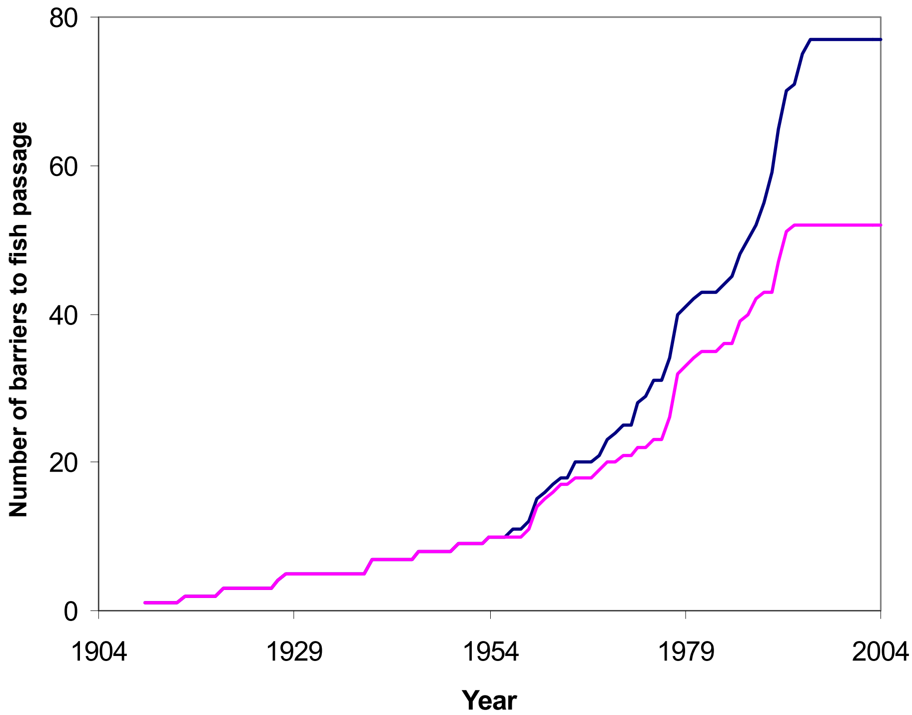


Figure 9.1. Number of barriers to fish passage constructed on streams in the Murrumbidgee catchment. The pink line represents engineered structures (concrete, steel or timber fixed crest dams, weirs, gated weirs or regulators). The blue line represents the engineered structures in addition to smaller earthen block banks and by-wash dams. An additional 12 engineered and 1 un-engineered structures have been identified but their date of construction was not recorded in the database. Therefore, they have been omitted from this figure.

9.1.6. Controlling alien species

Given the great impact of alien fish on riverine ecosystems, the control of pest fish is also a high priority for rehabilitation of fish communities. Apart from the freshwater pests program of the CRC for Australasian Invasive Animals (CRC-AIA), and its flagship ‘daughterless carp’ project, little is being done to control pest fish species in the Murray-Darling Basin. On-ground actions such as installation of carp-separation cages in fishways (Stuart *et al.* 2003), the installation of fish screens in wetland inlets to exclude adult carp from spawning areas (Nichols and Gilligan 2004) and support of community-organised carp fishing tournaments are all likely to have positive ecological benefits in the Murrumbidgee. However, support of the CRC-AIAs freshwater pests program is likely to result in the most cost-effective means of addressing the need for control of all pest fish species in the catchment.

9.1.7. Fostering community ownership and support

Education of the community and fostering community support for riverine ecosystems are also critical in the long term rehabilitation of the fish community of the Murrumbidgee catchment. As fish are hidden underwater, the community’s understanding of issues relating to fish is often less than for more visible terrestrial ecosystems. Further, the community’s perception of fish communities is drawn entirely from the status of recreationally important species, with little consideration given to the majority of less familiar species. An ongoing fish monitoring program is required in order to keep all stakeholders fully informed of the status of fish populations in the Murrumbidgee. Lastly, a widespread understanding on the dangers of introducing alien species into waterways (either unwanted aquarium fish or the illegal use of live fish as bait) may prevent further invasions of pest fish in the Murrumbidgee.

9.2. Ongoing monitoring requirements

The MDBCs SRA program is designed to fulfil the need for ongoing knowledge on the status of river health across the Murray-Darling Basin. The methods used in this benchmarking survey were deliberately designed to be consistent with those in use for the SRA program. Under the SRA, data from the Murrumbidgee will be collected on a three yearly basis, starting in 2006 and initially continuing for 6 years, and potentially for 50 years (MDBC 2004*a*). As a result, the data-gathering needs for a general fish community survey of the Murrumbidgee will be met by the SRA. However, although the SRA provides an avenue for regular data collection, the results of SRA sampling will require analysis and reporting in a catchment specific context in order to be useful for the Murrumbidgee CMA. Further, the SRA program does not include sampling of wetland habitats or the targeted sampling of threatened species populations. Ideally, the SRA program should be supplemented by regular sampling of targeted sites that will provide much more specific information on the status of fish populations in key parts of the Murrumbidgee catchment. Further, detailed assessment of any on-ground actions such as wetland rehabilitation, habitat restoration, construction of multi-level off-takes or fishways on dams would require specifically designed experiments with tailored sampling programs to assess their effectiveness, and refine their operation.

Data presented in this report, particularly the trends in monitoring data, commercial fishery data and stocking records, lend themselves to detailed analyses of the response of fish communities to long-term changes in threatening processes such as the degree of river regulation, the cumulative number of fish passage barriers, the degree of thermal pollution, the amount of de-snagging, the effectiveness of fish stocking, the response of fish populations to various flow parameters, etc. However, although illustrative, a uni-variate approach assessing each threatening process in isolation, is inadequate for teasing apart the many inter-related influences on fish populations. A detailed review and compilation of all available data, followed by a detailed multi-variate analytical approach is required to provide detailed and accurate information on the relative threats posed by a range of processes affecting fish communities. This approach would allow the development of models of the response of fish populations to implementation of the range of rehabilitation activities suggested above. In order to make these analyses possible, data on parameters related to each of these threatening processes needs to be compiled and made available. Such a model would provide a useful tool with which the CMA could develop the most cost-effective recovery options for fish communities in the Murrumbidgee catchment.

It is suggested that the Murrumbidgee CMA:

- Supports SRA sampling in the Murrumbidgee catchment on a three yearly basis as a long-term monitoring program.
- Funds additional sampling at wetland and targeted threatened species sites concurrently with SRA sampling ever three years (beginning 2006).
- Facilitates analysis and reporting on the combined SRA and CMA funded data collection.
- Acknowledges the need for fish monitoring activities associated with on-ground riverine and wetland rehabilitation activities.
- Undertakes the compilation of long term data-sets on ecological and physical processes of interest (i.e. water extraction, de-snagging activity, thermal pollution, sedimentation, river regulation, loss of aquatic and riparian vegetation etc) which will enable modelling of ecosystem responses and prioritisation of rehabilitation activities.

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11. APPENDIX 1

11.1. Points suitable for publication as a glossy brochure for distribution to the community – as requested by the Murrumbidgee CMA board at the Cooma meeting, November 2004

Fish are an integral component of aquatic ecosystems with the structure of fish assemblages providing an indication of the overall health of river systems.

Fish communities were sampled using electrofishing augmented with sampling for smaller fish using shrimp traps.

Fish were sampled from 50 sites across the Murrumbidgee catchment.

The fish community of the Murrumbidgee catchment is severely degraded with eight of the 21 native species which previously existed in the catchment either locally extinct or surviving at very low abundances. A ninth, trout cod, was extinct and has since been reintroduced.

Only three of the seven listed threatened species were detected. Populations of the endangered Murray hardyhead, olive perchlet, southern purple-spotted gudgeon and vulnerable southern pygmy perch were not detected at locations where they had previously occurred in the Murrumbidgee catchment for up to 36 years. It is highly likely that these four species are locally extinct.

Two of the remaining three threatened species, Macquarie perch and silver perch were found at only one site each, with only single individuals of each species collected.

The existence of trout cod anywhere in the catchment is a direct result of the stocking program initiated in the Murrumbidgee in 1988, the last wild bred individual having been recorded in 1976. Further studies to confirm self-sustainability of the stocked trout cod populations is required in order to downgrade them from their current endangered status.

A reintroduction program was initiated in 2004 for the southern purple spotted gudgeon in the Murrumbidgee.

Freshwater fish are the most threatened group of animals in the world, with 4.4% of species considered threatened. In the Murrumbidgee, 43% of native fish species in the catchment are endangered or vulnerable. In recognition, the entire ecological community of the Murrumbidgee below Burrinjuck and Blowering Dams has been classified as threatened.

Since European settlement, 11 species of alien fish have been introduced.

Introduced tench appear to be disappeared from the Murrumbidgee following the invasion of Boolara strain carp in the 1970's.

Lowland reaches were the least degraded, with the fish community having a higher proportion of native species and native individuals than the remainder of the catchment.

Introduced carp, eastern gambusia and redfin perch were three of the most widespread and abundant species in the catchment. Together these species made up 66% of individuals in the catchment. Any reduction in their numbers is likely to result in a substantial recovery of surviving populations of native fish.

Carp made up 87% of the total biomass (weight) of all fish sampled. The fact that they utilise 87% of the available fish resources within the catchment's rivers identifies carp as the single largest feature of the current poor state of the catchment's fish community and also the single largest factor preventing recovery to a more natural state.

Golden perch and Murray cod were the 2nd and 3rd most important species in terms of biomass and Australian smelt and carp-gudgeons were very abundant. However, compared to the combined data for carp, redfin perch and gambusia, the values for these native species are very low.

Silver perch and Macquarie perch were the two rarest species in the catchment. Silver perch are rare despite stocking just under 2 million fingerlings at 19 locations throughout the Murrumbidgee.

No native species at all were sampled from 7 of the 28 (25%) sites, whereas alien fishes were only absent from 2 (7%).

Carp-gudgeons were the only native species whose population size has changed significantly over the last 10 years, with a consistent increase throughout the catchment. Of the remaining 13 native species assessed, eight (including Murray cod) had increased and five had declined.

Redfin perch have increased in abundance consistently throughout the basin since 1994.

The abundance of carp has varied, but the trends have been different in different parts of the catchment. Carp have declined in the lowland and slopes zones, but have increased in the upland and highland zones.

The key threatening processes are habitat loss, pollution, erosion, river regulation, barriers to fish migration and introduced species. Illegal poaching still threatens protected trout cod, silver perch and Macquarie perch.

Without substantial intervention, the status of fish species and communities in the Murrumbidgee will not improve. Rehabilitation activities include:

1. Rehabilitation of instream and riparian vegetation.
2. Rehabilitation of wetlands.
3. Eliminating thermal pollution.
4. Improving environmental flow management.
5. Reinstating fish passage at a number of key barriers.
6. Contributing to the control of alien species.
7. Educating the community.
8. Captive breeding and reintroduction programs for each of the locally extinct populations.

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