Fish communities of the Lower Murray-Darling catchment: Status and trends

Dr Dean Gilligan

NSW Department of Primary Industries
Narrandera Fisheries Centre
Buckingbong Road, Narrandera, NSW 2700
Australia

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Helping Communities
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Abbreviations

AUSLIG	Australian Surveying and Land Information Group
CMA	Catchment Management Authority
EPBCA	Environment Protection and Biodiversity Conservation Act 1999
FM Act 1994	Fisheries Management Act 1994
MDBC	Murray-Darling Basin Commission
MDFRC	Murray-Darling Freshwater Research Centre
NFS	Native Fish Strategy (Murray-Darling Basin Commission)
NLWRA	National Land & Water Resources Audit
NSW	New South Wales
RMC	River Murray Commission
SKM	Sinclair Knight Merz
SARDI	South Australia Research & Development Institute
SRA	Sustainable Rivers Audit
ECA	Environmental Contingency Allowance
IMEF	Integrated Monitoring of Environmental Flows
SA	South Australia

NON-TECHNICAL SUMMARY

Integrated Fish Monitoring Project
Fish communities of the Lower Murray-Darling catchment: Status and trends

PRINCIPAL INVESTIGATOR: Dr Dean Gilligan

ADDRESS: NSW Department of Primary Industries
Narrandera Fisheries Centre
Buckingbong Road,
Narrandera NSW 2700
Telephone: 02 6959 9021 Fax: 02 6959 2935

OBJECTIVES

1) To benchmark the current status of fish species and fish communities in the Lower Murray-Darling catchment.
2) To determine trends in fish species and communities up until 2004 using pre-existing data.
3) To compile data-sets suitable for undertaking analysis of the relative impacts of a broad range of threats.

NON TECHNICAL SUMMARY:

Fish are an integral component of aquatic ecosystems and act as a good indicator of overall river health. 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 of on-ground (or in-water) remediation and demonstration of these outcomes to the community.

Fish communities were sampled using a standardised electrofishing protocol augmented with shrimp traps. Twenty-seven monitoring sites were sampled to benchmark the current (2004) fish community within five zones of the catchment: Murray I (Murrumbidgee junction to Darling junction), Murray II (Darling junction to the South Australian border), Lower Darling River, the Great Darling Anabranch, and Lakes & Reservoirs. Additionally, 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 represents the most comprehensive assessment of fish species and communities ever undertaken across the whole Lower Murray-Darling CMA catchment area. The randomised sampling design ensures that the results obtained can be extrapolated to all reaches of the catchment.

Current status of fish communities

Fourteen fish taxa (13 species and 1 species complex (group of two or more distinct but indistinguishable species)) were sampled from the 27 monitoring sites. Despite substantial sampling effort, only 45% of native species and 43% of alien species known to have existed in the Lower Murray-Darling catchment were sampled in 2004. Although a substantial number of species

were not detected, this program adequately sampled the fish community present, and adequately reflects the current composition and status of the fish community.

The fish community of the Lower Murray-Darling catchment (as it existed in 2004) is severely degraded. Ten of the 22 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 (23% of the species richness) that dominate the catchment in terms of the proportion of total biomass (56% of the total biomass).

Apart from fish communities within the Lakes & Reservoirs zone, including the Menindee Lakes, Lake Victoria and Imperial Lake (near Broken Hill), the structure of fish communities existing throughout the catchment was quite consistent. However, it was possible to detect significant differences between fish communities within each of the catchment zones analysed. The Lakes & Reservoirs sites had a consistently poorer fish community than existed in riverine sites with carp-gudgeons being the only species more abundant in the non-river sites. The Murray II zone supported a fish community with a high proportion of small fish species such as flyspecked hardyhead, Murray-Darling rainbowfish and gudgeon species. This group of small fishes (including others that are likely to be locally extinct) is the component of the fish community that has declined throughout many areas of the Murray-Darling Basin. This lower section of the Murray also had greater numbers of Murray cod, bony herring and golden perch than the remaining riverine zones. The Darling River zone differed from the Murray I zone in having a higher abundance of goldfish, bony herring, golden perch and carp, but a lower abundance of Australian smelt, Murray-Darling rainbowfish, carp-gudgeons and flyspecked hardyhead.

The Lower Murray-Darling CMA has developed catchment blueprint targets of a 55% change in the native:alien species ratio, a 25% change in the native:alien abundance ratio and a 25% change in the native:alien biomass ratio. Data was benchmarked for the 'proportion of native' rather than a ratio as proportions have much better statistical properties. Power analyses of the data collected indicates that statistical power exists to detect progress towards the Lower Murray –Darling CMA blueprint targets of a 55% improvement in the species ratio, and a 25% improvement in the abundance ratio. However due to variability in biomass across the catchment, the minimum detectable change in the biomass ratio is a 30% change, which is 5% greater than the blueprint target of 25%. Although trends in proportion of native biomass can still be demonstrated, only changes greater than 30% will be statistically significant. However, the biomass ratio is likely to be responsive to habitat rehabilitation, particularly for activities that promote large native species such as Murray cod, golden perch, silver perch and catfish, and reduce the number of carp. Hence improvements in the biomass ratio of greater than 30% could be expected.

Current status of individual species

Species can be considered secure only if their abundance, distribution and level of recruitment remain stable or increase through time. If any one of these factors declined significantly, a species could be considered at risk. These parameters were benchmarked for each species in the Lower Murray-Darling catchment.

Bony herring, Australian smelt and carp-gudgeons were three of the most abundant species in the catchment. However the fourth most abundant species in the catchment, carp, made up 49% of the total biomass of all fish sampled, with the three abundant native species only contributing 17% due to their generally small body sizes. The fact that carp make up 49% of the total fish biomass 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. Although they do not have as high a biomass as carp, the abundance and widespread distribution of eastern gambusia is also likely to have significant impacts on native fish communities. Together carp and gambusia made up 7% of individuals in the catchment but 54% of the biomass. Any reduction in numbers of these two species is likely to result in a substantial recovery of extant populations of native fish.

The three rarest taxa sampled were the alien redfin perch (0.03%), the threatened silver perch (0.06%) and freshwater catfish (0.6%).

Carp were the most widespread species occurring at 96% of sites sampled and being found in every zone. The next most widespread species were golden perch and Australian smelt which were both found at 81% of sites. The least widespread species were redfin perch and freshwater catfish, both being found at only one site (4%). The single site at which catfish were sampled was an artificial waterbody stocked with catfish in 1999. Silver perch also had a restricted distribution and were only found at three sites (11%).

Recruits (fish estimated to be < one year old) were found for all species except golden perch, freshwater catfish and redfin perch, and made up to 42% of the fish community across the catchment. New recruits made up 25% or more of the sampled populations of nine fish species: carp-gudgeon (94%), flyspecked hardyhead (76%), flat-headed gudgeon (75%), Australian smelt (70%), Murray-Darling rainbowfish (62%), bony herring (42%), Murray cod (29%) and silver perch (25%). Carp-gudgeon recruits were found in all five catchment zones and in wetlands and dominated carp-gudgeon populations throughout the catchment. Fly-specked hardyhead recruits were much more prominent in wetlands than in riverine sites. They were also more abundant in the Murray II zone than in the Murray I zone. Flat-headed gudgeon recruits were common in both the Murray II zone and in wetland sites. Australian smelt recruits were found in all five catchment zones, however no recruits were found in the Lakes & Reservoir sites. Australian smelt recruits were most abundant in the Murray II zone, and were more abundant in the Darling and Great Darling Anabranch than in the Murray I zone or wetland sites. Similarly, Murray-Darling rainbowfish recruits were most abundant in the Murray II zone but were found in all zones except the Lakes & Reservoirs. Bony herring recruits were found in all zones but comprised a higher proportion of the population in the Murray II zone. Murray cod recruits were only found in the Murray II and Darling zones. In contrast, to most other species, silver perch recruits were only found in the Murray I zone.

Trends over the last 11 years

Ongoing monitoring 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 electrofishing data collected within NSW since 1994 provides a means of quantitatively assessing changes in fish populations through time. Analysis of data collected from the Lower Murray-Darling catchment over the last 10 years indicates several significant changes.

The only significant change detected which suggested widespread recovery of a native species was for carp-gudgeons, which have increased in abundance consistently throughout the Lower Murray-Darling Basin. No other species showed uniform increases in abundance across the whole catchment, however Australian smelt had increased significantly in abundance in the two Murray River sites and Murray cod had increased significantly in abundance at Pooncarie on the Darling River. The only significant decline for any species was observed for carp at Carina Bend on the Murray River.

The only fish community parameters to change were a significant increase in the species richness at three of the four monitoring sites, and a significant increase in the proportion of fish parasitised by anchor worm. The increase in species richness could result from either the further invasion and spread of alien fish within the catchment, or increasing populations of native fishes. Given that eight of the nine native species analysed have increased in at least some parts of the catchment, and that no new alien species are known to have invaded the catchment since 1994 (although oriental weatherloach are dispersing downstream from the Murray Riverina), the second hypothesis is the most likely. The increasing parasite loads may reflect an increasing level of environmental stress in the system.

The commercial fishery

Data provided by the commercial fishery in the Lower Murray-Darling provides the most extensive long-term data set available. 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.

Pease and Grinberg (1995) and Reid *et al.* (1997) collated fishery records for all of NSW. These records exist from 1883 up until the 1994/95 season, although coverage and accuracy of the data were poor until compulsory fishers' returns were introduced in 1947. This report completes the data-set for the Lower Murray-Darling catchment up until the closure of the native fishery in 2001.

Analysis of trends over the 17 years between 1984 and 2001, based on commercial catch data standardised by fishing effort, identified some significant changes in commercial fishing stocks. The golden perch stock had increased significantly since 1984 in both the Murray and Darling Rivers. Murray cod had increased significantly in the Murray but not in the Darling River. Catfish and Macquarie perch both declined significantly in the Murray River and the last population of tench in the catchment area (the Darling) declined significantly. These changes may be partly due to stocking programs for golden perch and Murray cod, with the increases in commercial catches coinciding with the initiation of stocking activities for both species. However this hypothesis does not apply to golden perch stocks in the Darling River, which has never been stocked with this species. The declines in catfish, Macquarie perch and tench all reflect the final stages of decline in the 1980s, following declines of much greater magnitude prior to 1984. The decline of catfish and tench coincided with the invasion of Boolara strain carp in the 1970s, but the decline in Macquarie perch stocks began in the 1960s and may reflect the earlier combined impacts of the invasion of redfin perch into the catchment area and river regulation.

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 (NSW Fisheries 2003). A compilation of all stocking records from the NSW portion of the Lower Murray-Darling catchment since 1968 is presented.

Three native species have been, or continue to be stocked as part of harvest stocking programs to promote recreational fishing. Stocking of golden perch and Murray cod may be responsible for increasing stocks of these two species in the catchment. The only population of catfish in the Lower Murray-Darling catchment area is a stocked population in an artificial waterway.

Recommendations

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

- Rehabilitation of instream and riparian vegetation.
- Rehabilitation of wetlands.
- 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 Lower Murray-Darling CMA.

An ongoing monitoring program is required to assess the effectiveness of each of these actions. Under the MDBC's Sustainable River Audit (SRA) program, data from the Lower Murray-Darling will be collected on a three yearly basis. This started in 2005, and will initially continue for 6 years, and potentially for 50 years (MDBC 2004*b*). As a result, most of the data-gathering needs for a general fish community survey of the Lower Murray-Darling catchment will be met by the SRA. However the sites sampled will not necessarily be those sampled in this survey1 and sites in the Lakes & Reservoirs zone will not be included. Further, the SRA program does not include sampling of wetland habitats or the targeted sampling of threatened species populations. 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 Lower Murray-Darling CMA. 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 Lower Murray-Darling catchment. The next round of SRA sampling in the Lower Murray-Darling catchment is scheduled for 2008. Further, detailed assessment of any on-ground actions such as wetland rehabilitation, habitat restoration, and construction of 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 Lower Murray-Darling CMA:

- Supports SRA sampling in the Lower Murray-Darling catchment on a three yearly basis as a long-term monitoring program.
- Fund additional sampling at sites not incorporated in to the SRA site network, plus wetland sites and targeted threatened species sites concurrently with SRA sampling every three years (next round is scheduled for 2008).2
- 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, sedimentation, river regulation, loss of aquatic and riparian vegetation etc), which will enable modelling of ecosystem responses and prioritisation of rehabilitation activities.

KEYWORDS:
Murray River, Darling River, Menindee Lakes, Lake Victoria, Lower Murray-Darling, freshwater fish

1 Since starting this project, the MDBC has re-developed its SRA site selection process. Despite this, all sites in the Murray I zone and several sites in the other riverine zones are still consistent.

2 The Lower Murray-Darling CMA favours an annual fish monitoring program as a basis for determining changes in fish populations and the effectiveness of rehabilitation within the catchment and has allocated funds for annual sampling within its investment strategy.

Photo: Rob Rolls (Sunset at Upper Kulnine)

1. INTRODUCTION

Fish are an integral component of aquatic ecosystems and act as good indicators of overall river health. Subsequently, the health of river systems reflects the broad scale cumulative impacts of both land and aquatic management practices (MDBC 2004*c*). 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*b*). 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 Lower Murray-Darling catchment is the 5th largest in the New South Wales portion of the Murray-Darling Basin, draining an area of 63,000 km^2 (Figure 1.1). Although the catchment area is large, its semi-arid climate means that most of the flow is derived from tributary catchments further upstream. Therefore, the stream network within the Lower Murray-Darling catchment is quite simple, largely consisting of the southern portion of the main channel of the Darling River, the Great Darling Anabranch and the main channel of the Murray River downstream of the Murrumbidgee River Junction to the South Australian border. Tributary streams are generally ephemeral and only some anabranch systems regularly contain water. Given the low topography within the catchment (~ 40m ASL at the South Australian border and ~ 60m ASL at the northern and eastern extremities of the Darling and Murray Rivers respectively), limited mesohabitat variability exists. However the habitat, flow and water quality characteristics vary considerably within the catchment. Particularly between the Murray and Darling Rivers.

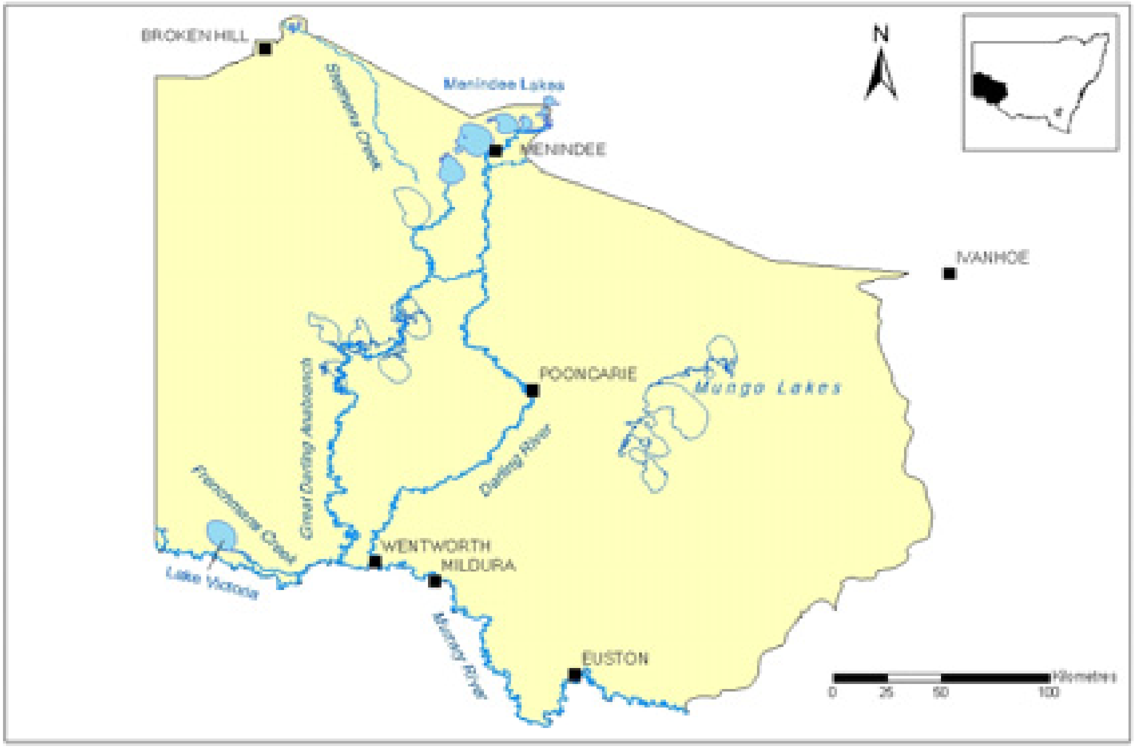

Figure 1.1. Map of the Lower Murray-Darling catchment. The stream network is derived from the AUSLIG 1:250,000 and NLWRA stream networks. Reaches not providing fish habitat (ephemeral streams and drainage lines) are depicted in a darker shade of blue. The catchment was divided into five zones for the purposes of analysing spatial structure in fish community variables: Murray River I (Murrumbidgee junction to Darling junction), Murray River II (Darling junction to South Australian Border), Lower Darling River, Great Darling Anabranch and Lakes & Reservoirs.

Twenty-two native fish taxa (21 species and one species complex of up to four tentative carp-gudgeon (*Hypseleotris*) species) are considered to have existed in the Lower Murray-Darling catchment area (Table 1.1). However, one of these species, the congoli (*Pseudaphritis urvillii*) is catadromous (migrates between freshwaters and the ocean to reproduce) and would rarely migrate upstream from the Murray estuary into the Lower Murray-Darling catchment. Further, the Lower Murray-Darling catchment approaches the southern range limit of Hyrtl’s tandan (*Neosilurus hyrtlii*), which is an uncommon vagrant from further upstream in the Darling River. Of the 20 native taxa expected to regularly exist within the catchment, four species; trout cod (*Maccullochella macquariensis*), Macquarie perch (*Macquaria australasica*), flat-headed gudgeon (*Philypnodon grandiceps*) and dwarf flat-headed gudgeon (*Philypnodon* sp 1.) are only known from the Murray River and have never been recorded in the Darling River[3], and spangled perch (*Leiopotherapon unicolor*) is only regularly captured in the Darling River and would be considered a vagrant in the Lower Murray. Therefore, 19 taxa are expected in the Lower Murray and 16 taxa are expected in the lower Darling components of the Lower Murray-Darling catchment.

3 Although they have never been recorded in the Darling River, they are known to exist in the middle and upper Macquarie catchment, which is a tributary of the Darling, entering that River between Brewarrina and Walgett.

Table 1.1. Native fish species of the Lower Murray-Darling catchment, their conservation status and most recent records within the catchment.

Common name	Scientific name	Conservation status	Most recent record in catchment area
Australian smelt	*Retropinna semoni*		2005 [SRA]
Bony herring	*Nematalosa erebi*		2005 [SRA]
Carp-gudgeon species complex	*Hypseleotris* spp.		2005 [SRA]
Congoli	*Pseudaphritis urvillii*	Catadromous vagrant	Unspecified date [Aus M.]
Dwarf flat-headed gudgeon	*Philypnodon* sp. 1		2004 [MDFRC] (Murray only)
Flat-headed galaxias	*Galaxias rostratus*		General observations only: 1949-50 [Langtry] & 1967 [Lake]. No documented samples.
Flat-headed gudgeon	*Philypnodon grandiceps*		2005 [SRA] in Murray 1958 [Aus M.] in Darling
Flyspecked hardyhead	*Craterocephalus stercusmuscarum*		2005 [SRA]
Freshwater catfish	*Tandanus tandanus*		1996 [ICF]
Golden perch	*Macquaria ambigua*		2005 [SRA]
Hyrtl's tandan	*Neosilurus hyrtlii*		1988 [B. Ebner (pers. comm..)] (Darling only)
Macquarie perch	*Macquaria australasica*	Vulnerable [NSW] Endangered [EPBCA]	1988 [ICF] (Murray only)
Murray cod	*Maccullochella peelii*	Vulnerable [EPBCA]	2005 [SRA]
Murray hardyhead	*Craterocephalus fluviatilis*	Endangered [NSW] Vulnerable [EPBCA]	2005 [SRA] but more common in saline Cardross Lakes and Lake Hawthorn in Victoria [MDFRC]
Murray-Darling rainbowfish	*Melanotaenia fluviatilis*		2005 SRA
Olive perchlet	*Ambassis agassizii*	Endangered population [NSW]	General comment only: Pre 1967 [Lake]. No documented samples.
Short-headed lamprey	*Mordacia mordax*		1978 [ICF]
Silver perch	*Bidyanus bidyanus*	Vulnerable [NSW]	2005 [SRA]
Southern purple-spotted gudgeon	*Mogurnda adspersa*	Endangered population [NSW]	General observations only: 1967 [Lake]. No documented samples. 1998 in Cardross Lakes, Victoria [Raadik *et al.* (1999)]
Southern pygmy perch	*Nannoperca australis*	Vulnerable [NSW]	General observations only: 1949-50 [Langtry] & 1967 [Lake]. No documented samples.
Spangled perch	*Leiopotherapon unicolour*		2000 [SKM]
Trout cod	*Maccullochella macquariensis*	Endangered [NSW] Endangered [EPBCA]	1958 [Aus M.] (Murray only)

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

Most recent record superscripts: [Aus M.] (Australian Museum collection via http://www.bionet.nsw.gov.au), [ICF] (NSW Fisheries Inland Commercial Fishery Database), [Lake] (Lake, 1967), [Langtry] (Cadwallader, 1977), [MDFRC] (Murray-Darling Freshwater Research Centre data (Sharpe *et al*., 2003; Ho *et al*. 2004; Ellis and Meredith 2005)), [SKM] (Menindee Lakes Aquatic Fauna Integration report for the Menindee Lakes ESD Project, Sinclair, Knight Merz), [SRA] (Sustainable Rivers Audit).

Since European settlement, an additional seven species of alien fish have been recorded (Table 1.2). Six of these are not endemic to Australia whilst the spotted galaxias (*Galaxias truttaceus*) is native to coastal Victorian streams but not to the Murray-Darling Basin. Knowledge of its existence in the catchment area is confined to a single larval individual sampled in the Murray River near Wentworth in 2002 (Gilligan, unpublished data).

Table 1.2. Alien fish species of the Lower Murray-Darling catchment and details of most recent records.

Common name	Scientific name	Status	Most recent records
Brown trout	*Salmo trutta*	Acclimatised sports fish	1949 [Langtry]
Common carp	*Cyprinus carpio*	Pest	2005 [SRA]
Eastern gambusia	*Gambusia holbrooki*	Pest	2005 [SRA]
Goldfish	*Carassius auratus*		2005 [SRA]
Redfin perch	*Perca fluviatilis*	Pest	2002 [MDFRC]
Spotted galaxias	*Galaxias truttaceus*	Native to coastal Victoria and probably translocated.	2002 [FFD]
Tench	*Tinca tinca*	No longer considered present	1988 [ICF]

Most recent record superscripts: [ICF] (NSW Fisheries Inland Commercial Fishery Database), [FFD] (NSW Fisheries Freshwater Sampling Database), [Langtry] (Cadwallader 1977)l, [MDFRC] (Murray-Darling Freshwater Research Centre data (Conallin *et al.* 2003)), [SRA] (Sustainable Rivers Audit).

Of these native and alien taxa, a number have not been recorded in the Lower Murray-Darling catchment for several decades (Table 1.1). Based on his observations in 1949-50, J.O. Langtry suggested that southern pygmy perch (*Nannoperca australis*) "… appear to abound throughout the whole Murray system" (Cadwallader 1977). Later, Lake (1967) reported that this species was patchily distributed in the Murray River. Langtry observed that flat-headed galaxias (*Galaxias rostratus*) (he referred to them as *G. attenuatus*) "have been taken throughout the system (Murray)" (Cadwallader 1977) whilst Lake (1967) specified an upper altitude limit of 150m. Although Langtry did not comment on populations of olive perchlet (*Ambassis agassizii*) or southern purple spotted gudgeon (*Mogurnda adspersa*) in the Murray, Lake (1967) reported that olive perchlet occurred throughout the lowlands of the Murray-Darling Basin but were patchily distributed and not very common, and that southern purple spotted gudgeon were patchily distributed throughout all reaches of the Murray-Darling Basin. There have been no reports of any of these species in the Lower Murray-Darling catchment area of NSW since that time. Specifically none have been recorded since initiation of the first widespread assessment of fish communities undertaken in NSW in 1975 (Llewellyn 1983). Further, trout cod have not been reported in the Lower Murray-Darling catchment since museum specimens were collected from the lower Murray River in 1958 (47 years ago). Two other native species, short-headed lamprey (*Mordacia mordax*) and Macquarie perch were last reported by commercial fishermen in 1975 (30 years ago) and 1988 (17 years ago) respectively. In addition to these native species, brown trout (*Salmo trutta*) have not been recorded since 1949 (56 years ago) and tench (*Tinca tinca*)(both alien species) have not been recorded in the catchment area since 1988 (17 years ago) (Table 1.2). All of these species could potentially be locally extinct in the Lower Murray-Darling catchment.

Omitting the vagrant and potentially extinct populations, the current fish fauna of the Lower Murray-Darling catchment consists of 11 native fish species and 5 alien fish species.

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 Lower Murray-Darling catchment is no exception. Within the Lower Murray-Darling, eight fish species are listed as threatened under state 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 locally extinct in the Lower Murray-Darling catchment. Therefore, nine of the 20 (45%) native freshwater fish species occurring within the Lower Murray-Darling catchment are listed as threatened species. In recognition of this, the entire ecological community of the Lower Murray-Darling catchment has been declared endangered as part of the Lower Murray and Lower Darling Endangered Ecological Communities under the *NSW Fisheries Management Act 1994*. These ecological communities include all main channels, tributaries, anabranches, lagoons, wetlands and lakes, including the Menindee Lakes.

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; Lugg 2000). Most of the threats identified are relevant to fish communities in the Lower Murray-Darling catchment. Recently, Kearney *et al.* (1999) identified six 'major' threats, which were (in decreasing order of priority): habitat degradation, pollution, reduced flows, barriers to migration, introduced species and over-fishing. 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 Lower Murray-Darling catchment, the Lower Murray-Darling 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.

1.1. Previous fish research in the Lower Murray-Darling CMA area

Data from a number of fish surveys, and other sources, exist for the Lower Murray-Darling catchment. The earliest data-set available was collected by J.O. Langtry from a fish trap at Euston Weir between 1938 and 1942 (Cadwallader 1977). Sampling was continued by the River Murray Commission (RMC – now the MDBC) until 1945, with the data from 1940 –1945 presented in Mallen-Cooper (1996). The next dataset collated was the NSW Fisheries Inland Commercial Fishery Database (now incorporated into the Comcatch database) presented by Pease and Grinberg (1995) and Reid *et al.* (1997), which contains data collected between 1955 and 1994. Data collection for native species continued through to the close of the native inland commercial fishery in 2001 and continues for the inland carp and yabby fisheries, but has not been published. The next report available presents observations and data collected from the Murray River and some of its tributaries (including the lower Darling) made by Langtry in 1949-50 (Cadwallader 1977). Twenty-five years later in 1975-76, state-wide freshwater fish surveys were undertaken in New South Wales and are presented in Llewellyn (1983). Of the 210 sites sampled throughout the state, only four sites were within the Lower Murray-Darling catchment. From 1987 to 1992 the RMC and NSW Fisheries recommenced monitoring fish passage through the Euston fishway (Mallen-Cooper 1996). In 1992-93, NSW Fisheries undertook a fish recruitment study (Gehrke *et al.* 1995) that included sampling at four sites in the lower Darling catchment around Menindee. The 'NSW Rivers Survey' (Harris and Gehrke 1997) followed, with the first comprehensive state-wide standardised fish community survey from 1994-96. Sampling for the NSW Rivers Survey continued in 1998-99 but the data have not yet been published. Four of the NSW River Survey sites were within the Lower Murray-Darling catchment. In 1997-98, the CRC for Freshwater Ecology undertook fish community surveys of the Menindee Lakes as part of an assessment of the impact of drying on the ecology of the Lake (Scholz *et al.,* 1999), with samples collected from lakes Malta, Balaka, Bijiji, Tandure, Menindee and Cawndilla. In 1999, NSW Fisheries trialled a number of carp harvesting gear types on the North-Eastern shore of Menindee Lake. Although carp were targeted, the complete catch was recorded and reported in Gilligan *et al.* (2005). In 2000, SKM (Sinclair Knight Merz) undertook fish community surveys of Lake Wetherell and fish passage assessments in Morton Boulka Creek and between lakes Bijiji, Balaka and Lake Wetherell as part of the *Menindee Lakes ESD project* (SKM 2002). In 2001 the MDBCs *Murray River Fishway Assessment Program* sampled fish communities in the vicinity of Lock 7 as part of its pilot program (MDBC 2001). Tagged Murray cod and golden perch were radio-tracked at Lock 7 between 2001 and 2003 as part of this program (MDBC 2003*a*). From October 2001 to February 2002, the Murray-Darling Freshwater Research Centres - Lower Basin Laboratory sampled fish in the Lindsay River and Mullaroo Creek, Victorian anabranches of the lower Murray River (Meredith *et al.* 2002). In 2002, the Lower Basin Laboratory sampled the fish community of Bottle Bend Lagoon near Buronga (McCarthy *et al.*, 2003) and Purda Billabong near Wentworth (Conallin *et al.*, 2003). Also in 2002, fish communities were sampled at two of the *NSW Rivers Survey* sites in the Lower Murray-Darling catchment area as part of the pilot study for the MDBC's *Sustainable Rivers Audit* (SRA) reference sites sampling program (MDBC 2004*c*). In 2003, the MDBCs Murray Fishways Assessment program commenced trapping fish migrating through the newly constructed fishway on lock 8 (MDBC 2004*a*). Also in 2003, NSW DPI and the MDBC repaired/modified the Euston fishway and recommenced fishway trapping and fish community surveys (L. Baumgartner, unpublished data). In 2004, at the same time as sampling for this project was undertaken, the Lower Basin Laboratory undertook fish community surveys at 24 sites throughout the Victorian Mallee CMA catchment area (Ho *et al.*, 2004). This included 19 Victorian wetland and creek sites and 5 sites in the Murray River in NSW.

Since completion of sampling for this project, the Lower Basin Laboratory has sampled the fish community of Thegoa Lagoon near Wentworth in October 2004 (Ellis and Suitor, 2004) and wetlands 351 and 491 near Wentworth in November 2004 (Ellis and Meredith 2005). In 2005, 21 sites were sampled across the Lower Murray-Darling catchment as part of the Murray-Darling Basin Commission's SRA program (unpublished data) and Thegoa Lagoon was resampled by the MDFRC Lower Basin Laboratory (unpublished data). Australian Museum collection records are also available through the Bionet website (http://www.bionet.nsw.gov.au).

Through these previous studies, data on the Lower Murray-Darling fish community spans a substantial period of time. However, the available data do not incorporate the very early periods of European settlement of the catchment when vegetation clearing and de-snagging was undertaken, 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 weirs and locks in the system. 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), Gehrke *et al.* (1995), Mallen-Cooper (1996), Harris and Gehrke (1997), Scholz *et al.* 1999, MDBC (2001), SKM (2002), Meredith *et al.* (2002), Conallin *et al.* (2003), McCarthy *et al.* (2003), MDBC (2003), Ho *et al.* (2004), MDBC (2004*a*, 2004*c*), Ellis and Meredith (2005), Ellis and Suitor (2005) and Gilligan *et al.* (2005) provide useful insights into fish communities. However, in many cases sampling utilised either a non-standardised 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 one zone, or an insufficient number of sites to adequately assess fish communities across the Lower Murray-Darling catchment as a whole. As a result, these studies provide only parts of the complete picture of fish communities and the changes they have experienced since European-settlement of the Lower Murray-Darling catchment area.

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 (NSW DPI) 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). However, to be effective, the number of monitoring sites must be sufficient to provide statistical power to detect change (MDBC 2004*c*), the distribution of sites must be representative of the variety of habitats existing within the catchment, 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.

In 2005, the Murray-Darling Basin Ministerial Council began implementation of the SRA program (MDBC 2004*b*) to monitor changes in river health resulting from MDBC environmental initiatives. The SRA program builds 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 SRA program excludes non-riverine habitats and as a result, important wetland fish communities will not be addressed. This is particularly important in the Lower Murray-Darling catchment, which contains the Menindee Lakes system, Lake Victoria and many other floodplain lake systems. Therefore the sampling strategy utilised for the fish survey presented in this report, incorporated the standard SRA riverine fish community monitoring strategy as well as additional sampling in lakes and reservoirs and also in floodplain wetlands adjacent to riverine monitoring sites. As a result, this Lower Murray-Darling catchment fish monitoring program builds upon past and upcoming fish surveys by contributing to a 10 year standardised data-set from pre-existing sites within the Lower Murray-Darling catchment. Further, it is consistent with the SRA programs methodology (but not necessarily at the same sampling locations), which will collect standardised fish community data for at least the next six years and potentially for the next 50 years (MDBC 2004*c*).

Photo: Lee Baumgartner (Electrofishing in FRV Pole Volt)

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 (see MDBC 2004*b*) was followed for selection of monitoring sites in the Lower Murray-Darling catchment.

A Lower Murray-Darling catchment map was created in a Geographical Information System (GIS) using the ArcView software program. The map displayed the NLWRA stream network (all streams 3^{rd} 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. 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 five zones representing the 'aquatic ecosystem management units' specified by the CMA (Lower Murray Darling Catchment Management Board 2003). These zones were: Murray River I (Murrumbidgee junction to Darling junction), Murray River II (Darling junction to South Australian Border), the Lower Darling River, the Great Darling Anabranch and the Menindee Lakes.

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 four NSW Rivers Survey sites in the Lower Murray-Darling catchment, one was in Murray River I, one was in the Murray River II and two were in the Darling River. 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*c*). 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 criterion 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. The ‘accepted’ monitoring sites selected following this procedure are listed in Table 2.1 and plotted on Figure 2.1.

The Great Darling Anabranch was almost totally dry in the 2004 sampling season. The only water available in the entire zone was at its junction with the Murray River, where Murray water was backed up into the anabranch mouth. So only one targeted site (instead of the seven randomly selected ones) could be sampled in this zone.

Although the CMA specified a Menindee Lakes zone, a broader ‘Lakes & Reservoirs’ zone was used given that much of the Menindee Lakes system was dry during sampling. This ‘Lakes & Reservoirs’ zone encompassed the Menindee Lakes, Lake Victoria, the Euston Lakes and Imperial Lake (an artificial water storage near Broken Hill). However as for the Great Darling Anabranch, most lakes within the catchment area were dry in the 2004 sampling season. As a result only five “Lakes & Reservoirs’ could be sampled in 2004. One of these sites was randomly selected (Lake Victoria), with two being located at pre-existing sampling sites (Lake Pamamaroo and Lake Wetherell) and the remaining two located at two other available access points (Copi Hollow and Imperial Lake (Broken Hill)).

As standardised fish monitoring in wetlands has not been a feature of recent fish monitoring programs in Australia, the floodplain 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, three wetlands associated with randomly selected sites were sampleable (Table 2.1). The location of these sites, and those wetlands that were present but dry in 2004, are plotted on Figures 2.2 and 2.3. Increasing the radius to 5 km around the monitoring sites did not increase the number of wetlands available for sampling.

Table 2.1. Sites sampled within each of five catchment zones in the Lower Murray-Darling CMA catchment area.

		UTM zone 54		
Site name	**Waterway**	**Easting**	**Northing**	**Wetland**
Darling River				
Bono	Darling River	630500	6396700	Dry
Downham Farm	Darling River	593000	6254000	None
Moorara	Darling River	628000	6361200	Dry
Pooncarie	Darling River	645100	6305100	Dry
Lethero	Darling River	634100	6282500	Dry
Pomana	Darling River	583559	6239880	Dry
Lelma	Darling River	629300	6272800	Dry
Great Darling Anabranch				
Allanvale	Great Darling Anabranch	565800	6250000	None
Watara	Great Darling Anabranch	569600	6263400	None
Hunter waterhole	Great Darling Anabranch	586350	6322000	Dry
Milkengay Creek junction	Great Darling Anabranch	574000	6296250	None
Four-wings Shack	Great Darling Anabranch	592500	6327350	None
Bob's Lake	Tandou Creek	616350	6391600	None
Packer's Crossing	Redbank Creek	600250	6375000	Dry
Darling Anabranch mouth *	Great Darling Anabranch	570000	6227300	Dry
Lakes & Reservoirs				
Imperial Lake	Broken Hill reservoir	546811	6465397	
Copi Hollow	Menindee Lakes	630090	6428815	
Lake Pamamaroo	Menindee Lakes	641500	6424700	
Lake Wetherell	Menindee Lakes	643300	6423500	
Lake Victoria	Lake Victoria	526500	6233500	
Murray I				
Tangles Corner	Murray River	687500	6158500	Sampled
Yangera Island	Murray River	680000	6160300	Sampled
Carina Bend	Murray River	653700	6161500	Dry
Wemen	Murray River	647500	6149500	Dry
Lake Cantala	Murray River	636200	6162150	None
Nangiloc	Murray River	625500	6183200	Dry
Cowana Bend	Murray River	625500	6223200	Dry
Murray II				
Upper Kulnine	Murray River	577400	6222800	Sampled
Frenchman's Creek	Frenchman's Creek	536800	6226500	Dry
Ned's Corner	Murray River	531200	6223200	Dry
Tareena	Salt Creek	500300	6241700	Dry
10 km below Lock 7	Murray River	517800	6229500	Dry
Hancock Hill- Wompinni	Murray River	504100	6232100	Dry
Salt Creek	Salt Creek	503700	6237500	Dry

* This site was sampled as it was the only part of the Great Darling Anabranch containing water in 2004. It is not one of the seven randomly selected fish monitoring sites designed to represent this zone.

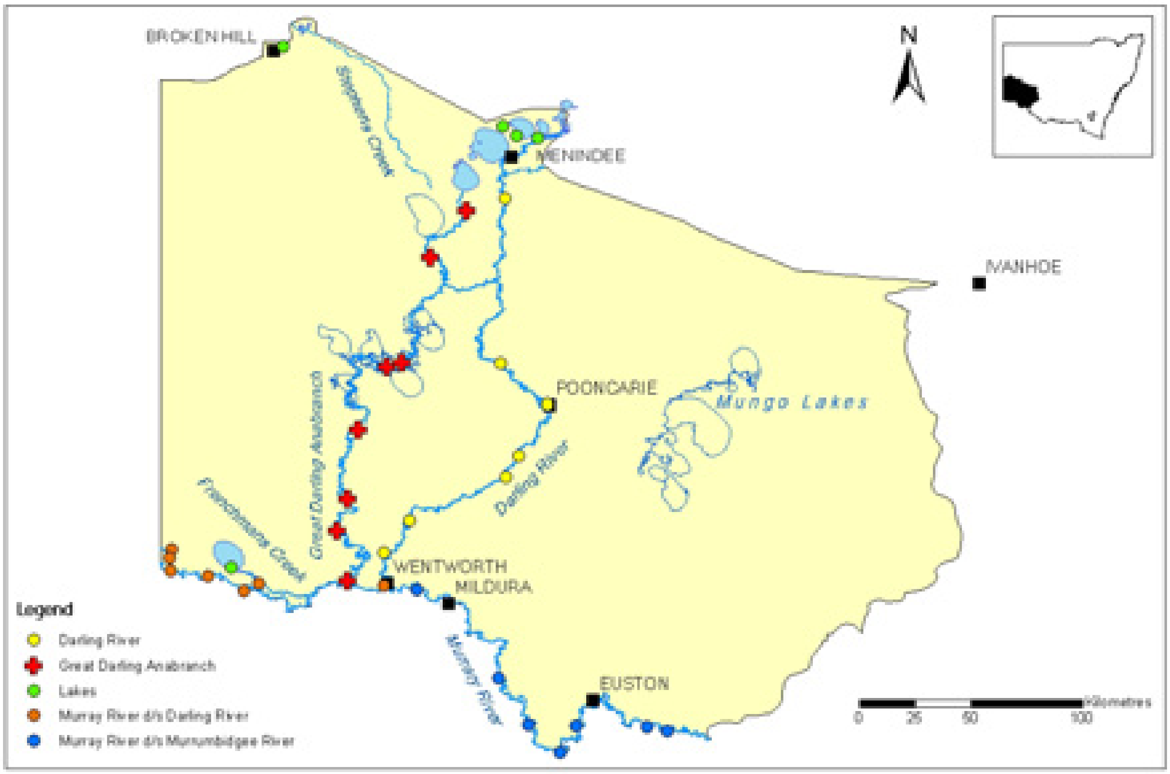

Figure 2.1. Plot of locations sampled in the Lower Murray-Darling CMA catchment area. All sites apart from those in the Lakes & Reservoirs zone were randomly selected. The Great Darling Anabranch was dry during the sampling period apart from the lowest end containing backed-up waters from the Murray River. Although this site was not randomly selected, it was sampled as it was the only available water in this zone. The unsampled but randomly selected sites are indicated for future surveys in years when the anabranch contains water.

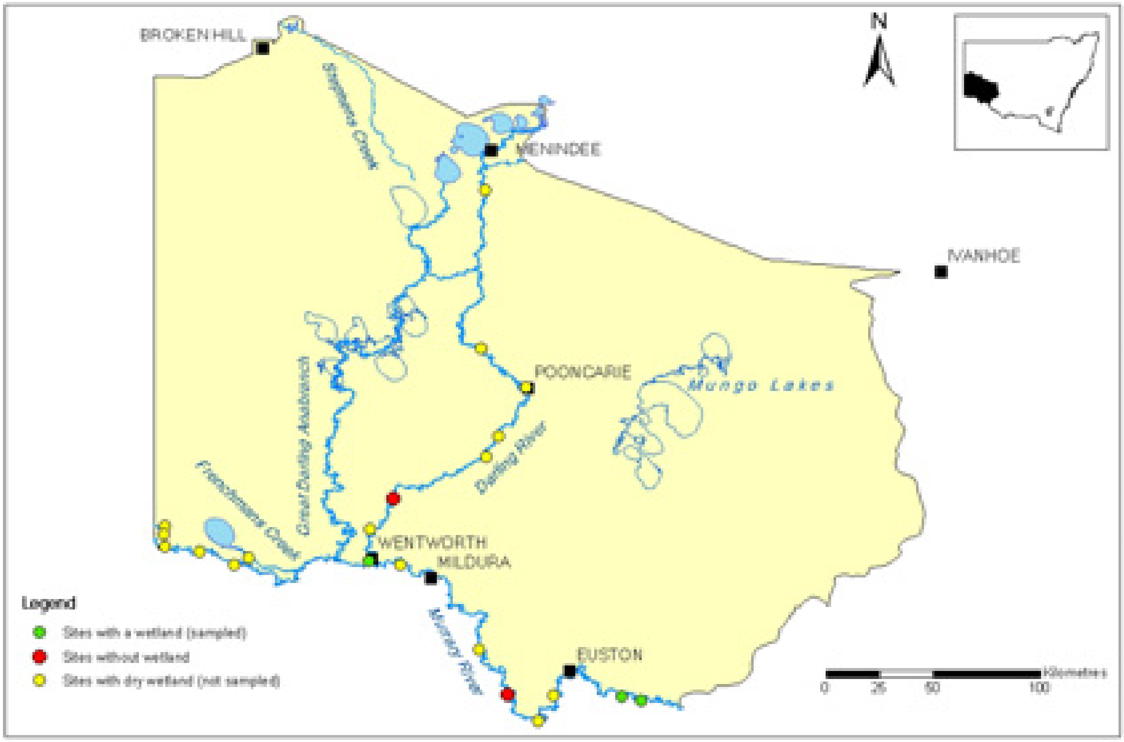

Figure 2.2. Plot of locations of sampled riverine sites, which have a wetland within 2.5 km. Green points represent sites where the wetland contained water and was sampled. Yellow represents sites where the wetland was dry during the sampling period. Only two riverine sites did not have a wetland within either 2.5km or 5km (red points).

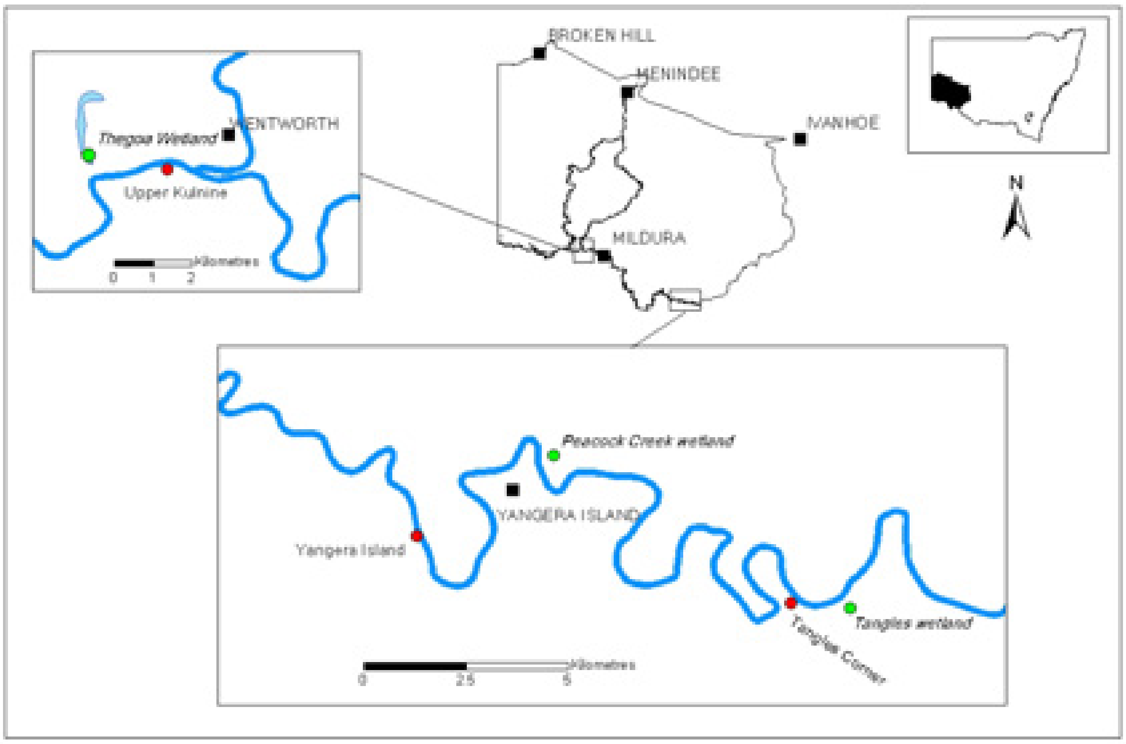

Figure 2.3. Plot of locations of floodplain wetlands sampled in the Lower Murray-Darling catchment relative to the riverine monitoring sites.

2.2. Sampling procedure

Samples were collected between March and June 2004.

2.2.1. Riverine sites

The sampling procedure for riverine sites was based on standardised boat electrofishing in addition to 10 un-baited concertina-type shrimp traps as developed for the SRA program (MDBC 2004*c*). A boat electrofishing system (7.5 kW Smith-Root model GPP 7.5 H/L) was used at all sites. Boat operations consisted of 90 seconds of electrofishing (power on). Each operation was undertaken using intermittent electrofishing. This protocol minimises the 'herding' of fish. As a further prevention of herding, each operation was undertaken on alternate banks. Each operation took an average of four minutes to complete. Twelve electrofishing operations were undertaken within each 1 km sampling site. Two operations were undertaken 'mid-stream' to sample potential pelagic fish (species that swim in open water).

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.

The shrimp traps were set in an 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 separate operations.

At the completion of each operation (electrofishing or shrimp traps), captured individuals were identified, counted, measured and observed for health conditions such as 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 completed, 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.

2.2.2. Lake & Reservoir sites

Sampling was undertaken in a similar manner to riverine sites, although as alternating operations between each bank was impractical in large lake environments, operations were undertaken by first manoeuvring the boat diagonally away from the bank and then for the subsequent shot manoeuvring the boat diagonally back towards the bank. This was repeated for a total of 10 operations with an additional two 'mid-water' operations undertaken.

2.2.3. Wetland sites[4]

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 (~ 2 hour sets (minimum)). 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.

2.2.4. Habitat assessment

In addition to fish sampling, a habitat assessment and water quality testing were 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 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 DPI Freshwater Fish Research Database. Within this data storage system, data are first entered into intermediate tables by technical staff. The data are 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.

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4 Concurrent with the development of this project, the Murray-Darling Freshwater Research Centre (MDFRC) - Lower Basin Laboratory were undertaking a number of wetland fish community surveys in and around the Lower Murray-Darling catchment. MDFRC developed a more extensive wetland fish surveying strategy than that utilised in this project, that included the use of shrimp traps and seine nets, but also utilised large mesh fyke nets, small mesh fyke nets, light traps, panel nets and electrofishing (McCarthy *et al.* 2003; Conallin *et al.* 2003; Ho *et al.* 2004; Ellis and Suitor, 2004; Ellis and Meredith 2005). We would recommend adoption of this more intensive wetland survey method for subsequent surveys but maintain the same seine net and shrimp trap sampling methodology as used in this study to ensure temporal consistency.

Photo: Ian Wooden (The lower Darling River in January 2004)

3. STATUS OF FISH COMMUNITIES OF THE LOWER MURRAY-DARLING 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 varying nature of the Darling and Murray catchments, differences in water chemistry, geomorphology, hydrology and management, and the differences between riverine reaches and floodplain lakes, the composition of fish communities occurring at sites within the Lower Murray-Darling catchment are unlikely to be consistent throughout the catchment area.

The structure of fish communities is expected to be similar in areas that contain similar habitat types and have been exposed to similar disturbances. These include both natural events such as cyanobacterial blooms 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 can then be used to assess temporal changes in community status. These include species richness (number of species), total abundance, biomass, species diversity and evenness (population level indices reflecting both the species richness and the degree to which common species dominate the fish community), the proportion of alien taxa and estimates of recruitment (entry of offspring into the population). 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

All 22 riverine sites and five ‘Lakes & Reservoirs’ sites were included in the assessment of bio-zonation within the catchment. Data from the three sampled wetlands was omitted due to the low number of sites sampled. Therefore, the remainder of this section refers only to the 27 riverine/’Lakes & Reservoirs’ sites. Data from all operations at a site (boat 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 for a particular waterbody type.

Biomass per site was estimated from length-weight relationships presented in Table 8 of MDBC (2004*c*). 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 where a species was only observed at a site (rather than actually caught and measured), 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 Lower Murray-Darling 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. 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 = 0.805, p = 0.0002). As a result, only abundance data were analysed further. Data were plotted using both a hierarchical agglomerative classification analysis using the group-average linking algorithm and multi-dimensional scaling (MDS) ordinations in 2 dimensions. ANOSIM (ANalysis Of SIMilarities) (Clarke 1993) was used to test differences in fish community structure across zones. 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, proportion of fish with a health condition (also broken down into proportion of fish with lernaea, wounds and ulcers) and the proportion new recruits 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, proportion with a health condition (also broken down into lernaea, wounds and ulcers) and proportion of new recruits were also estimated for each individual species within each zone.

Shannon’s 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.

Non-parametric Kruskal-Wallis rank sum tests in S-Plus 6.1 were used to test for differences between zones for all parameters.

Power analyses were undertaken using S-Plus 6.1 to assess the minimum detectable change for each population parameter within each zone, using the same sampling strategy as was used for this benchmarking study. The 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 analysis 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	
Australian smelt	40 (Pusey *et al.* 2004)
Bony herring	67 (Cadwallader 1977)
Carp-gudgeon species-complex	35 (Pusey *et al.* 2004)
Flat-headed gudgeon	50 (Pusey *et al.* 2004)
Flyspecked hardyhead	40 (Pusey *et al.* 2004)
Freshwater catfish	83 (Davis 1975)
Golden perch	75 (Mallen-Cooper 1996)
Murray cod	235 (Rowland 1998)
Murray-Darling rainbowfish	45 (Pusey *et al*. 2004: for *M. duboulayi*)
Silver perch	75 (Mallen-Cooper 1996)
Alien species	
Common carp	200 (Brown *et al.* 2003)
Eastern gambusia	20 (McDowall 1996)
Goldfish	100 (Brumley 1996)
Redfin perch	150

NOTE: Pusey *et al.* (2004) presented length data as standard length. Data in this table reflects the average of the mean male and female lengths presented, and rounded up to the nearest 5mm increment to reflect either total length or fork length.

3.3. Results

3.3.1. Catch data

Fourteen fish taxa (13 species and 1 species complex (potentially four separate but indistinguishable *Hypseleotris* species (Allen *et al.* 2002)) were sampled from the 27 monitoring sites (excluding the three wetland sites) (Table 3.2). This represents 45% of the native taxa (10 of 22) and 57% of the alien species (four of seven) known to have historically occurred in this river system. The species not sampled included the two vagrant native taxa (congoli and Hrytl's tandan), six threatened species (olive perchlet, Murray hardyhead, Macquarie perch, southern purple spotted gudgeon, southern pygmy perch and trout cod), four other native species not listed as threatened (flat-headed galaxias, spangled perch, short-headed lamprey and dwarf flat-headed gudgeon), and three species of alien fish (tench, brown trout and spotted galaxias).

Due to the prevailing drought conditions at the time of sampling, only three of the 20 wetlands selected for sampling contained water. Seven species were sampled from wetland habitats, six native species: flyspecked hardyhead, carp-gudgeons, Murray-Darling rainbowfish, bony herring, flat-headed gudgeon and Australian smelt, and only one alien species: eastern gambusia, which made up 53% of the overall fish abundance in the three wetlands (Table 3.2). Spatial structure of fish communities within the Lower Murray-Darling catchment.

Classification analysis of abundance data from the 27 sites demonstrated some spatial variability in fish community structure within the catchment. This is indicated by deep branching (Figure 3.1) and is a result of low similarities among some individual and groups of sites. However, the classification analysis demonstrated that there are relatively few associations (clusters) of sites at higher levels of similarity, suggesting either 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).

Three of the five 'Lakes & Reservoirs' sites were substantially divergent from each other and the remainder of sites, with similarities of only 15% (Imperial Lake), 36% (Lake Pamamaroo) and 39% (Copi Hollow) (Figure 3.1). The most dissimilar site was Imperial Lake, an artificial impoundment at Broken Hill, which was the only site where freshwater catfish were found and the only site lacking bony herring or common carp. The only three species found in Imperial Lake were freshwater catfish, silver perch and carp-gudgeons. The next most divergent site was Lake Pamamaroo which was also unique with only two species, bony herring and common carp caught, both in very low numbers. Copi Hollow also had a poor catch of just three species, carp, carp-gudgeon and golden perch.

All other sites, including the remaining two 'Lakes & Reservoirs' sites (Lake Wetherell and Lake Victoria) had similarities greater than 60% (Figure 3.1). This suggests a consistent fish community structure throughout the entire riverine component of the catchment. Although subsequent breakdown of the fish community was still possible, the distinctions between fish communities became harder to interpret. A cluster of three sites consisting of Lake Victoria, Lake Wetherell (Lakes & Reservoirs) and Tangles corner (Murray I zone) differed from the remaining sites with a similarity of 60% and all had a generally lower abundance of all species (Figure 3.1). Salt Creek was the next most divergent site with a similarity of 61% and like the previous cluster, had a lower abundance of all species except for carp, which were more abundant than generally found throughout the remaining sites (Figure 3.1). The next divergence, at a similarity of 64% separated four sites from the Murray II zone, one site from the Murray I zone and the single Great Darling Anabranch site, from all the sites in the Darling zone, six of the seven sites in the Murray I zone and the remaining two Murray II zone sites. This divergence was based on a greater abundance of smaller native species in the cluster dominated by Murray II sites, with Australian smelt, flyspecked hardyhead, Murray-Darling rainbowfish and carp-gudgeons contributing 58% of the difference.

The MDS ordination (Figure 3.2) confirms these relationships with the ‘Lakes & Reservoirs’ sites are obviously very diverse, the Darling zone sites tightly clustered, the Murray I sites tightly clustered and the Murray II sites showing similarities to both Murray I and Darling zones. The single Great Darling Anabranch site was most similar to the Murray II zone as expected given that the site was at the junction of the Great Darling Anabranch and the Murray River in zone Murray II.

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

Species	**Murray I**	**Murray II**	**Darling**	**Great Darling Anabranch**	**Lakes & Reservoirs**	**Wetlands**	**Total**
Native species							
Australian smelt	705	805	20	90	6	9	1,635
Bony herring	730	1,127	803	105	114	58	2,937
Carp-gudgeon species complex	81	220	29	58	133	350	871
Congoli	0	0	0	0	0	0	0
Dwarf flat-headed gudgeon	0	0	0	0	0	0	0
Flat-headed galaxias	0	0	0	0	0	0	0
Flat-headed gudgeon	0	45	0	0	4	7	56
Flyspecked hardyhead	13	176	0	2	0	30	221
Freshwater catfish	0	0	0	0	22	0	22
Golden perch	33	73	66	1	2	0	175
Hyrtl’s tandan	0	0	0	0	0	0	0
Macquarie perch	0	0	0	0	0	0	0
Murray cod	14	15	13	0	0	0	42
Murray hardyhead	0	0	0	0	0	0	0
Murray-Darling rainbowfish	31	103	2	69	2	19	226
Olive perchlet	0	0	0	0	0	0	0
Short-headed lamprey	0	0	0	0	0	0	0
Silver perch	2	0	0	0	1	0	3
Southern purple spotted gudgeon	0	0	0	0	0	0	0
Southern pygmy perch	0	0	0	0	0	0	0
Spangled perch	0	0	0	0	0	0	0
Trout cod	0	0	0	0	0	0	0
Alien species							
Brown trout	0	0	0	0	0	0	0
Common carp	92	139	213	3	8	0	455
Eastern gambusia	0	1	3	0	2	535	541
Goldfish	5	13	59	0	0	0	77
Redfin perch	0	4	0	0	0	0	4
Spotted galaxias	0	0	0	0	0	0	0
Tench	0	0	0	0	0	0	0
Number of sites sampled	*7*	*7*	*7*	*1*	*5*	*3*	*30*
Total	1,706	2,721	1,208	328	294	1,008	7,265

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

Species	Murray I	Murray II	Darling	Great Darling Anabranch	Lakes & Reservoirs	Wetlands	Total
Native species							
Australian smelt	0.321	0.170	0.010	0.046	0.004	0.007	0.557
Bony herring	23.464	15.947	23.498	3.322	2.389	0.324	68.944
Carp-gudgeon species complex	0.031	0.063	0.007	0.016	0.021	0.097	0.235
Congoli	0	0	0	0	0	0	0
Dwarf flat-headed gudgeon	0	0	0	0	0	0	0
Flat-headed galaxias	0	0	0	0	0	0	0
Flat-headed gudgeon	0	0.069	0	0	0.005	0.006	0.080
Flyspecked hardyhead	0.010	0.065	0	0.002	0	0.008	0.085
Freshwater catfish	0	0	0	0	3.752	0	3.752
Golden perch	32.476	44.559	24.437	0.501	1.803	0	103.776
Hyrtl's tandan	0	0	0	0	0	0	0
Macquarie perch	0	0	0	0	0	0	0
Murray cod	45.455	38.781	25.229	0	0	0	109.466
Murray hardyhead	0	0	0	0	0	0	0
Murray-Darling rainbowfish	0.038	0.114	0.002	0.080	0.002	0.035	0.271
Olive perchlet	0	0	0	0	0	0	0
Short-headed lamprey	0	0	0	0	0	0	0
Silver perch	0.854	0	0	0	1.888	0	2.742
Southern purple spotted gudgeon	0	0	0	0	0	0	0
Southern pygmy perch	0	0	0	0	0	0	0
Spangled perch	0	0	0	0	0	0	0
Trout cod	0	0	0	0	0	0	0
Alien species							
Brown trout	0	0	0	0	0	0	0
Common carp	127.574	246.193	141.568	8.302	10.018	0	533.655
Eastern gambusia	0	0	0	0	0	0.101	0.101
Goldfish	2.640	1.883	6.218	0	0	0	10.741
Redfin perch	0	0.411	0	0	0	0	0.411
Spotted galaxias	0	0	0	0	0	0	0
Tench	0	0	0	0	0	0	0
Number of sites sampled	7	7	7	1	5	3	30
Total	232.863	348.255	220.970	12.269	19.883	0.577	834.815

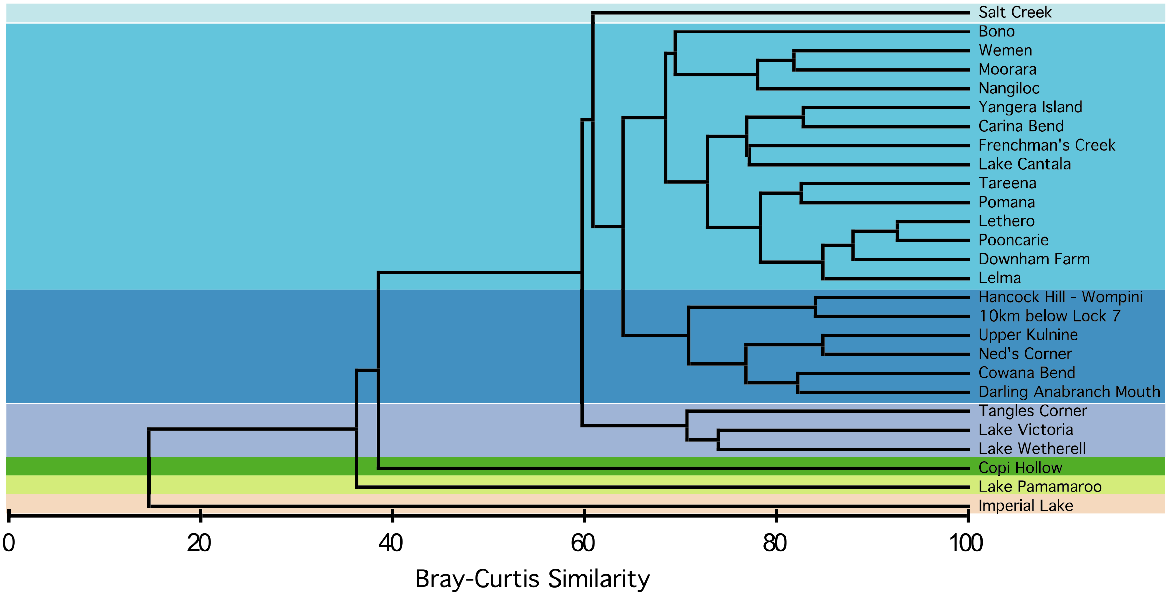


Figure 3.1. Classification analysis of sites in the Lower Murray-Darling catchment based on similarities calculated from abundance data. Colouration represents the seven clusters of sites with greater than 35% dissimilarity.

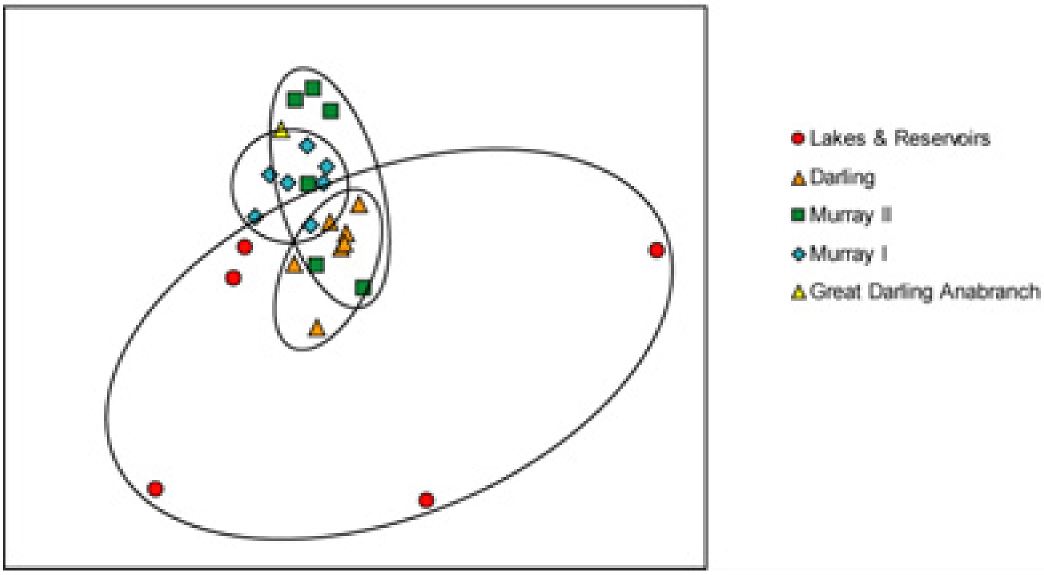


Figure 3.2. MDS ordination of fish community data from sites in the Lower Murray-Darling catchment. Stress = 0.14.

3.3.2. Analysis of fish communities among zones

Comparison of the fish communities of each of the five pre-determined zones using ANOSIM identified significant differences (Global $R = 0.44$, $p < 0.0001$). The fish communities of all zones were found to be significantly different (Table 3.4).

The ‘Lakes & Reservoirs’ zone was the most distinct, with an average dissimilarity of 58.94%. The fish community in this zone was characterised by a consistently lower abundance of all species except carp-gudgeons. Bony herring, Australian smelt, golden perch, carp, Murray-Darling rainbowfish and Murray cod contributed 76% of the dissimilarity between this zone and the remainder of the catchment (Table 3.5). Murray II was the next most distinct fish community with an average dissimilarity value of 34.49%. The Murray II fish community was characterised by a greater abundance of Australian smelt, flyspecked hardyhead, Murray-Darling rainbowfish, flat-headed gudgeon, carp-gudgeon, bony herring, Murray cod and golden perch than the combined Darling and Murray I zones (Table 3.5). These species contributed 90.68% of the dissimilarity between fish communities in these zones. The most similar fish communities occurred in the Darling and Murray I zones, with an average dissimilarity of 32.49%. The Darling River fish community was characterised by a higher abundance of goldfish, bony herring, golden perch and carp, but a lower abundance of Australian smelt, Murray-Darling rainbowfish, carp-gudgeons and flyspecked hardyhead (Table 3.5). These species contributed 88.36% of the dissimilarity in fish communities between the Darling and Murray I zones.

Table 3.4. Summary of ANOSIM comparisons of fish communities within zones. Comparisons with the Great Darling Anabranch were omitted as a significant result was not possible given the single site sampled in that zone.

Comparisons	***R***	***P***
Lakes & Reservoirs v Murray II	0.529	0.001
Lakes & Reservoirs v Murray I	0.561	0.001
Lakes & Reservoirs v Darling	0.574	0.001
Murray II v Murray I	0.196	0.036
Murray II v Darling	0.466	0.001
Murray I v Darling	0.535	0.001

Table 3.5. 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 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%
	Lakes & Reservoirs	**Murray I, Murray II and Darling**			58.94
Bony herring	22.80	125.68	1.40	15.96	
Australian smelt	1.20	73.64	1.41	29.98	
Golden perch	0.40	7.86	1.95	40.88	
Carp-gudgeon species complex	26.60	17.64	1.23	50.84	
Common carp	1.60	20.32	1.63	60.30	
Murray-Darling rainbowfish	0.40	9.32	1.22	68.40	
Murray cod	0.00	1.91	1.27	75.83	
	Murray II	**Murray I and Darling**			34.49
Australian smelt	115.00	51.79	1.39	14.98	
Flyspecked hardyhead	25.14	0.93	1.18	27.16	
Murray-Darling rainbowfish	14.71	2.36	1.64	39.04	
Flat-headed gudgeon	6.43	0.00	1.38	49.67	
Carp-gudgeon species complex	31.43	7.86	1.30	60.14	
Bony herring	161.00	109.50	1.44	69.39	
Goldfish	1.86	4.57	1.20	78.04	
Murray cod	2.14	1.93	1.11	85.29	
Golden perch	10.43	7.07	1.10	90.68	
	Murray I	**Darling**			32.49
Australian smelt	100.71	2.86	1.40	19.07	
Goldfish	0.71	8.43	1.41	33.00	
Murray-Darling rainbowfish	4.43	0.29	1.61	45.96	
Carp-gudgeon species complex	11.57	4.14	1.27	57.44	
Bony herring	104.29	114.71	1.28	65.77	
Flyspecked hardyhead	1.86	0.00	1.08	73.99	
Golden perch	4.71	9.43	1.02	81.94	
Common carp	13.14	30.43	1.52	88.36	

3.3.3. 2004 benchmark of fish communities in the Lower Murray-Darling catchment

Fish community parameters for individual monitoring sites are presented in Table 3.6.

3.3.3.1. Species richness

Species richness differed significantly among zones (χ^2_3 = 13.86, p = 0.003) with the Lakes & Reservoirs zone having a lower mean species richness than riverine zones (Figure 3.3).

3.3.3.2. Total abundance

Total abundance differed significantly among zones (χ^2_3 = 8.81, p = 0.032) (Figure 3.4). The 'Lakes & Reservoirs' zone had a substantially lower abundance than the riverine zones and the Darling had a slightly lower abundance, particularly compared to the Murray II zone which had the highest average abundance of any zone.

3.3.3.3. Total biomass

There were significant differences in total biomass among zones (χ^2_3 = 11.73, p = 0.008). The 'Lakes & Reservoirs' zone had a substantially lower total biomass per sample. The Darling zone had a biomass more similar to the two Murray River zones than was found for species richness or total abundance (Figure 3.5).

3.3.3.4. *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 = 1.08). Neither Shannon's diversity H (χ^2_3 = 5.73, p = 0.126) nor Shannon's evenness J (χ^2_3 = 1.14, p = 0.767) indices differed among zones (Figures 3.6 and 3.7).

3.3.3.5. 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, that were native fish species. These are the indices most relevant to the CMA's catchment blueprint targets. Ratios were expressed as proportions as they have statistical properties more suited to statistical analyses than do ratios.

There were significant differences between the proportion of species (χ^2_3 = 8.38, p = 0.039) (Figure 3.8) and individuals (χ^2_3 = 9.15, p = 0.027) (Figure 3.9) that were native among catchment zones. However these differences were not evident for the proportion of biomass (χ^2_3 = 1.29, p = 0.731) (Figure 3.10).

Table 3.6. Fish community parameters estimated from data collected from 27 monitoring sites and three associated wetland sites in the Lower Murray-Darling catchment.

Site name	Catchment zone	Species richness	Total abundance	Total biomass (kg)	Shannon's *H*	Shannon's *J*	Proportion native species	Proportion native abundance	Proportion native biomass	Proportion recruits	Proportion with health condition
Bono	Darling	5	53	32.696	1.32	0.82	0.80	0.70	0.46	0.07	0.13
Downham Farm	Darling	6	192	14.076	0.93	0.52	0.67	0.82	0.35	0.19	0.01
Moorara	Darling	5	111	25.407	0.82	0.51	0.80	0.84	0.60	0.36	0.00
Pooncarie	Darling	7	241	54.818	1.06	0.54	0.71	0.71	0.10	0.46	0.05
Lethero	Darling	7	151	28.248	1.30	0.67	0.71	0.70	0.38	0.14	0.16
Pomana	Darling	8	185	26.349	1.07	0.52	0.63	0.83	0.50	0.15	0.01
Lelma	Darling	6	275	39.373	0.99	0.55	0.67	0.78	0.21	0.34	0.05
Darling Anabranch Mouth	Great Darling Anabranch	7	328	12.269	1.45	0.74	0.86	0.99	0.32	0.56	0.00
Tangles Corner	Murray I	6	52	9.456	1.57	0.88	0.83	0.90	0.50	0.75	0.00
Yangera Island	Murray I	9	342	21.028	0.66	0.30	0.78	0.96	0.53	0.64	0.01
Carina Bend	Murray I	10	232	66.895	1.59	0.69	0.80	0.88	0.35	0.34	0.01
Wemen	Murray I	7	98	32.898	1.12	0.57	0.86	0.93	0.64	0.06	0.02
Lake Cantala	Murray I	7	180	32.878	0.84	0.43	0.86	0.94	0.61	0.21	0.00
Nangiloc	Murray I	6	193	23.450	0.84	0.47	0.83	0.96	0.34	0.10	0.02
Cowana Bend	Murray I	7	609	46.256	0.96	0.49	0.86	0.96	0.31	0.75	0.004
Upper Kulnine	Murray II	10	922	33.464	1.30	0.57	0.80	0.99	0.38	0.18	0.00
Frenchman's Creek	Murray II	8	414	50.763	0.83	0.40	0.75	0.97	0.86	0.80	0.02
Ned's Corner	Murray II	10	631	25.107	1.31	0.57	0.80	0.98	0.24	0.78	0.003
Tareena	Murray II	7	56	15.114	1.31	0.67	0.71	0.71	0.15	0.34	0.00
10km below Lock 7	Murray II	7	257	24.367	1.55	0.80	0.86	0.92	0.52	0.68	0.01
Hancock Hill - Wompinni	Murray II	10	354	28.579	1.39	0.61	0.80	0.92	0.64	0.60	0.004
Salt Creek	Murray II	7	87	170.861	1.22	0.63	0.71	0.32	0.02	0.20	0.02

Table 3.6. (cont.) Fish community parameters estimated from data collected from 27 monitoring sites and three associated wetland sites in the Lower Murray-Darling catchment.

Site name	Catchment zone	Species richness	Total abundance	Total biomass (kg)	Shannon's *H*	Shannon's *J*	Proportion native species	Proportion native abundance	Proportion native biomass	Proportion recruits	Proportion with health condition
Imperial Lake	Lakes & Reservoirs	3	127	5.653	0.51	0.46	1.00	1.00	1.00	0.87	0.00
Copi Hollow	Lakes & Reservoirs	3	9	3.114	1.00	0.91	0.67	0.78	0.58	0.38	0.00
Lake Pamamaroo	Lakes & Reservoirs	2	14	0.246	0.26	0.37	0.50	0.93	0.89	0.09	0.00
Lake Wetherell	Lakes & Reservoirs	6	109	3.669	0.84	0.47	0.67	0.95	0.22	0.51	0.00
Lake Victoria	Lakes & Reservoirs	6	35	7.200	1.22	0.68	0.83	0.94	0.19	0.72	0.00
Thegoa Lagoon	Murray II	2	75	0.013	0.54	0.77	0.50	0.23	0.38	0.94	0.00
Peacock Creek wetland	Murray I	7	524	0.476	1.25	0.64	0.86	0.84	0.97	0.53	0.00
Tangles Corner wetland	Murray I	3	409	0.088	0.17	0.16	0.67	0.04	0.11	0.42	0.00
Lake Pamamaroo											

Table 3.7. Presence/absence of fish species in each catchment zone.

Species	Murray I	Murray II	Darling	Great Darling Anabranch	Lakes & Reservoirs
Native species					
Silver perch	●				●
Flyspecked hardyhead	●	●		●	
Carp-gudgeon species-complex	●	●	●	●	●
Golden perch	●	●	●	●	●
Murray cod	●	●	●		
Murray-Darling rainbowfish	●	●	●	●	●
Bony herring	●	●	●	●	●
Flat-headed gudgeon		●			●
Australian smelt	●	●	●	●	●
Freshwater catfish					●
Alien species					
Goldfish	●	●	●		
Common carp	●	●	●	●	●
Eastern gambusia		●	●		●
Redfin perch		●			

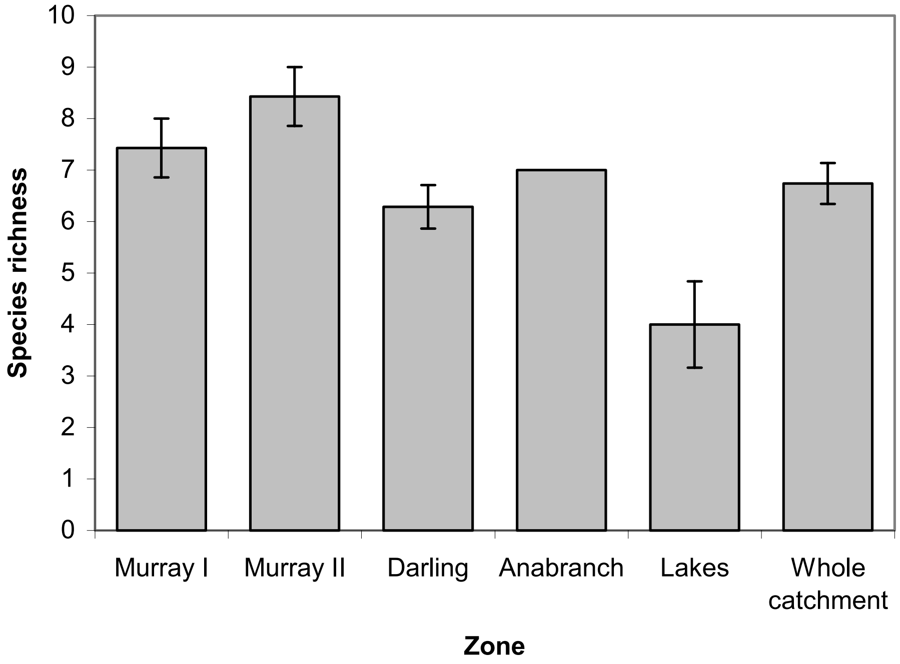


Figure 3.3. Average species richness at sites in each of the five zones and the average over the whole catchment. Error bars represent the standard error.

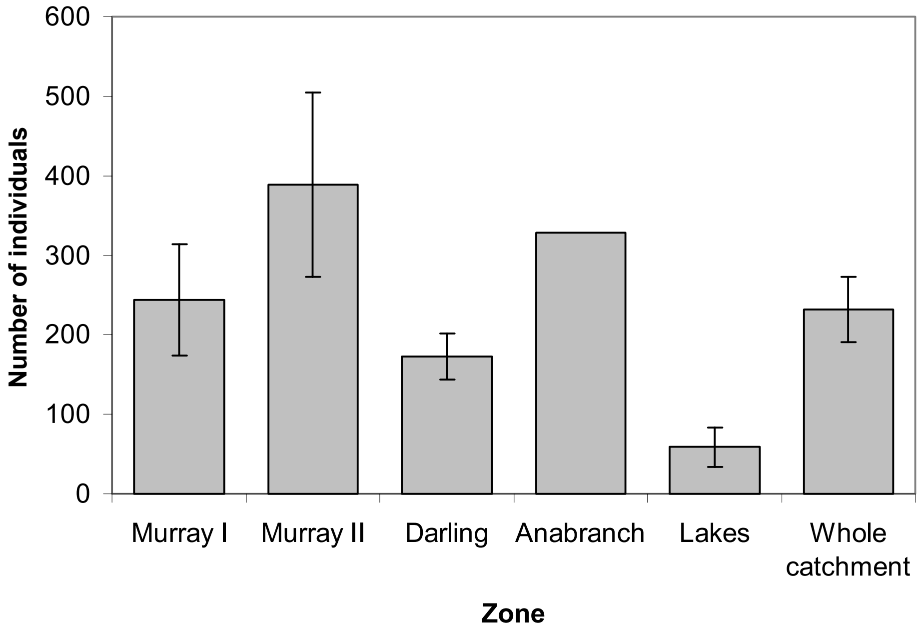


Figure 3.4. Average number of individuals at sites in each of the five catchment zones and the average over the whole catchment. Error bars represent the standard error.

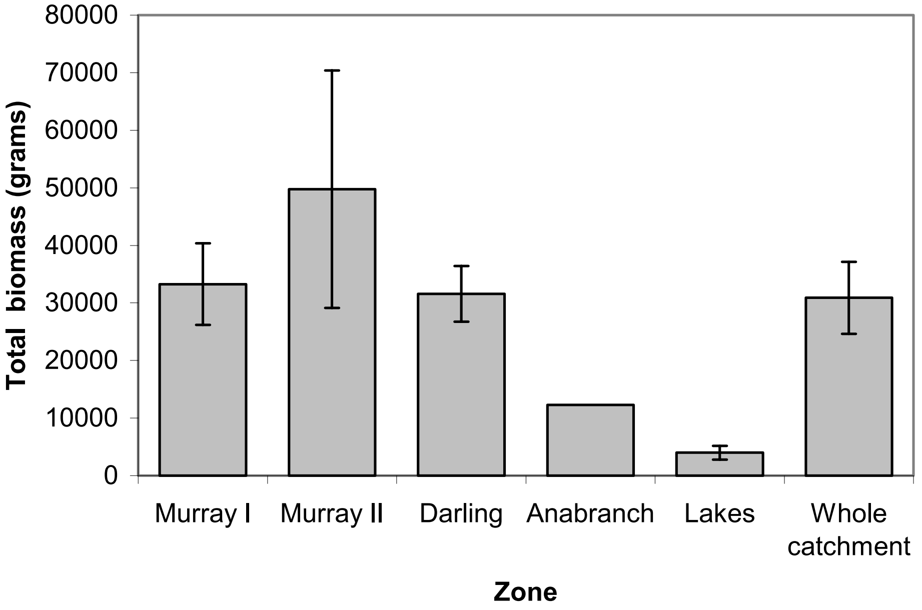


Figure 3.5. Average total biomass estimated at sites in each of the catchment zones and the average over the whole catchment. Error bars represent the standard error.

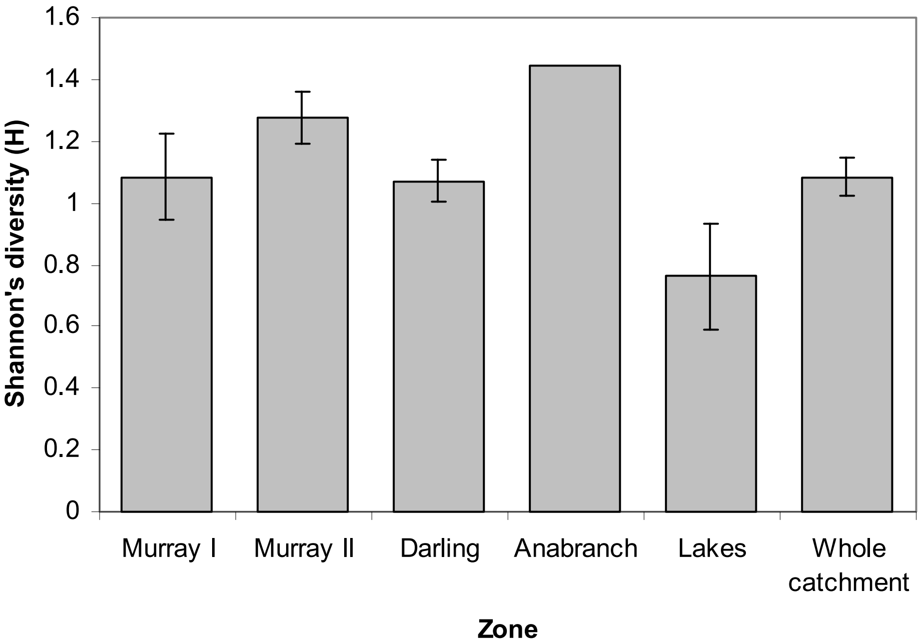


Figure 3.6. Average Shannon's diversity index (*H*) at sites in each of the catchment zones and the average over the whole catchment. Error bars represent the standard error.

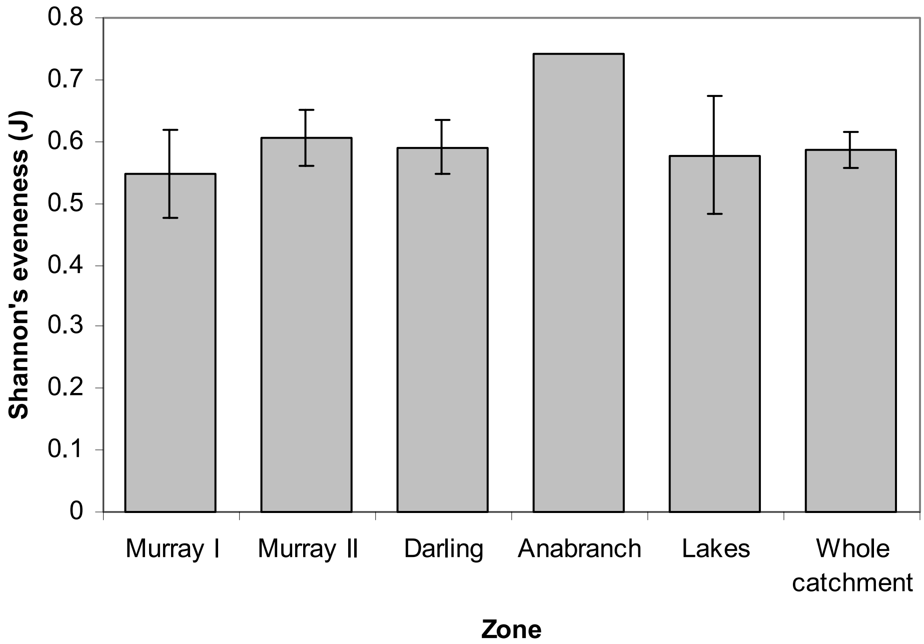


Figure 3.7. Average Shannon's evenness (*J*) at sites in each of the catchment zones and the average over the whole catchment. Error bars represent the standard error.

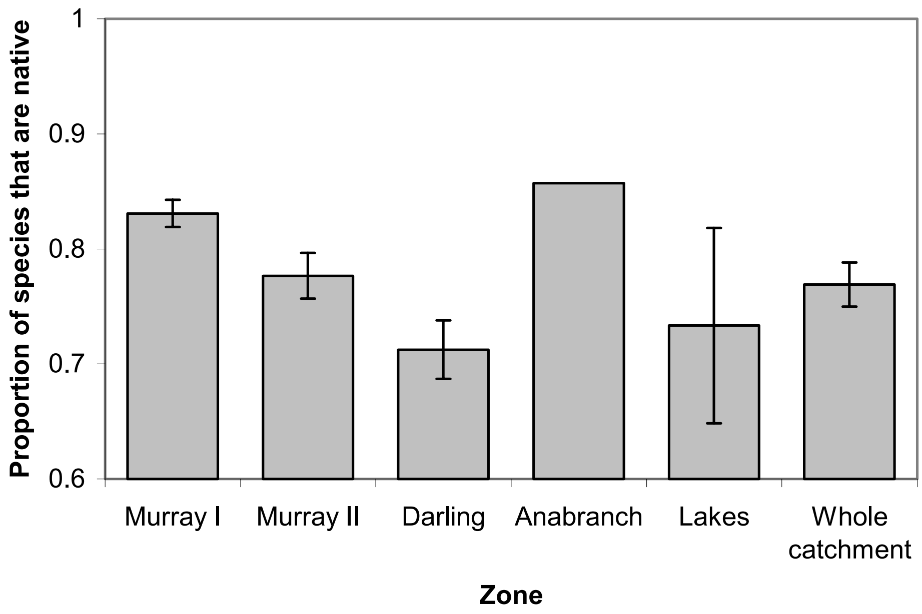


Figure 3.8. Average proportion of native species at sites in each of the catchment zones and the average over the whole catchment. Error bars represent the standard error.

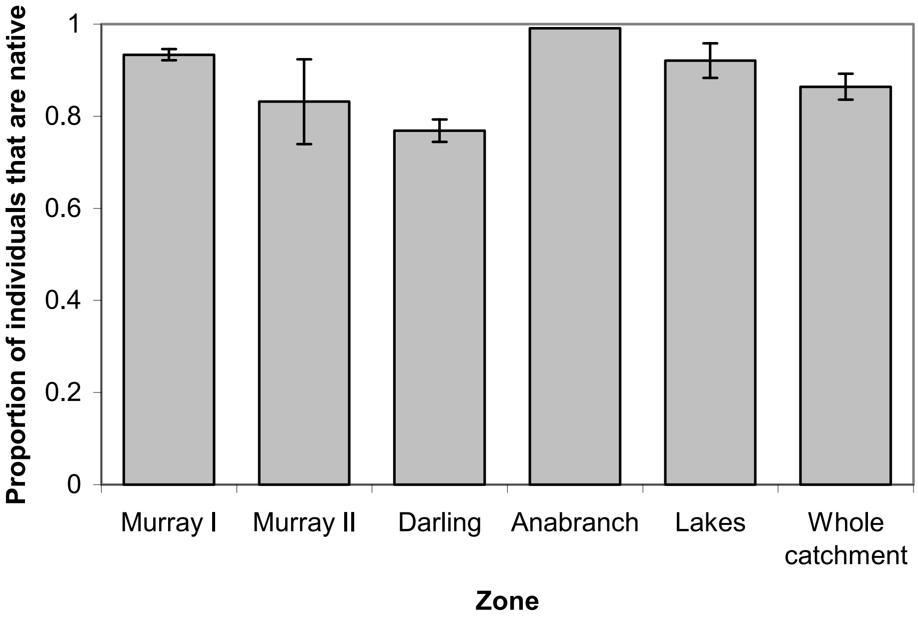


Figure 3.9. Average proportion of total number of native fish individuals at sites in each of the catchment zones and the average over the whole catchment. Error bars represent the standard error.

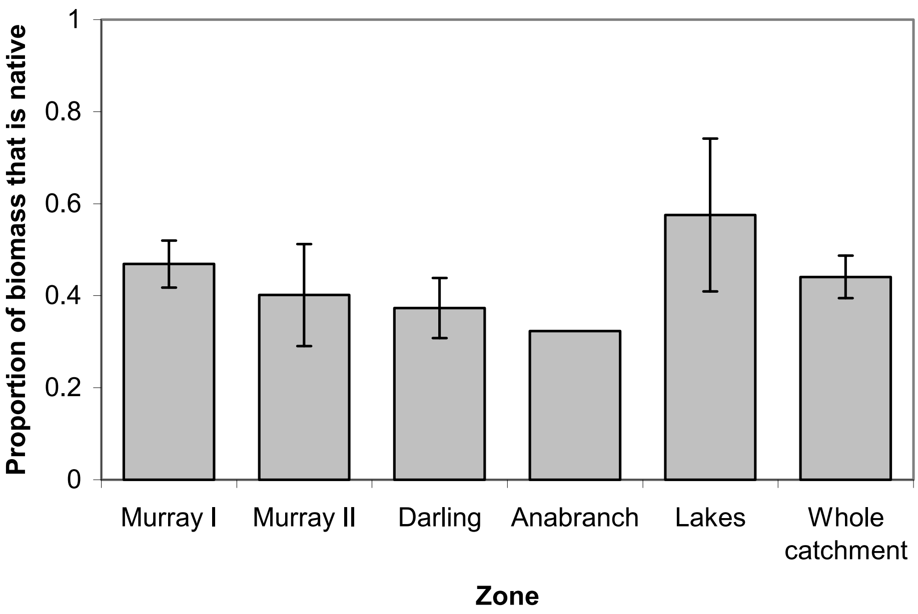


Figure 3.10. Average proportion of total biomass for native fish at sites in each of the catchment zones and the average over the whole catchment. Error bars represent the standard error.

3.3.3.6. Proportion of recruits

There were no significant differences among catchment zones (χ^2_3 = 4.32, p = 0.229) in the proportion of new recruits in the assemblage (Figure 3.11).

3.3.3.7. Proportion of individuals with a health condition

There were significant differences among catchment zones (χ^2_3 = 10.83, p = 0.013) in the proportion of individuals in the fish community that suffered an observed health condition (Figure 3.12). A higher proportion of fish in the Darling River zone were affected.

Of all the individuals sampled, 1.4% suffered a health condition (disease, parasites or injuries). Only three health conditions were observed. The parasitic copepod, *Lernaea* spp. was the most common, affecting 1.1% of all individuals, followed by wounds affecting 0.2% (hook wounds and or bird-strikes) and ulcers (usually resulting from a Lernaea) affecting 0.1%. These health conditions were only observed to affect six of the 14 species sampled: golden perch, Murray cod, carp, goldfish, bony herring and Australian smelt (Figure 3.13). Three of these species were commonly found with health conditions, with 20% of golden perch, 19% of goldfish and 17% of Murray cod affected. Less severe was carp, with 6% of individuals suffering a health condition. Bony herring and Australian smelt were little affected with only 0.1% affected (Figure 3.13). Lernaea affected goldfish the most, with 19% of individuals carrying the parasite, followed by Murray cod (17%), golden perch (13%), carp (5%) and Australian smelt (0.1%). Wounds were observed on 4% of golden perch, 1% of carp and 0.1% of bony herring. Lastly, ulcers were observed on 3% of golden perch and 0.004% of carp.

3.3.5.7 Power analyses

Power analysis indicated a range of sensitivities across the five zones analysed and among population parameters (Table 3.8). An average of ~33% change in parameters is required in order to have a high probability of detection across the whole catchment. Analyses in the Darling zone are most sensitive due to the lower variability between samples, followed by the two Murray zones and finally the Lakes & Reservoirs zone, which has the lowest sensitivity due to variation between samples. Power in the Lakes & Reservoirs would be increased by increasing the number of samples to seven (as opposed to the five sampled in this survey). No power analyses were possible for the Great Darling Anabranch zone individually due to only a single sample being collected.

A change of two species is sufficient to detect a significant change in species richness across all zones (Table 3.8). A change of between 69 and 325 individuals is required to detect a change in abundance (Table 3.8). A change of between 3 and 58 kg is required in order to detect a change in biomass (Table 3.8). Shannon's diversity index and evenness index must change by at least 0.48 and 0.27 respectively to be statistically detectable in all zones, but only 0.18 and 0.08 to be detectable across the whole catchment (Table 3.8). Changes in all three population parameters based on the proportion of native fish are detectable within all zones if the change is greater than 0.24 for the proportion of native species, 0.26 for the proportion of native abundance and 0.47 for native biomass (Table 3.8). However the detectable change across then whole catchment is much lower at only 0.05, 0.08 and 0.13 respectively for the nativeness parameters. An increase in the proportion of new recruits of between 0.15 and 0.38% is also detectable. Given the variability between sites in the proportion of individuals with a health condition, a large change of at least 100% is required in order to be statistically detectable.

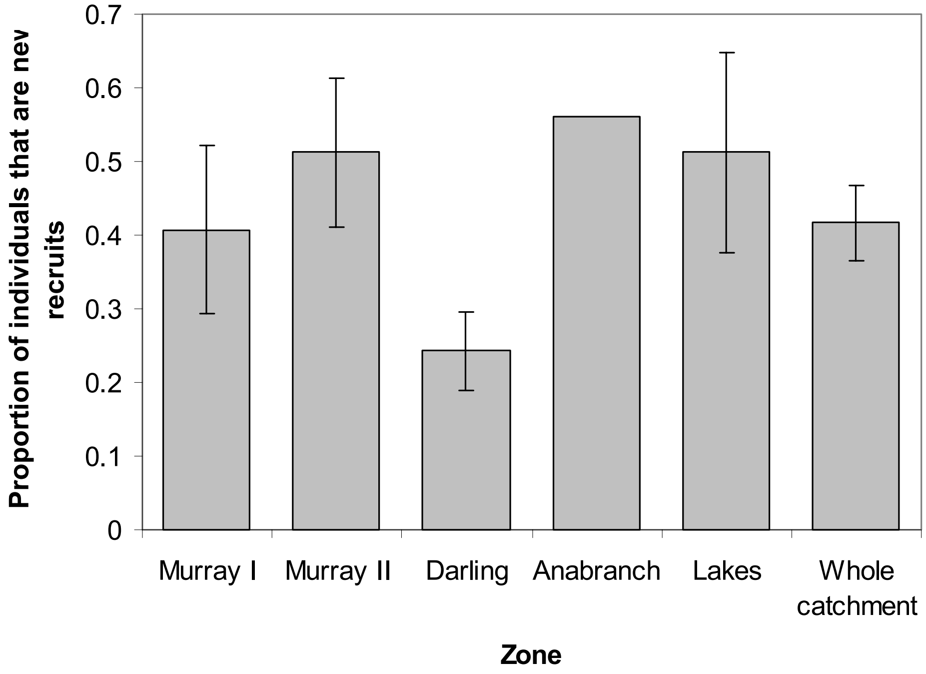


Figure 3.11. Average proportion of the total catch which are new recruits at sites in each of the catchment zones and the average over the whole catchment. Error bars represent the standard error.

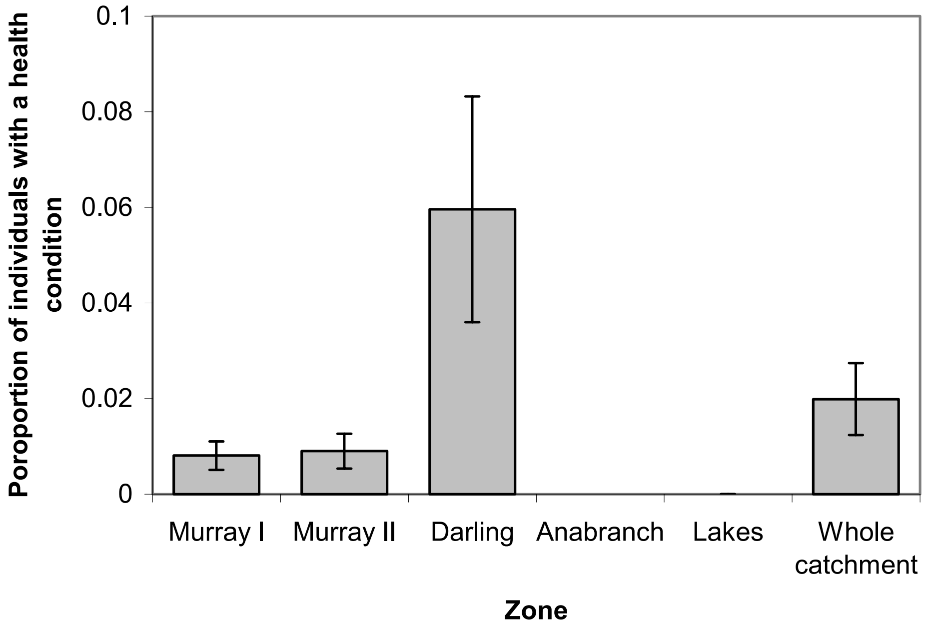


Figure 3.12. Average proportion of individuals sampled which suffered an observed health condition in each of the five catchment zones and the average over the whole catchment. Error bars represent the standard error.

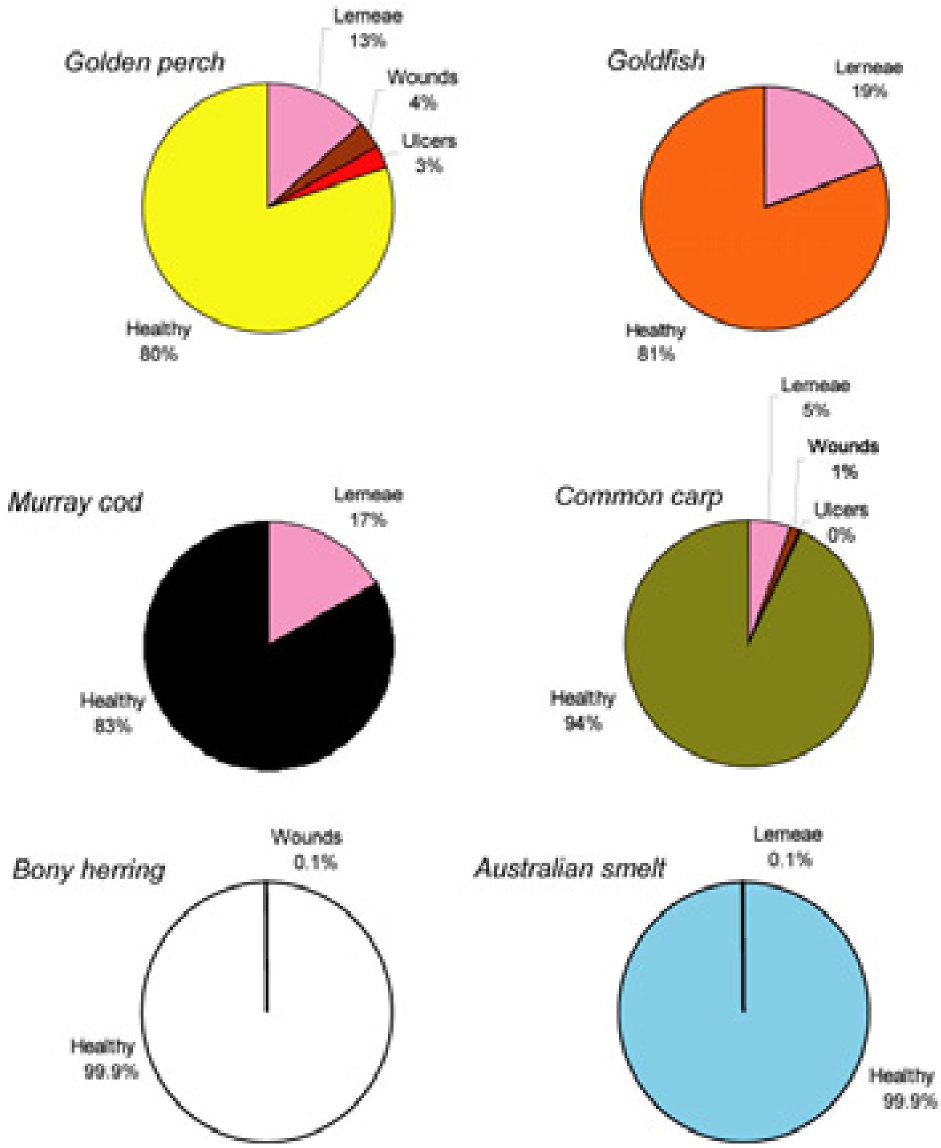


Figure 3.13. Pie charts showing the proportion of individuals with each type of health condition for the six species found to have at least one individual affected.

Table 3.8. 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 $\beta = 0.8$.

	Murray I	**Murray II**	**Darling**	**Lakes & Reservoirs**	**Whole catchment**
Species richness	± 1.6 (22%)	± 1.6 (19%)	± 1.2 (19%)	± 2.3 (58%)	± 1.1 (16%)
Total abundance (individuals)	± 197 (81%)	± 325 (84%)	± 80 (46%)	± 69 (117%)	± 115 (50%)
Total biomass (kg)	± 19.9 (60%)	± 57.7 (116%)	± 13.6 (43%)	± 3.3 (83%)	± 17.5 (57%)
Shannon's *H*	± 0.39 (36%)	± 0.23 (18%)	± 0.20 (19%)	± 0.48 (63%)	± 0.18 (17%)
Shannon's *J*	± 0.20 (36%)	± 0.13 (21%)	± 0.12 (20%)	± 0.27 (47%)	± 0.08 (14%)
Proportion native (species richness)	± 0.03 (4%)	± 0.06 (8%)	± 0.07 (10%)	± 0.24 (33%)	± 0.05 (6%)
Proportion native (abundance)	± 0.03 (3%)	± 0.26 (31%)	± 0.07 (9%)	± 0.11 (12%)	± 0.08 (9%)
Proportion native (biomass)	± 0.14 (30%)	± 0.31 (78%)	± 0.18 (49%)	± 0.47 (81%)	± 0.13 (30%)
Proportion new recruits	± 0.32 (78%)	± 0.28 (55%)	± 0.15 (63%)	± 0.38 (68%)	± 0.14 (33%)
Proportion with health condition	± 0.01 (100%)	± 0.01 (100%)	± 0.07 (117%)	NA	± 0.02 (100%)

3.4. Discussion

Following substantial sampling effort, 45% of native species and 43% of alien species known or suspected to have existed in the Lower Murray-Darling catchment were not sampled in 2004. This suggests a greater species loss in the Lower Murray-Darling than the neighbouring Murrumbidgee catchment where 38% of native species were not sampled (Gilligan 2005). It was not unexpected that many species were not found in the 2004 surveys. Despite a likely historical presence, there have never been any published records of olive perchlet, southern purple-spotted gudgeon, southern pygmy perch, or flat-headed galaxias collected from within the NSW Lower Murray-Darling catchment area. The threatened Murray hardyhead is known to exist in a small number of Victorian floodplain wetlands adjacent to the lower Murray River (Ho *et al.* 2004), but had not been recorded in the Lower Murray-Darling catchment area since 1958 (Australian Museum records). However, a single specimen has since been collected from the NSW Lower Murray River during SRA sampling in 2005 (SARDI, unpublished data). The threatened trout cod and Macquarie perch have not been recorded from the Lower Murray River since 1958 and 1988 respectively (Reid *et al.* 1997). The existence of short-headed lamprey in the catchment is temporally variable, with the last specimens recorded in the catchment area 27 years ago (Reid *et al.* 1997). The two vagrant species, Hyrtl's tandan and congoli 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. Freshwater catfish was only sampled within a stocked impoundment and no individuals were collected from riverine or natural lake populations.

Of the alien species not detected, brown trout have not been recorded for 56 years (Cadwallader 1977) and stocking of brown trout in the catchment area has not been undertaken since at least 1960 (NSW Freshwater fish stocking database). Tench has not been recorded in the Lower Murray-Darling catchment for 17 years (Reid *et al.* 1997) and spotted galaxias has only ever been recorded as a single individual (Gilligan, unpublished data).

The only unexpected absences from samples were the failure to detect the spangled perch in either the Darling River or in the Menindee Lakes, and the failure to detect dwarf flat-headed gudgeon in the Lower Murray River or Murray River wetland samples. In these cases, the lower Darling River and Menindee Lakes system approaches the southern range limit of spangled perch and the lower Murray River approaches the upstream range limit of dwarf flat-headed gudgeon (NSW Bionet: http://www.bionet.nsw.gov.au).

Aspects of the 'nativeness' (represented by the proportion of the total population that is made up of native fish) of the Lower Murray-Darling catchment are substantially better than that of the Murrumbidgee catchment. The Lower Murray-Darling had an average of 23% of the species collected per site were alien, 14% of individuals sampled were alien species and 56% of the total biomass was alien. In the neighbouring Murrumbidgee catchment, 33% of species, 71% of individuals and 90% of biomass was alien (Gilligan 2005). However, when comparing the Lower Murray-Darling data with only the lowland zone of the Murrumbidgee, the two catchments were similar for the proportion of alien species and proportion of alien individuals, with 25% of species being alien and 20% of individuals being alien species in the lowland Murrumbidgee (Gilligan 2005). However the third 'nativeness' index, the proportion of alien biomass was almost twice as high in the Lower Murray-Darling catchment (56%) than was found in the lowlands of the Murrumbidgee (30%) (Gilligan 2005).

Native fish were more widespread in the Lower Murray-Darling catchment than they were in the Murrumbidgee (Gilligan 2005). Where no native species at all were sampled from 25% of sites in the Murrumbidgee catchment (Gilligan 2005), there were no sites where no native fish existed in the Lower Murray-Darling. However alien fish were also slightly more widespread in the Lower Murray-Darling, with alien fish absent from 7% of sites in the Murrumbidgee (Gilligan 2005), but only 4% (1 site) in the Lower Murray-Darling.

Apart from fish communities within the 'Lakes & Reservoirs' zone, including the Menindee Lakes, Lake Victoria and Imperial Lake (an artificial reservoir near Broken Hill), the structure of fish communities existing throughout the catchment was quite consistent. However it was possible to detect significant differences between fish communities within each of the catchment zones analysed. The Lakes & Reservoirs sites had a consistently poorer fish community than existed in riverine sites with carp-gudgeons being the only species more abundant in the non-river sites. The lower Murray River, downstream of the Darling River junction, supported a fish community with a high proportion of small fish species such as flyspecked hardyhead, Murray-Darling rainbowfish and gudgeons. This group of small fishes (including others that are likely to be locally extinct) is the component of the fish community that has declined throughout many areas of the Murray-Darling Basin. This lower section of the Murray also had greater numbers of Murray cod, bony herring and golden perch than the remaining riverine zones. The Darling River zone differed from the upper Murray zone in having a higher abundance of goldfish, bony herring, golden perch and carp, but a lower abundance of Australian smelt, Murray-Darling rainbowfish, carp-gudgeons and flyspecked hardyhead.

The Lower Murray-Darling CMA has developed catchment blueprint targets of a 55% change in the native:alien species ratio, a 25% change in the native:alien abundance ratio and a 25% change in the native:alien biomass ratio. Data was benchmarked for the 'proportion of native' rather than a ratio, as proportions have much better statistical properties. Power analyses of the data collected indicates that statistical power exists to detect progress towards the Lower Murray –Darling CMA blueprint targets of a 55% improvement in the species ratio, and a 25% improvement in the abundance ratio. However, due to variability in biomass across the catchment, the power analysis suggest that the minimum detectable change in the biomass ratio is a 30% change, which is 5% greater than the blueprint target of 25%. Although trends in the biomass ratio can still be demonstrated, only changes greater than 30% will be statistically significant. This is not a catastrophic short-fall in either the blueprint target or in the site density for the fish monitoring program (although an additional number of sites would increase the power of the test). The biomass ratio is likely to be responsive to habitat rehabilitation, particularly for activities that promote large native species such as Murray cod, golden perch, silver perch and catfish, and reduce the number of carp. Hence improvements in the proportion of native biomass of greater than 30% could be expected. This equates to a change from 44% native biomass in 2004 to 57.2% native biomass in order to achieve a catchment target of 30% (55% if for a 25% target). Both the 25% and 30% blueprint targets encompass the important milestone of changing from an alien dominated biomass to a native dominate biomass.

Photo: Gunther Schmida (Murray-Darling rainbowfish)

4. STATUS OF INDIVIDUAL SPECIES IN THE LOWER MURRAY-DARLING CATCHMENT IN 2004

4.1. Introduction

Although assessments of fish community structure are informative for the 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 viability 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 where 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 changes in 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

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.

As only three wetland samples were collected given the prevailing drought conditions in 2004, little can be interpreted from the few data obtained.

4.3. Results and Discussion

4.3.1. Proportion of catch

The three most numerous species in the catchment were bony herring, Australian smelt and carp-gudgeons (Figure 4.1). However there was substantial variation among catchment zones (Table 4.1) with carp, eastern gambusia and Murray-Darling rainbowfish also well represented in some individual catchment zones (Table 4.1). Eastern gambusia dominated the wetland communities sampled, making up 63% of the catch in these habitats (Table 4.1).

The three rarest taxa sampled were the alien redfin perch (0.03%), the threatened silver perch (0.06%) and freshwater catfish (0.6%) (Figure 4.1).

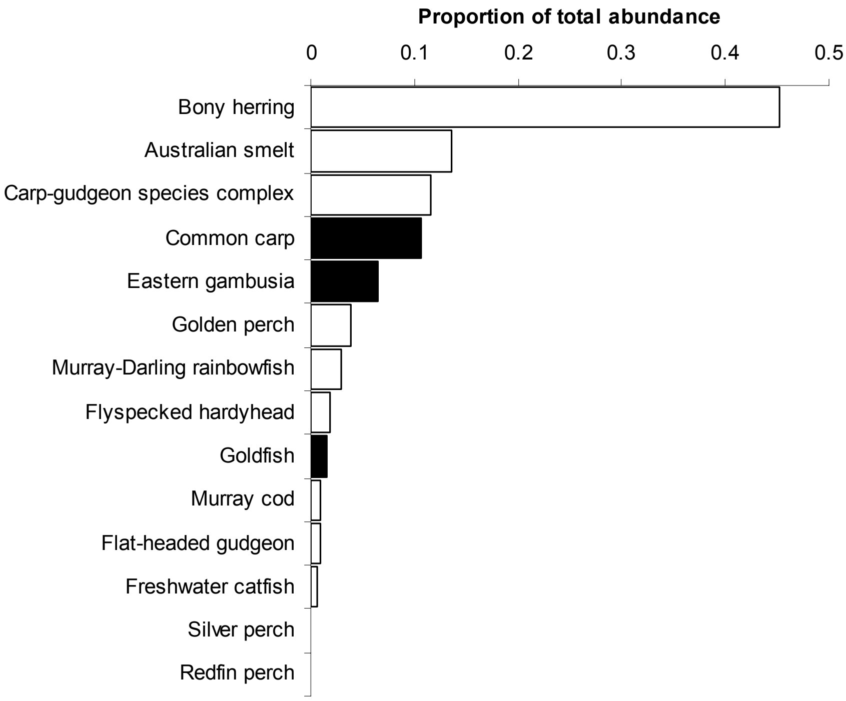


Figure 4.1. Proportions of each species of the total number of individuals sampled throughout the catchment. Black: Alien species. White: Native species.

Table 4.1. Proportion of each species of the total catch within catchment zones, wetland sites and the whole catchment. The whole catchment value was calculated for riverine sites only and excludes the wetland samples.

Catchment zone	**Murray I**	**Murray II**	**Darling**	**Great Darling Anabranch**	**Lakes & Reservoirs**	**Wetland**	**Whole catchment**	**Rank (total)**
Australian smelt	0.334	0.175	0.014	0.274	0.027	0.006	0.260	2
Bony herring	0.474	0.436	0.639	0.320	0.456	0.037	0.460	1
Carp-gudgeon species –complex	0.036	0.052	0.024	0.177	0.327	0.290	0.083	3
Common carp	0.064	0.150	0.185	0.009	0.076	0	0.073	4
Eastern gambusia	0	0.0002	0.002	0	0.004	0.632	0.001	5
Flat-headed gudgeon	0	0.021	0	0	0.023	0.004	0.008	11
Flyspecked hardyhead	0.008	0.061	0	0.006	0	0.019	0.031	8
Freshwater catfish	0	0	0	0	0.035	0	0.004	12
Golden perch	0.022	0.038	0.071	0.003	0.044	0	0.028	6
Goldfish	0.003	0.017	0.044	0	0	0	0.012	9
Murray cod	0.020	0.004	0.019	0	0	0	0.007	10
Murray-Darling rainbowfish	0.039	0.045	0.002	0.210	0.008	0.012	0.033	7
Redfin perch	0	0.001	0	0	0	0	0.001	14
Silver perch	0.001	0	0	0	0.002	0	0.0005	13

4.3.2. Proportion of biomass

Carp dominated the fish biomass of the catchment, contributing 49% of the total biomass (Figure 4.2). Carp were followed by bony herring (15%), Murray cod (12%) and golden perch (12%) (Figure 4.2). These four species together contributed 87% of the total fish biomass in the catchment. Australian smelt and carp-gudgeons, which contributed 14% and 12% of abundance, together only contributed 2.4% of the total biomass due to their small size. However, in the wetland samples, which were largely occupied by small fish, gambusia contributed 52% of the biomass (Table 4.2).

4.3.3. Proportion of sites

The most widespread species was carp occurring at 96% of sites sampled and being found in every zone (Table 4.3). Although carp were not collected from any of the three wetlands, it is known that carp frequent these habitats (Conallin *et al.* 2003; McCarthy *et al.* 2003; Ho *et al.* 2004; Ellis and Suitor 2004; Ellis and Meredith 2005). The methods used to sample wetlands in this survey were not appropriate for sampling most large bodied species of fish such as adult carp, although they were suitable for sampling juvenile carp if present in the wetlands sampled. The next most widespread species was bony herring occurring at 93% of sites (Table 4.3). Golden perch and Australian smelt were both found at 81% of sites.

The least widespread species were: redfin perch and freshwater catfish, both being found at only a one site (Table 4.3). The single site at which freshwater catfish were sampled was a stocked artificial waterbody. The third least widespread species was silver perch, which were only found at three sites.

4.3.4. Proportion recruits

Recruits were found for all species except golden perch, freshwater catfish and redfin perch and made up to 42% of the fish community across the catchment (Figure 3.11). New recruits made up 25% or more of the sampled populations of nine fish species: carp-gudgeon (94%), flyspecked hardyhead (76%), flat-headed gudgeon (75%), Australian smelt (70%), Murray-Darling rainbowfish (62%), bony herring (42%), Murray cod (29%) and silver perch (25%) (Table 4.4).

Carp-gudgeon recruits were found in all five catchment zones (and in the three sampled wetlands) and dominated carp-gudgeon populations throughout the catchment. Fly-specked hardyhead recruits were much more prominent in wetlands than in riverine sites (Table 4.4). They were also more abundant in the Murray II zone than in the Murray I zone. Flat-headed gudgeon recruits were common in both the Murray II zone and in wetland sites. Australian smelt recruits were found in all catchment zones, except the ‘Lakes & Reservoirs’. They were most abundant in the Murray II zone, and were more abundant in the Darling and Great Darling Anabranch than in the Murray I zone or wetland sites (Table 4.4). Similarly, Murray-Darling rainbowfish recruits were most abundant in the Murray II zone but were found in all zones except the Lakes & Reservoirs. Bony herring recruits were found in all zones but comprised a higher proportion of the population in the Murray II zone. Murray cod recruits were only found in the Murray II and Darling zones. In contrast, to most other species, silver perch recruits were only found in the Murray I zone.

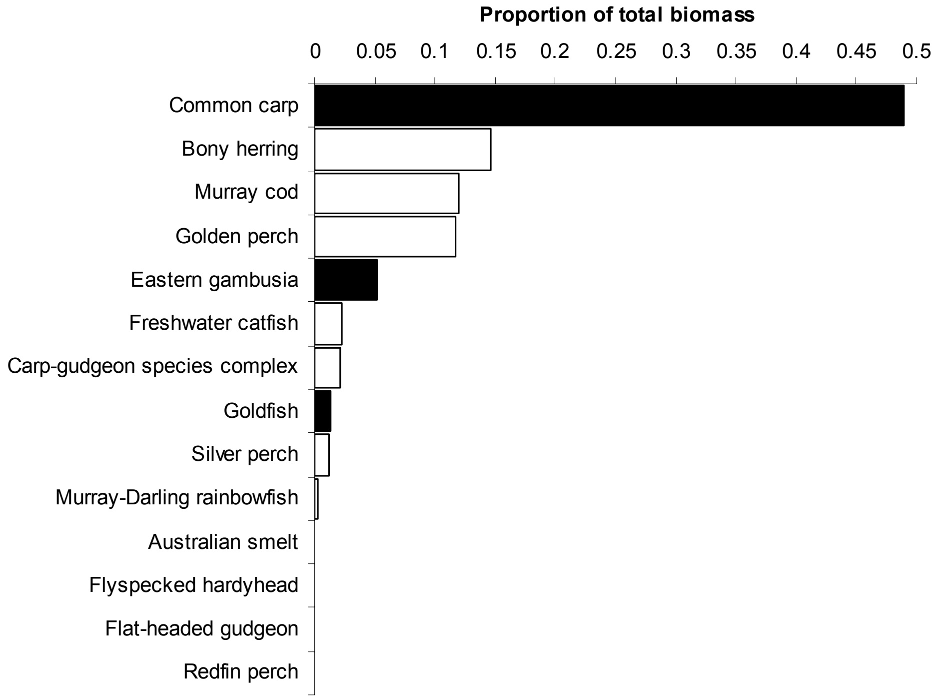


Figure 4.2. Proportions of each species of the total biomass sampled throughout the catchment. Black: Alien species. White: Native species.

Table 4.2. Proportion of each species of the total biomass within catchment zones, wetland sites and the whole catchment. The whole catchment value was calculated for riverine sites only and excludes the wetland samples.

Catchment zone	**Murray I**	**Murray II**	**Darling**	**Great Darling Anabranch**	**Lakes & Reservoirs**	**Wetland**	**Whole catchment**	**Rank (total)**
Australian smelt	0.002	0.0008	0.00006	0.004	0.0002	0.009	0.002	11
Bony herring	0.099	0.077	0.132	0.271	0.259	0.227	0.147	2
Carp-gudgeon species –complex	0.0001	0.0003	0.00004	0.001	0.001	0.215	0.022	7
Common carp	0.523	0.583	0.592	0.677	0.425	0	0.490	1
Eastern gambusia	0	0.0000008	0.000002	0	0.00002	0.515	0.052	5
Flat-headed gudgeon	0	0.0004	0	0	0.0001	0.004	0.0005	13
Flyspecked hardyhead	0.00005	0.0003	0	0.0002	0	0.006	0.001	12
Freshwater catfish	0	0	0	0	0.133	0	0.022	6
Golden perch	0.121	0.182	0.111	0.040	0.116	0	0.117	4
Goldfish	0.008	0.014	0.035	0	0	0	0.013	8
Murray cod	0.244	0.140	0.129	0	0	0	0.120	3
Murray-Darling rainbowfish	0.0002	0.0005	0.00001	0.007	0.0001	0.024	0.003	10
Redfin perch	0	0.001	0	0	0	0	0.0003	14
Silver perch	0.004	0	0	0	0.067	0	0.012	9

Table 4.3. Proportion of sites within catchment zones, wetland sites and the whole catchment at which each species was sampled. The whole catchment value was calculated for riverine sites only and excludes the wetland sample.

Catchment zone	Murray I	Murray II	Darling	Great Darling Anabranch	Lakes & Reservoirs	Wetland	Whole catchment	Rank (total)
Australian smelt	1	0.86	0.86	1	0.4	0.67	0.89	3.5
Bony herring	1	1	1	1	0.6	0.33	0.96	2
Carp-gudgeon species –complex	0.71	0.86	0.71	1	0.8	1	0.89	5
Common carp	1	1	1	1	0.8	0	0.96	1
Eastern gambusia	0	0.14	0.14	0	0.2	1	0.22	11.5
Flat-headed gudgeon	0	0.71	0	0	0.2	0.33	0.26	10
Flyspecked hardyhead	0.57	0.571	0	1	0	0.33	0.37	9
Freshwater catfish	0	0	0	0	0.2	0	0.04	13.5
Golden perch	0.86	1	1	1	0.2	0	0.81	3.5
Goldfish	0.29	0.57	0.71	0	0	0	0.41	8
Murray cod	0.86	0.57	0.71	0	0	0	0.56	7
Murray-Darling rainbowfish	0.86	1	0.14	1	0.4	0.33	0.67	6
Redfin perch	0	0.14	0	0	0	0	0.04	13.5
Silver perch	0.29	0	0.	0	0.2	0	0.11	11.5

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 catchment zones, wetland sites and the whole catchment at which each species was sampled. The whole catchment value was calculated for riverine sites only and excludes the wetland samples.

Catchment zone	Murray I	Murray II	Darling	Great Darling Anabranch	Lakes & Reservoirs	Wetland	Whole catchment	Rank (total)
Australian smelt	0.55	0.89	0.68	0.63	0	0.56	0.71	4
Bony herring	0.41	0.69	0.22	0.18	0.35	0.28	0.45	6
Carp-gudgeon species – complex	0.85	0.95	0.93	0.97	0.97	0.92	0.94	1
Common carp	0	0.09	0.30	0	0.33		0.20	10
Eastern gambusia		0	0.66		0	0.06	0.33	11
Flat-headed gudgeon		0.74				0.86	0.74	3
Flyspecked hardyhead	0.46	0.76				0.93	0.69	2
Freshwater catfish					0		0.00	13
Golden perch	0	0	0	0	0		0.00	13
Goldfish	0	0.36	0.26				0.24	9
Murray cod	0	0.38	0.36				0.29	7
Murray-Darling rainbowfish	0.58	0.68	0.50	0.51	0	0.63	0.62	5
Redfin perch		0					0.00	13
Silver perch	0.5				0		0.25	8

Photo: Gunther Schmida (carp-gudgeon)

5. TRENDS IN FISH COMMUNITIES AND FISH SPECIES IN THE LOWER MURRAY-DARLING CATCHMENT FROM 1994 – 2005: ANALYSIS OF STANDARDISED ELECTROFISHING DATA

5.1. Introduction

Ongoing sampling using a consistent standardised sampling methodology that 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). 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).

In 1976, Llewellyn undertook the first broad-scale survey of fish populations throughout NSW, including four sites in the Lower Murray-Darling catchment (Llewellyn 1983). The methods used in Llewellyn's 1976 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.

Coincident with the development of this Lower Murray-Darling CMA 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*b*). Although the fish sampling protocol developed for this program varies slightly from that used initially in NSW, the electrofishing procedures are comparable with the original NSW protocol after standardisation to catch-per-unit-effort (fish per hour). 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.

5.2. Methods

5.2.1. Data

To qualify for inclusion in these analyses, individual sites must have been sampled using the same standardised method over at least four years, which is the minimum number of data points required for statistical correlation. Data from only four sites were available: Downham Farm (sampled 9 times between: 1994-2005), Pooncarie (8: 1994-2005), Carina bend (4: 1998-2005) and Upper Kulnine (5: 1998-2005). All these sites were re-sampled in 2004 as part of this survey as well as in 2005 as part of the full implementation of the SRA program. Site coordinates are provided in Table 2.1.

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.

5.2.2. Data analysis

Meta-analysis is a means of combining the results of multiple tests of the same hypothesis. The analytical process includes testing the uniformity of responses amongst tests and the outputs represent a quantifiable means of assessing the weight of evidence. In this case, correlation of a fish community parameter or data from an individual species with time at any one sampling site represents an individual test of the hypothesis on no change in abundance etc. Combining the data from multiple sites gives a catchment wide assessment of the 'general' trend.

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. A significant positive correlation indicates increasing abundance and a significant negative correlation indicates a decline.

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 and then as individual sites if necessary.

5.3. Results

5.3.1. Fish community parameters

There was significant variance in trends in species richness across the four sites (Table 5.1). The Downham farm site, which has experienced a non-significant decline in species richness ($r = -0.601$, $p = 0.141$) was inconsistent with the other three sites that experienced a consistent significant increase in species richness ($r = 0.360$, $p = 0.006$) (Table 5.1). There were no significant trends in total abundance or total biomass (Table 5.1).

There were no significant trends for Shannon's diversity or evenness indices, or the proportion of native species (species richness), native abundance or native biomass (Table 5.1). However the trends for all these parameters were consistent across the four sites analysed (Table 5.1).

Of the health conditions observed during sampling (anchor worm (*Lernaea* spp.), wounds, ulcers, fin damage and deformities), only the proportion of individuals parasitised by anchor worm has changed, with a consistent significant increase between 1994 and 2005 (r = 0.658, p = 0.008) (Table 5.1).

Table 5.1. Meta-analysis output of trends in the fish community parameters across long-term monitoring sites (4) in the Lower Murray-Darling 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 $\alpha = 0.05$. 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.

	Fisher's Z ± SE	***z*-score**	***p* value**	**Q (df)**	***p* value**
Species richness	0.442 ± 0.508	0.870	0.384	9.035 (3)	0.029
Downham Farm (Darling)	-0.601 ± 0.408	-1.472	0.141		
Remainder (Murray & Darling)	0.878 ± 0.354	2.482	0.013	1.538 (2)	0.463
Total abundance	0.208 ± 0.267	0.777	0.437	0.485 (3)	0.922
Total biomass	-0.018 ± 0.267	-0.066	0.947	0.634 (3)	0.888
Shannon's *H*	-0.093± 0.267	-0.350	0.726	0.829 (3)	0.842
Shannon's *J*	-0.222 ± 0.267	-0.830	0.407	1.791 (3)	0.617
Proportion native (species richness)	0.157 ± 0.274	0.573	0.567	3.099 (3)	0.377
Proportion native (abundance)	0.117 ± 0.267	0.439	0.661	0.250 (3)	0.969
Proportion native (biomass)	-0.586 ± 0.367	-1.595	0.111	4.899 (3)	0.179
Proportion of fish with anchor worm	0.789 ± 0.297	2.660	0.008	3.472 (3)	0.324
Proportion of fish with ulcers	0.212 ± 0.267	0.795	0.427	0.967 (3)	0.809
Proportion of fish with wounds	0.743 ± 0.479	1.551	0.121	2.510 (1)	0.113
Proportion of fish with fin damage	0.450 ± 0.302	1.494	0.135	0.358 (1)	0.550
Proportion of fish with deformities	0.000 ± 0.700	0.000	1.000		

5.3.2. Individual species

Carp-gudgeons, Murray cod and Australian smelt have all significantly increased in abundance over the last decade in at least some parts of the catchment (Table 5.2). Carp-gudgeons have increased consistently in abundance since 1994 across all three of the long-term sites where they have been sampled (r = 0.639, p = 0.032) (Table 5.2). In contrast, Murray cod have increased significantly at Pooncarie on the Darling River (r = 0.791, p = 0.016), but the relationship was not consistent throughout the basin, with consistent (Q_2 = 0.348, p = 0.840) but non-significant declines at the remaining three sites (r = -0.550, p = 0.064) (Table 5.2). Lastly, Australian smelt have increased consistently and significantly in abundance in the Murray sites (r = 0.987, p = 0.029) (Table 5.2) but the trends were inconsistent at the two Darling River sites, with a non-significant decline at Downham farm and a non-significant increase at Pooncarie (Table 5.2). Of the remaining six native species for which analyses were possible (sampled at least one of the long-term monitoring sites), five species showed increasing (but non-significant) trends in abundance and only one species, golden perch, showed a decreasing (but non-significant) trend (Table 5.2).

Although the overall trend for carp was a non-significant decline in abundance (r = -0.575, p = 0.356), the relationship was inconsistent among the four long-term monitoring sites (Q_3 = 17.872, p = < 0.001) (Table 5.2). At Carina Bend there has been a significant decline in carp abundance over the last decade (r = -0.999, p <0.001) whilst the abundance of carp has experienced a consistent non-significant increase (r = 0.180, p = 0.600) at the remaining three sites (Table 5.2). Of the remaining alien species sampled at the four long-term monitoring sites, goldfish, goldfish-carp hybrids and eastern gambusia, have all experienced a non-significant increase in abundance (Table 5.2).

Table 5.2. Meta-analysis output of trends in the abundance of each species across long-term monitoring sites in the Lower Murray-Darling 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 are the mean ± standard deviation of all correlations for each species (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.

Species	Fisher's Z ± SE	*z*-score	*p* value	Q (df)	*p* value
Native species					
Australian smelt	1.17 ± 0.63	1.846	0.065	14.121 (3)	0.003
Downham Farm (Darling)	-0.02 ± 0.41	-0.042	0.967		
Pooncarie (Darling)	0.46 ± 0.45	1.032	0.302		
Carina Bend & Upper Kulnine (Murray)	2.25 ± 0.58	3.894	< 0.001	3.613 (1)	0.057
Bony herring	0.17 ± 0.27	0.648	0.517	0.657 (3)	0.883
Carp-gudgeon species complex	0.76 ± 0.35	2.412	0.032	0.420 (2)	0.810
Flat-headed gudgeon	0.88	1.246	0.213		
Flyspecked hardyhead	0.92 ± 0.70	1.319	0.187	1.387 (1)	0.239
Golden perch	-0.66 ± 0.39	-1.675	0.094	5.492 (3)	0.139
Murray cod	-0.13 ± 0.52	-0.250	0.802	9.556 (3)	0.023
Pooncarie (Darling)	1.07 ± 0.45	2.402	0.016		
Remainder (Murray & Darling)	-0.62 ± 0.33	-1.855	0.064	0.348 (2)	0.840
Murray-Darling rainbowfish	0.29 ± 0.29	1.014	0.311	3.305 (3)	0.347
Silver perch	0.42	0.42	0.673		
Alien species					
Common carp	-0.66 ± 0.71	-0.923	0.356	23.028 (11)	0.018
Carina Bend (Murray)	-3.80 ± 1.00	-3.800	< 0.001		
Remainder (Murray & Darling)	0.219 ± 0.28	0.753	0.451	2.947 (2)	0.229
Carp/Goldfish hybrids	0.66	1.472	0.141		
Goldfish	0.15 ± 0.38	0.403	0.687	5.205 (3)	0.157
Eastern gambusia	0.72 ± 0.41	1.765	0.078	0.116 (1)	0.733

5.4. Discussion

Analysis of data collected from the Lower Murray-Darling catchment over the last 11 years indicates several significant changes. The number of species sampled at sites has increased at three of the four long-term monitoring sites analysed. The proportion of fish parasitised by the parasitic copepod, anchor worm (*Lernaea* spp.) has increased significantly across the catchment. The abundance of carp-gudgeons has increased consistently. The abundance of Murray cod has increased at one site in the Darling River (Pooncarie), but a similar increase was not observed at the remaining sites. The abundance of Australian smelt has increased at both Murray River sites but not in either of the Darling River sites. And carp have declined at one site in the Murray River but not at the remaining three sites across the catchment.

The observed increase in species richness at three of the four sites over the last 11 years is counter to the local extinction of several threatened species that occurred in the catchment decades earlier. The observed relationship could result from either the continued spread of alien species, which is a negative effect, or the increasing abundance of less common native species, which is a positive change. The alien oriental weatherloach (*Misgurnus anguillicaudatus*) present in the Murray Riverina catchment, will inevitably invade the Lower Murray River. However there is no evidence that they have done so yet. Further, although a single spotted galaxias larva was collected at the Upper Kulnine site in 2002, no large population of spotted galaxias appears to have established in the Murray River. Therefore, there is no evidence to suggest that the increase in species richness has been driven by increasing numbers of alien fish species at sites in the Lower Murray-Darling over the last decade. The alternative mechanism of increasing populations of formerly less common native species (as at 1994) is much more likely to have occurred given that the abundance of eight of the nine species analysed have increased in at least some parts of the catchment (although not all increases were statistically significant). This relationship was also observed in the neighbouring Murrumbidgee catchment (Gilligan 2005).

Although alien fish species were reasonably abundant and widespread throughout the catchment, no significant trends were detected in the proportion of alien species richness, proportion of abundance that was alien species or proportion of alien biomass. This is indicative of some level of stability in the system and suggests that alien species may have reached equilibrium within fish communities.

The increasing proportion of fish affected by the ectoparasitic copepod, anchor worm (*Lernaea* spp.) (see Rowland and Ingram 1991) (Figure 5.1), was a consistent trend observed across the four long-term monitoring sites analysed. Anchor worms progress through three free-swimming nauplius stages before entering the gill cavity of fish as copepodids and feeding on gill mucus (Rowland and Ingram 1991). Sexual maturity is reached at the fifth copepodid stage when females are fertilised and move to the skin of the host. The females head then becomes modified into an anchor shape, which is buried into the skin and secures the parasite. The site of attachment often becomes infected with fungi or bacteria after the female *Lernaea* detaches from the host and often results in a ulcer at the point of attachment. Heavy infestations of anchor worm cause lethargy and emaciation, and have caused failure to spawn in Murray cod broodfish in hatcheries (Rowland and Ingram 1991). Common carp have been suggested as a potential vector for the spread of anchor worm within native fish (Rowland and Ingram 1991). Little is understood regarding the relationships of anchor worm burdens with the 'health' of individual hosts, but increasing parasite loads are indicative of some level of stress within the environment (Wedemeyer *et al.* 1976).

Only four species showed clear trends in abundance over the last 11 years. Carp-gudgeons were the only species whose population size has changed with a consistent increase throughout the catchment. This increase is more widespread than just the NSW Lower Murray-Darling catchment, with the same relationship observed in the Murrumbidgee (Gilligan 2005). Although Murray cod and Australian smelt abundance had increased significantly at some sites, non-significant declines in abundance were observed at other sites within the catchment. All other native species, apart from golden perch, experienced widespread but non-significant increases in abundance over the last 11 years. The alien species, goldfish and gambusia also experienced consistent but non-significant increases in abundance.

Golden perch were the only species exhibiting a consistent decline across the catchment although the trend was not significant.

The carp population at Carina Bend in the Murray I zone was found to have declined significantly, yet the trend was for increasing carp populations at the remaining three sites analysed. The decline in carp populations at, at least one site, is consistent with the observations of recreational fishers who have increasingly claimed a decline in carp numbers in the Murray River.

Figure 5.1. *a*) Catfish parasitised by numerous adult female anchor worm (*Lernaea* spp.)(photo: http://www.fisheries.org), and *b*) a close up photo of an adult female *Lernaea* (photo: http://www.heems.nl/arob0409.htm).

Photo: Ian Wooden (Commercial fisherman clearing drum nets)

6. TRENDS IN THE HARVEST OF FISH SPECIES FROM THE LOWER MURRAY-DARLING CATCHMENT BETWEEN 1955 AND 2001: THE INLAND COMMERCIAL FISHERY

6.1. Introduction

Commercial fisheries had received criticism for its perceived role in depleting stocks of native fish 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 was 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.

Details of the inland fishery in NSW had been recorded since 1880, but a large number of records have been lost or were destroyed in a warehouse fire in the 1980's (Pease and Grinberg 1995). Only those from 1955 until the closure of the inland commercial fishery in September 2001 are available for the Lower Murray-Darling fisheries: Darling River, Anabranch River, Menindee Lakes (general), Lake Cawndilla, Lake Tandure, Lake Menindee, Lake Pamamaroo, Lake Bijiji, Anabranch lakes, Speculation Lake, Lake Teryaweynya, Lake Balaka, Kangaroo Lake, Lake Victoria, Lower Murray, Frenchman's Creek, Murrumbidgee Riverina, Lake Benanee, Dry Lake, Murray River (Darling junction to Murrumbidgee). Reid *et al.* (1997) collated fishery records, which exist from 1883 onwards for all of NSW, up until the 1994/95 season. Although coverage and accuracy of the data were poor until compulsory fishers' returns were introduced in 1947. This report completes the data-set for the Lower Murray-Darling catchment up until the closure of the native fishery in 2001.

6.2. Data analysis

The commercial fishery dataset has some limitations that must be taken into consideration (Pease and Grinberg, 1995; Reid *et al.* 1997). Firstly, only species of interest to commercial fisherman were recorded consistently and only marketable species were recorded at all. Between 1970 and 1977, golden perch, carp (which also included goldfish), eels (which probably comprised mostly lampreys in the Murray-Darling Basin fishery), redfin perch, freshwater catfish, Macquarie perch, Murray cod/trout cod, silver perch and tench were recorded consistently (see Pease and Grinberg (1995) for copies of the forms). The remainder of the catch were classified as 'other species'. After 1977, eels were relegated to the 'other species' category and trout cod were removed from the form (presumably due to the lack of a viable fishery) (Pease and Grinberg 1995). In 1990, Macquarie perch and tench were also removed from the form and therefore relegated to the 'other species' category (Pease and Grinberg 1995). However the revised 1990 forms required that identity of species put in the 'other species' category be specified. Therefore, the datasets for all but golden perch, redfin perch, freshwater catfish and silver perch may be either incomplete or consist of two taxa (for carp/goldfish and Murray cod/trout cod). Secondly, effort (fisher days) was not recorded until 1977 and therefore the commercial catch cannot be standardised to fishing effort prior to that time. As a result, it is impossible to determine whether fluctuations in the commercial catch data are due to changes in fish populations or changes in fishing effort (Pease and Grinberg 1995). And lastly, prior to 1978/79, a majority of data returns did not distinguish between catches from the Lower Murray and Murray Riverina fisheries, recording the data as Murray River (general). Therefore, it is impossible to accurately document the volume of the Murray component of the fishery within the Lower Murray-Darling CMA catchment area without either including the data from the Murray Riverina (upstream of the Lower Murray-Darling catchment boundary), or omitting data potentially collected from the lower Murray River.

Despite the limitations applying to the pre-1977 fishery, all commercial fishery data collected since 1977 documents the species captured (but still excludes non-marketable species) and enables standardisation to catch-per-unit-effort. Therefore, from 1977 it is possible to interpret commercial fishery data as an assessment of the status of fish stocks for a limited number of marketable species.

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). Methods used included haul netting, drum netting, gill netting, eel traps and set-lines.

Data of the Lower Murray-Darling commercial fishery (registered as: Darling River, Anabranch River, Menindee Lakes (general), Lake Cawndilla, Lake Tandure, Lake Menindee, Lake Pamamaroo, Lake Bijiji, Anabranch lakes, Speculation Lake, Lake Teryaweynya, Lake Balaka, Kangaroo Lake, Lake Victoria, Lower Murray, Frenchman's Creek, Murrumbidgee Riverina, Lake Benanee, Dry Lake, Murray River (Darling junction to Murrumbidgee) from 1955 to 1994 were extracted from Appendix 2(b) of Reid *et al.* (1997). Data from all registered commercial fishing zones within the catchment were combined into one of three categories; i) the Darling fisheries (including the Great Darling Anabranch, Anabranch Lakes, all the Menindee Lakes and Lake Teryaweynya), ii) the Lower Murray fisheries (including Lake Victoria and Frenchman's Creek), and iii) the Murray river (general) fishery. The Murray River (general) fishery is presented separately as it may contain catches from the Murray Riverina as well as the Lower Murray. Remaining data from 1995 to the close of the fishery in 2001 are unpublished and were accessed directly from the NSW Fisheries Comcatch database.

To enable inclusion of all available data, two data sets were used. The first includes all available data, but is not standardised by any effort information and should therefore be interpreted with caution. The second includes only catch data for which effort information was available and is presented as catch-per-unit-effort (kilograms per day fished) and is more readily interpretable as an assessment of the status of fish stocks.

Standardised catch-per-unit-effort data was correlated with year to assess the statistical significance of changes occurring since 1984.

6.3. Results and Discussion

The total catch of each species across the entire Lower Murray-Darling CMA catchment area is presented in Figure 6.1. This figure presents the complete catch from 1955 through until 2001. However since 1973, the greatest annual catch has consistently been carp. The declining level of fishing effort in the three fisheries since 1984, when effort was routinely recorded on monthly catch return forms is presented in Figure 6.2.

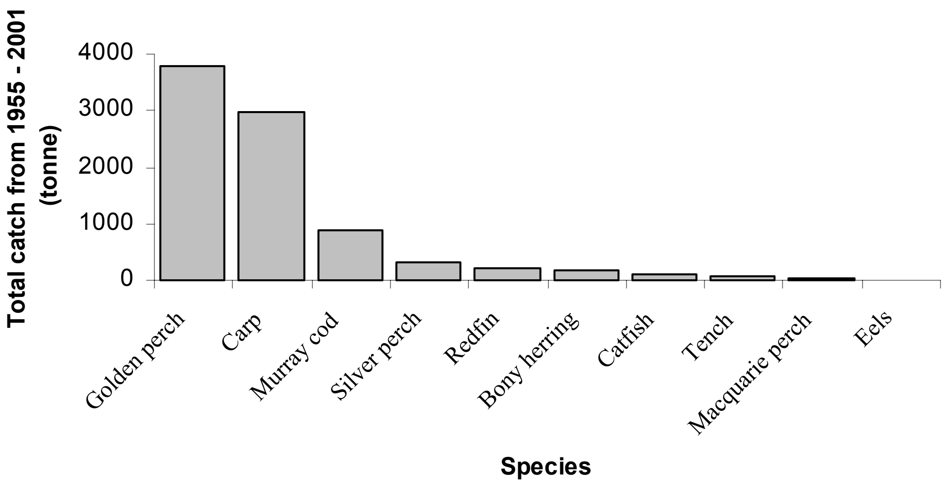


Figure 6.1. Total tonnage of each species harvested from the Lower Murray-Darling catchment area from 1955 to 2001.

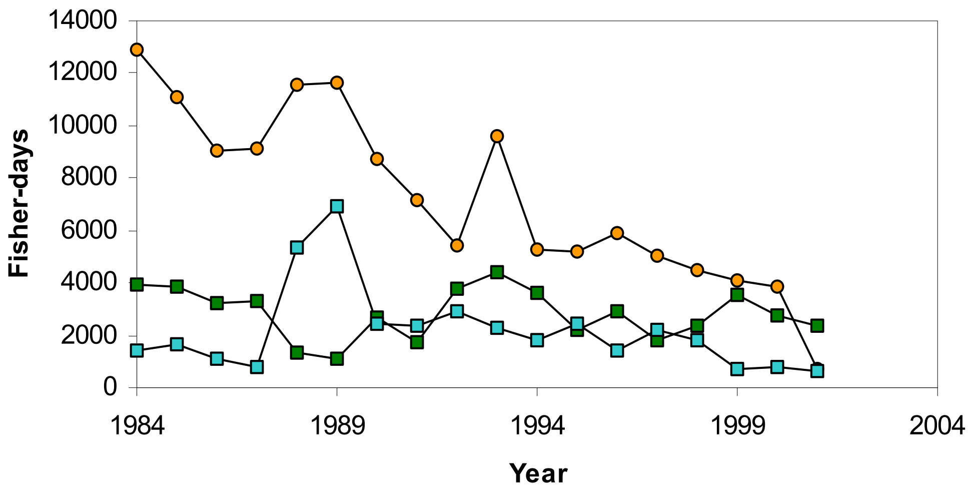


Figure 6.2. The level of commercial fishing effort applied to the Darling fisheries (orange), Murray fisheries (green) and Murray River (general) (blue) fisheries between 1984 and the close of the commercial fishery in 2001.

6.3.1. Golden perch

Golden perch were the most heavily harvested species from the Lower Murray-Darling catchment. The highest catch recorded within the catchment was within the Murray River (general) fishery during the first year on record in 1955 (Figure 6.3). The catch declined during the 60's and was lowest during the late 60's and early 70's before peaking again in the mid 70's and early 90's (Figure 6.3). The pattern in the Darling fishery was very different, with relatively consistent catches since the early 70's (Figure 6.3).

Data standardised by fishing effort since 1984 suggests significant increases in the golden perch stocks of both the Darling ($p = 0.03$) and Murray River (general) ($p = 0.04$) fisheries between 1984 and 2001, but not in the Murray fishery (Figure 6.4).

6.3.2. Carp

Carp are the second most harvested species in the Lower Murray-Darling catchment (Figure 6.1). However, a bulk of the harvest has occurred since the early 1970's when the tonnage of carp harvested became greater than that of golden perch. Small catches of carp (probably goldfish) were recorded in the Lower Murray-Darling catchment prior to 1970/71 (Figure 6.5). However, it was not until after the colonisation of the Murray River by Boolarra strain carp (discovered in Lake Hawthorn, near Mildura, in 1964/65) that carp numbers increased significantly (Koehn *et al.* 2000). An increase in the annual carp catch from 33 tonnes to 117 tonnes between 1972/73 and 1973/74 (Figure 6.5) corresponds with the high flows that occurred those years (http://www.mdbc.gov.au/education/encyclopedia/surface_water/surface_water_resources.htm). Carp populations increased rapidly in the Lower Murray, reaching a peak in 1977/78 (Figure 6.5). The population then declined until 1988/89 and has remained relatively stable since that time. Carp did not colonise the Darling until 1973/74, reaching their peak in abundance in the Darling in 1983/84 (Figure 6.5). They then began to decline in abundance until a second short-term peak in the catch occurred in 1993/94 (Figure 6.5).

Although there was an increasing trend in the commercial catches (kg per day) between 1984 and 2001, the trend was not significant in either the Darling ($p = 0.22$) or Murray ($p = 0.40$) fisheries (Figure 6.6).

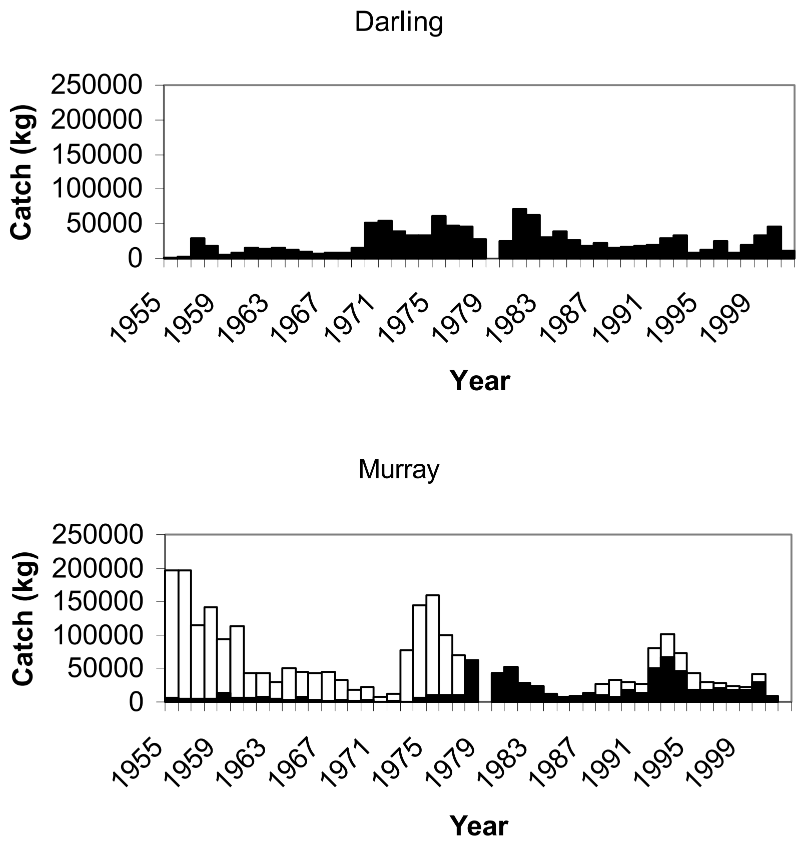


Figure 6.3. Raw commercial catch data for Golden perch in the Darling and Murray fisheries of the Lower Murray-Darling catchment. The white portion of the bars in the Murray represents the catch from the Murray River (general) fishery, which may include catch data from the Murray-Riverina fishery upstream of the Lower Murray-Darling catchment area.

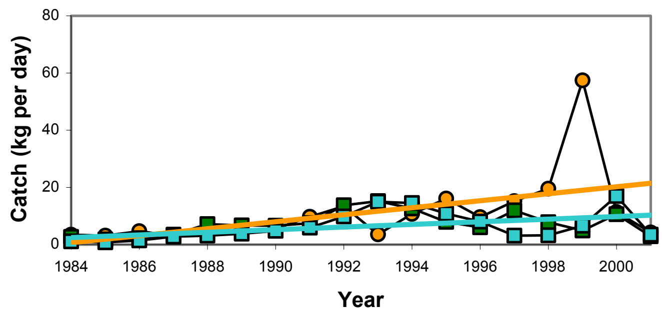
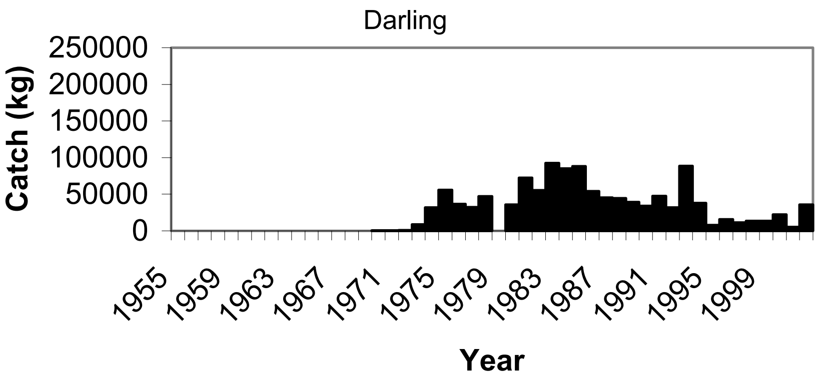


Figure 6.4. Commercial catch data for golden perch standardised by fishing effort (fisher-days) for the Darling (orange) and Murray (green) fisheries of the Lower Murray-Darling catchment. The Murray River (general) fishery (blue) may include data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area. The trendlines represent the lines-of-best fit reflecting significant growth in the golden perch stocks of the Darling (orange) and Murray River (general) (blue) fisheries between 1984 and 2001.



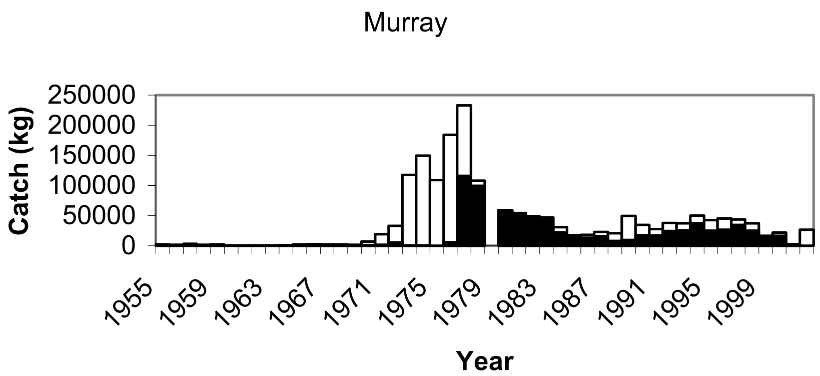


Figure 6.5. Raw commercial catch data for carp in the Darling and Murray fisheries of the Lower Murray-Darling catchment. The white portion of the bars in the Murray represents the catch from the Murray River (general) fishery, which may include catch data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area.

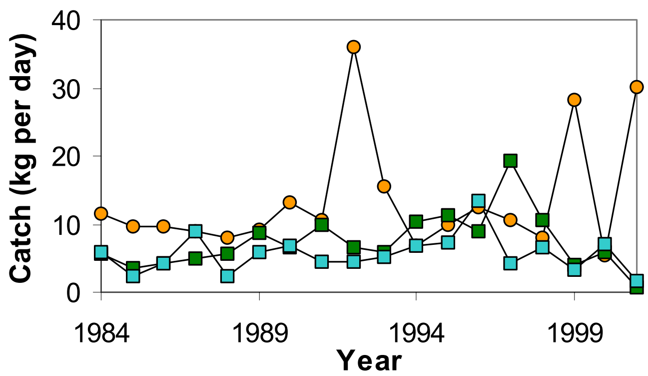


Figure 6.6. Commercial catch data for carp standardised by fishing effort (fisher-days) for the Darling (orange) and Murray (green) regions of the Lower Murray-Darling catchment. The Murray River (general) fishery (blue) may include data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area.

6.3.3. Murray cod

Murray cod were the third most commercially harvested species in the Lower Murray-Darling catchment (Figure 6.1). The scale of the Murray cod fishery in the Murray and Darling fisheries was similar in extent, although catch rates were initially higher in the Darling until the mid 1970s and then becoming higher in the Murray until 2001 (Figure 6.7). Between 1955 and 1975, catch rates recorded in the Murray River (general) fishery were much higher than those of either the Darling or Murray fisheries. It is largely the decline in this large fishery, which drove the observed pattern of a state-wide decline in Murray cod presented in Reid *et al.* (1997).

The highest catch of Murray cod occurred in the first year on record in the Murray River (general) fishery, with over 80 tonnes harvested over 12 months (Figure 6.7). The fishery declined rapidly through until the 1960's (Figure 6.7). Murray cod catches remained comparatively low until the early to mid 90's when commercial harvest increased slightly (Figure 6.7). The resulting peak was still only 24% of the 1955 catch figure. A similar increase in the fishery did not occur in the Darling catchment (Figure 6.7). The decline in the Murray fishery corresponds to the data collected from the Euston weir fishway from 1940 - 1945 and 1987 - 1992 (Mallen-Cooper 1996). Comparison of these data indicate that the population of Murray cod migrating upstream through the Euston fishway declined by 96% over the 50 year period (Mallen-Cooper 1996). This is supported by analysis of catch data standardised by fishing effort, which suggests no increase in the Murray cod population in the Darling section of the catchment since 1984, but significant increasing trends in both the Murray (p = 0.01) and Murray River (general) (p = 0.04) fisheries (Figure 6.8).

6.3.4. Silver perch

The highest annual catch of silver perch in the Lower Murray-Darling catchment occurred in 1958 in the Murray River (general) fishery when over 25 tonnes were harvested (Figure 6.9). In this fishery, the commercial catch declined steadily until the late 1970s and remained small since that time (Figure 6.9). In contrast, the silver perch fisheries in the Darling and Murray (Lower Murray and Murrumbidgee Riverina) fisheries remained small and annually variable, but persisted through until the early 1990s (Figure 6.9). Due to poor catches, in 1993, commercial fishers implemented a voluntary ban on the harvest of silver perch (Reid *et al.* 1997).

The decline in the Murray fishery corresponds to the data collected from the Euston Weir fishway from 1940 - 1945 and 1987 - 1992 (Mallen-Cooper 1996). Comparison of these data indicate that the population of silver perch migrating upstream through the Euston fishway declined by 94% over this 50 year period (Mallen-Cooper 1996).

Data standardised by fishing effort since 1984 suggests no significant trends in silver perch stock sizes of the Darling, Murray River or Murray River (general) fisheries (Figure 6.10).

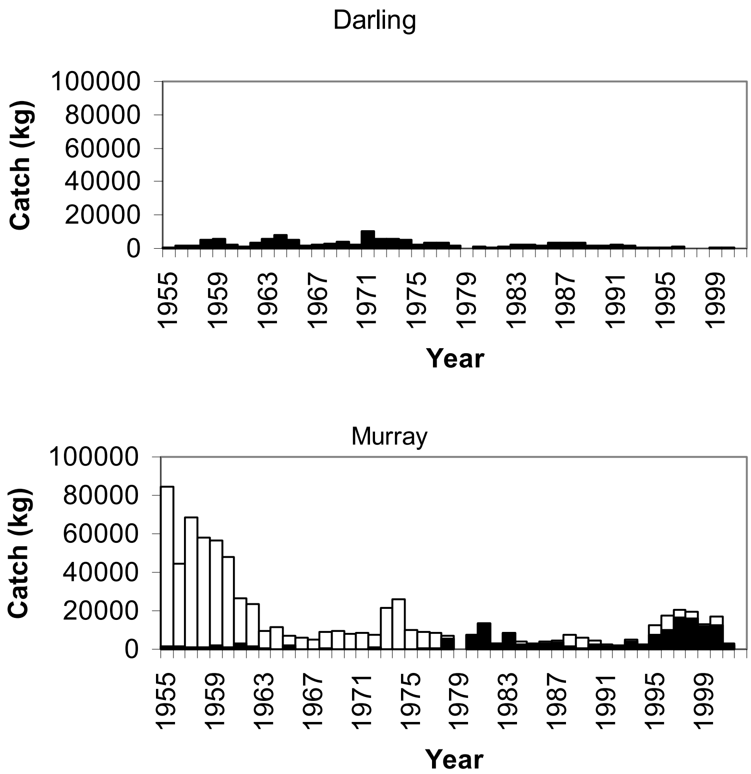


Figure 6.7. Raw commercial catch data for Murray cod in the Darling and Murray fisheries of the Lower Murray-Darling catchment. The white portion of the bars in the Murray represents the catch from the Murray River (general) fishery, which may include catch data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area.

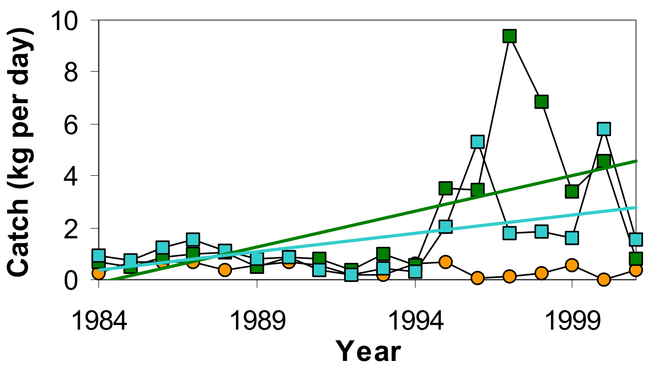


Figure 6.8. Commercial catch data for Murray cod standardised by fishing effort (fisher-days) for the Darling (orange) and Murray (green) fisheries of the Lower Murray-Darling catchment. The Murray River (general) fishery (blue) may include data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area. The trendlines represent the lines-of-best fit reflecting significant increases in the Murray cod stocks of the Murray (green) and Murray River (general) (blue) fisheries.

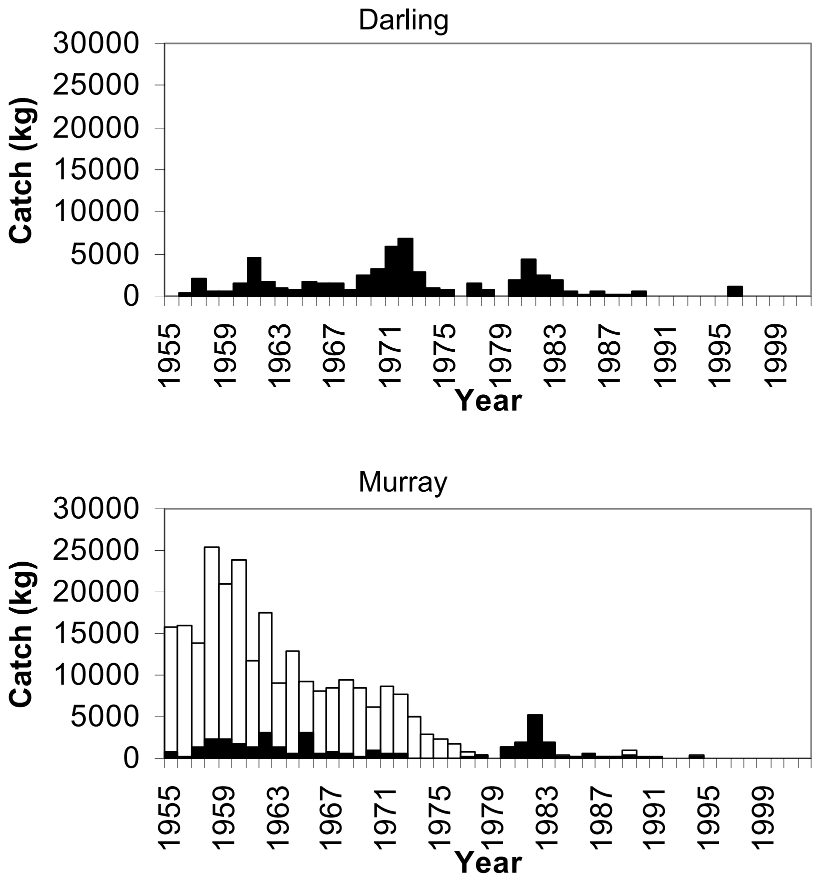


Figure 6.9. Raw commercial catch data for silver perch in the Darling and Murray fisheries of the Lower Murray-Darling catchment. The white portion of the bars in the Murray represents the catch from the Murray River (general) fishery, which may include catch data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area.

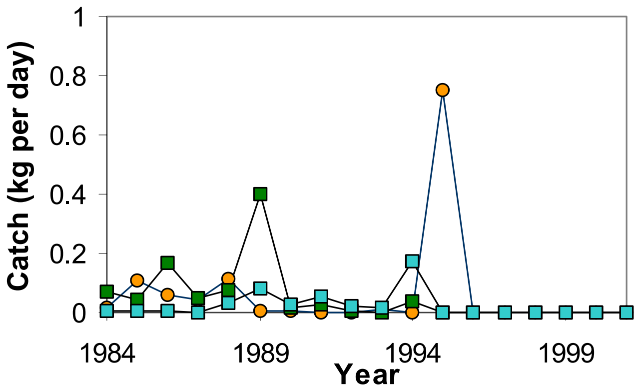


Figure 6.10. Commercial catch data for silver perch standardised by fishing effort (fisher-days) for the Darling (orange) and Murray (green) fisheries of the Lower Murray-Darling catchment. The Murray River (general) fishery (blue) may include data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area.

6.3.5. Redfin perch

Redfin perch colonised the Lower Murray River from upstream in the 1940s, and supported a small to moderate commercial harvest in most years (Figure 6.11). The fishery in the Darling was much smaller than that in the Murray, with a bulk of the harvest registered under the Murray River (general) fishery (Figure 6.11). Redfin catches in the Murray River (general) fishery declined sharply in the late 1970s and remained small since then (Figure 6.11). This corresponds to greatly increased catches of carp at that time (Figure 6.5).

Data standardised by fishing effort since 1984 suggests no significant changes in the redfin perch stocks in either the Darling, Murray or Murray River (general) fisheries (Figure 6.12). However as sampling for this project demonstrated, in 2004, redfin perch are now the rarest extant species in the Lower Murray-Darling CMA catchment area (section 4.3.1).

6.3.6. Bony Herring

Bony herring do not appear in commercial catch records until 1984 when they were first recorded in the Lower Murray-Darling catch (Figure 6.13). The lack of data prior to 1977 reflects the absence of bony herring as a listed species on the commercial fishers monthly return forms. However between 1977 and 1984, it is unknown whether they were actually absent from the catch, or whether fisherman were not recording them. An identical pattern was observed in the Murrumbidgee catchment (Gilligan 2005). In the Murrumbidgee, it was possible that the absence of bony herring reflected a real absence from the fish community, 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 1900s” and “last seen in large numbers in 1927 in lagoons” (Cadwallader 1977). In the Murray, Langtry stated that bony herring were once dominant but had retracted to the Lake Victoria district by 1949/50 (Cadwallader 1977). This is supported by Langtry’s 1949 sampling data showing that at that time, bony herring made up 83.2% of the catch in Lake Victoria, 10.3% in Frenchman’s Creek and 38.4% in the Rufus River (Cadwallader 1977). But in the main channel of the Murray River at Locks 7, 8 and 9, bony herring only made up 0.3% of the catch and they were rarely found upstream in the Murray River as far as Euston (Cadwallader 1977). The first available commercial catch data from Lake Victoria was in 1958, nine years after Langtry’s surveys, at which time no bony herring were recorded in the catch (Reid *et al.* 1997).

The most probable scenario is that bony herring had declined in the Murray River prior to 1949. Although they existed in the Lake Victoria area in quite high abundances, with much lower abundances in the adjoining Murray River, they were not recorded in the commercial catch data prior to 1984 and may have been lumped in the ‘other fish’ category. However since 1984, catch-per-unit-effort for bony herring has not changed significantly in either the Darling (p =0.09) or Murray sections (p = 0.22) of the Lower Murray-Darling catchment although the trend has been for an increase in abundance in both cases (Figure 6.14).

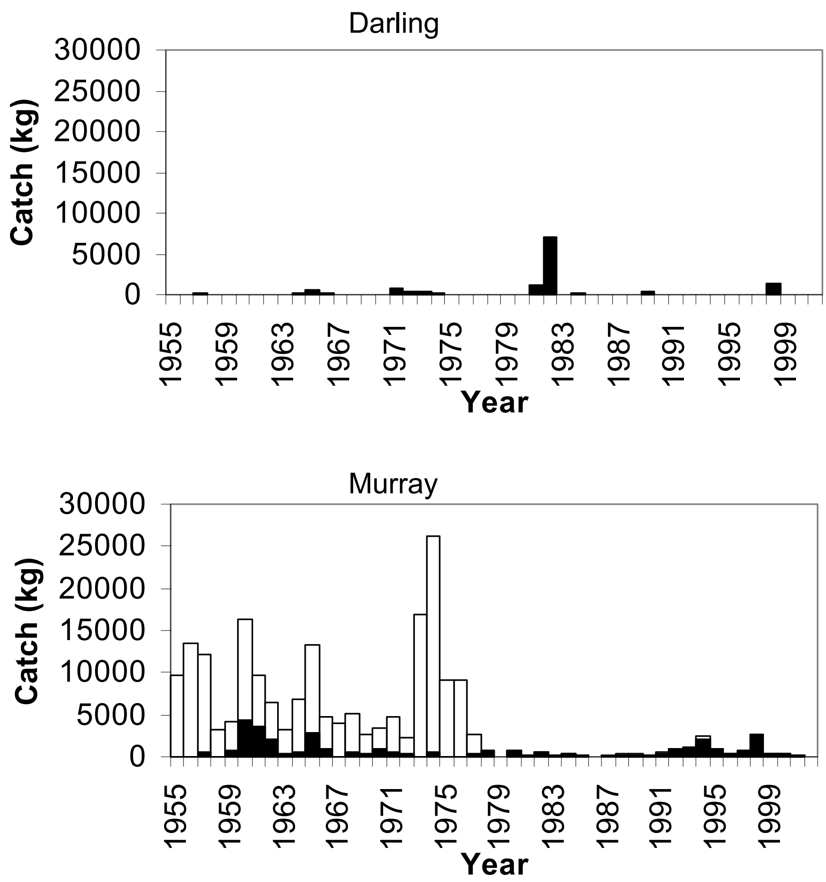


Figure 6.11. Raw commercial catch data for redfin perch in the Darling and Murray fisheries of the Lower Murray-Darling catchment. The white portion of the bars in the Murray represents the catch from the Murray River (general) fishery, which may include catch data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area.

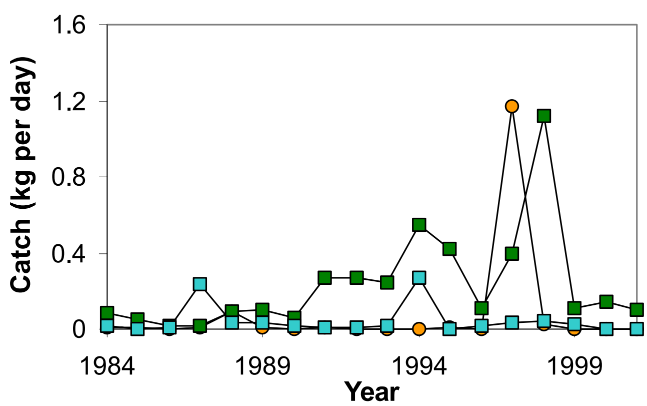


Figure 6.12. Commercial catch data for redfin perch standardised by fishing effort (fisher-days) for the Darling (orange) and Murray (green) fisheries of the Lower Murray-Darling catchment. The Murray River (general) fishery (blue) may include data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area.

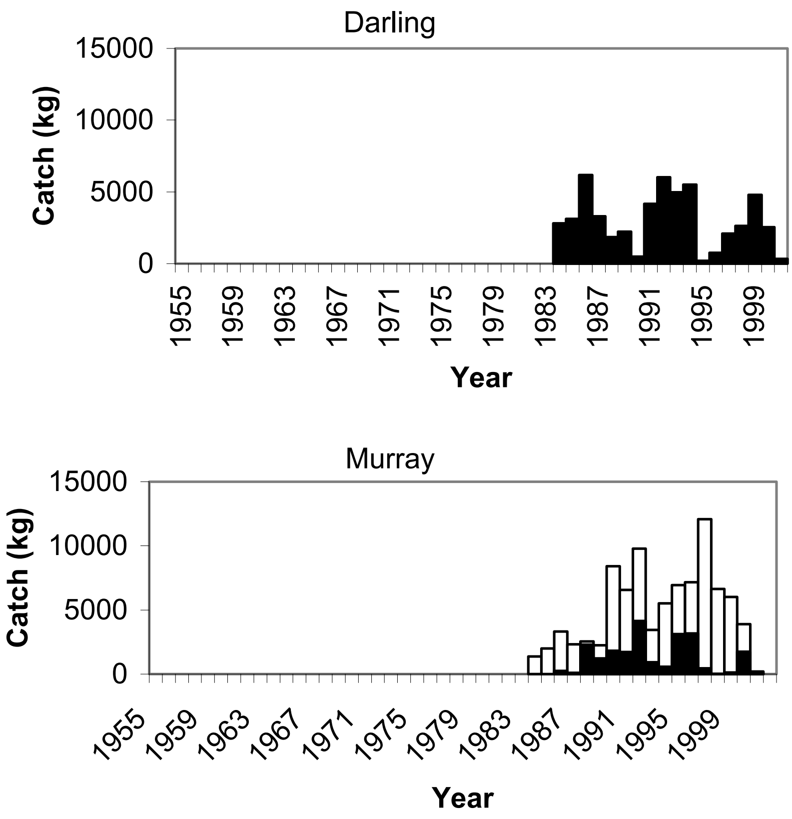


Figure 6.13. Raw commercial catch data for bony herring in the Darling and Murray fisheries of the Lower Murray-Darling catchment. The white portion of the bars in the Murray represents the catch from the Murray River (general) fishery, which may include catch data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area.

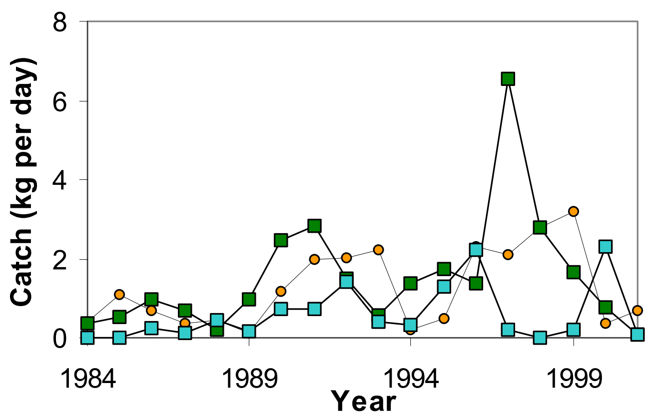


Figure 6.14. Commercial catch data for bony herring standardised by fishing effort (fisher-days) for the Darling (orange) and Murray (green) fisheries of the Lower Murray-Darling catchment. The Murray River (general) fishery (blue) may include data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area.

6.3.7. Freshwater catfish

Commercial catches of freshwater catfish were greater in the Murray than in the Darling sections of the Lower Murray-Darling catchment (Figure 6.15), but the catches were greatest in the Murray River (general) fishery, which may include catch data from the Murray Riverina fishery. Catfish appear to have been an inconsistent but not uncommon component of the commercial catch through until the late 1980s, when they virtually disappeared from the commercial catch (Figure 6.15). Commercial fishers implemented a voluntary ban on the harvest of freshwater catfish in 1993 (Reid *et al.* 1997).

Analysis of the commercial catch data standardised by fishing effort identified a significant decline in the freshwater catfish catch in the Murray River between 1984 and 2001 (p = 0.04) (Figure 6.16). A negative trend in the Darling catchment also approaches statistical significance (p = 0.06).

6.3.8. Tench

Tench were mostly harvested from the Murray River (general) fishery, with smaller harvests from both the Darling and Murray fisheries of the Lower Murray-Darling catchment. The commercial catches of tench in the Lower Murray River in 1982 and in the Lower Darling in 1988 were the last records of this species in the Lower Murray-Darling catchment. The catch was at its highest in 1971 and crashed almost as soon as carp populations increased and spread through the catchment (Figures 6.17).

Analysis of the commercial catch data standardised by fishing effort identified a significant decline in the tench catch in the Darling River between 1984 and 2001 (p = 0.03) (Figure 6.18), although tench had virtually disappeared by 1980 anyway. Langtry reports the spread of tench in the Lower Murray-Darling catchment occurring shortly before his investigations in 1949/50 (Cadwallader 1977). Therefore, tench existed in the Lower Murray-Darling catchment for a period of only 30 years. It is highly likely that the invasion of common carp contributed to this decline.

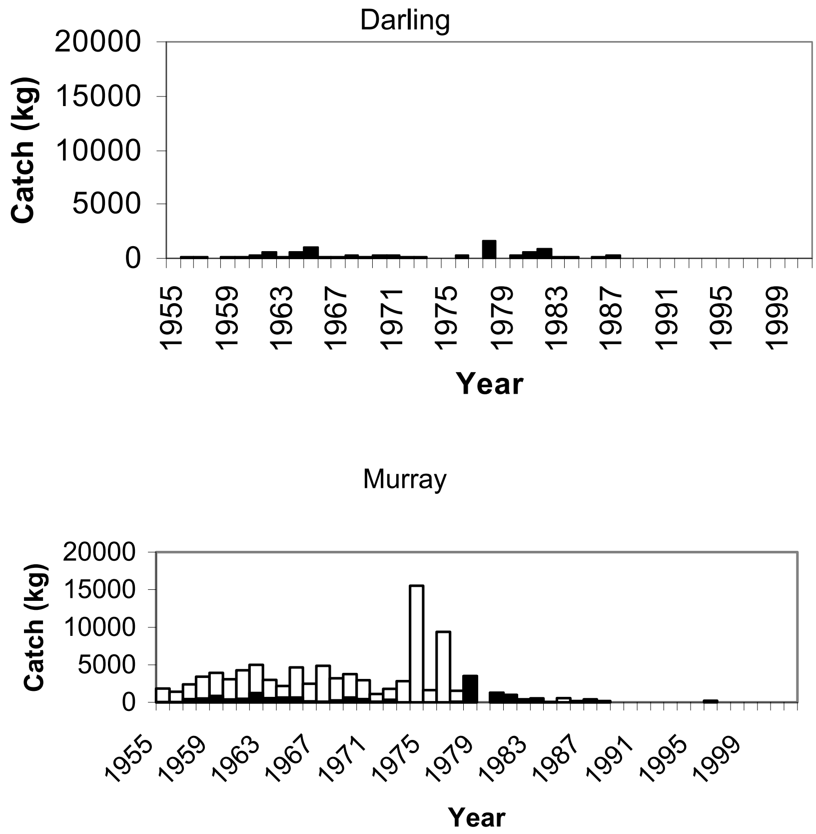


Figure 6.15. Raw commercial catch data for freshwater catfish in the Darling and Murray fisheries of the Lower Murray-Darling catchment. The white portion of the bars in the Murray represents the catch from the Murray River (general) fishery, which may include catch data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area.

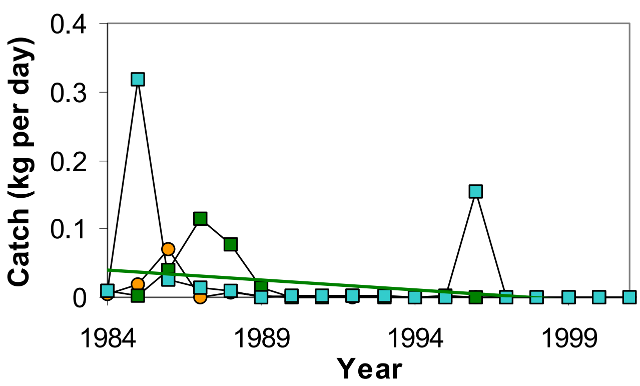


Figure 6.16. Commercial catch data for freshwater catfish standardised by fishing effort (fisher-days) for the Darling (orange) and Murray (green) fisheries of the Lower Murray-Darling catchment. The green trendline represents the line-of-best fit reflecting a decline in the freshwater catfish fishery. The Murray River (general) fishery (blue) may include data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area.

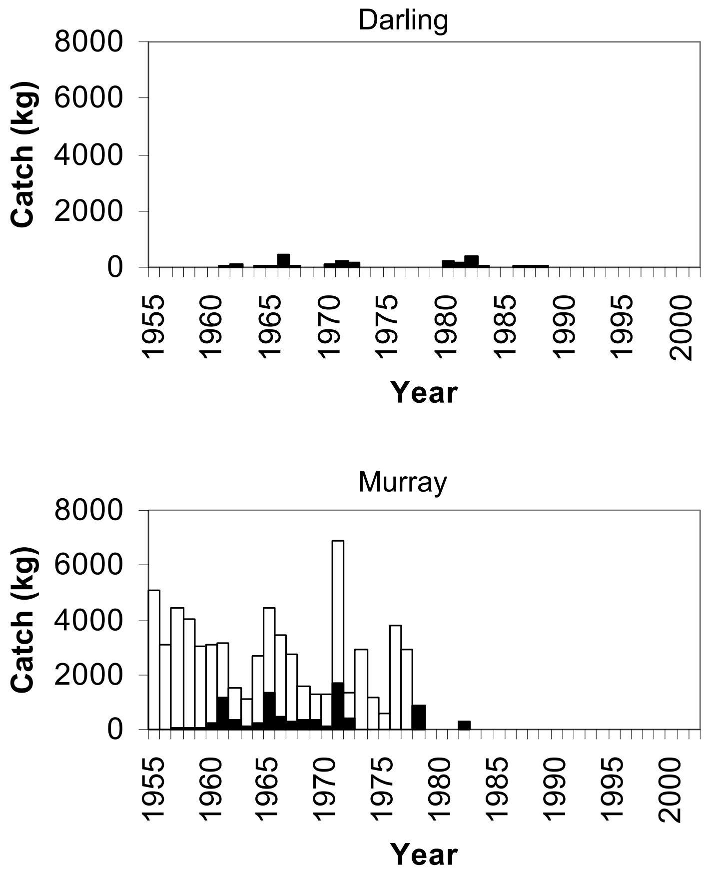


Figure 6.17. Raw commercial catch data for tench in the Darling and Murray fisheries of the Lower Murray-Darling catchment. The white portion of the bars in the Murray represents the catch from the Murray River (general) fishery, which may include catch data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area.

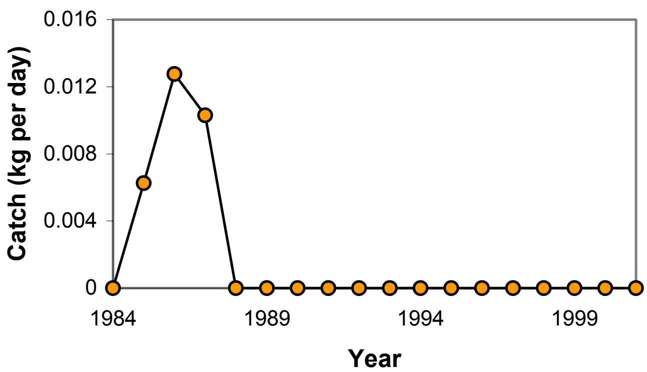


Figure 6.18. Commercial catch data for tench standardised by fishing effort (fisher-days) for the Darling region of the Lower Murray-Darling catchment. No tench had been harvested in the Murray or Murray River (general) fisheries since 1982.

6.3.9. Macquarie perch

The commercial catch of Macquarie perch was orders of magnitude smaller than for other perch and cod species (Figure 6.1). However they were consistently harvested in the Murray River (general) fishery up until 1977, with declining harvests throughout that period (Figure 6.19). A second small peak occurred in the late 1980s before Macquarie perch disappeared from the commercial catch. It is likely that much of the catch in the Murray River (general) fishery was harvested upstream of the Lower Murray-Darling catchment area. However, Macquarie perch were reported in the commercial catch of both the lower Murray and Murrumbidgee Riverina fisheries, both within the Lower Murray-Darling CMA catchment area (Figure 6.19). The last commercial harvest from the Lower Murray-Darling catchment was in 1988 (Figure 6.19).

Data standardised by fishing effort since 1984 demonstrates the significant decline in the Murray River (general) fishery ($p = 0.04$) (Figure 6.20). However, this decline is at the end of a much more substantial decline since 1955 (Figure 6.20).

6.3.10. Freshwater eels / lamprey

The NSW portion of 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 and the South Australian section of the Murray River (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, presumably having moved between the headwater streams of the coastal and inland rivers along the ridge of the Great Dividing Range. Alternatively, eels may be translocated into the Murray-Darling Basin through water diversion schemes such as the Snowy Hydro system. Therefore the occasional occurrence of freshwater eels in the Lower Murray-Darling catchment is possible. However, it is much more probable that these fish were lamprey recorded as eels, given that the commercial fisher monthly report forms included a category for freshwater eel up until 1977 (Pease and Grinberg 1995). Mr Henry Davies, a commercial fisherman in the early 1970s, was able to confirm that these catches were not freshwater eels, but were in fact a species of lamprey.

Although lamprey also require a marine stage in their life-cycle (McDowall 1996), unlike eels, lamprey are anadromous and migrate upstream from the ocean as adults to spawn in freshwaters. There are two species of lamprey known to inhabit the South Australian coastline, the short-headed lamprey and the pouched lamprey (McDowall 1996). However, only the short-headed lamprey is confirmed to migrate upstream in the Murray River as far as NSW.

The earliest report of lamprey in the Lower Murray-Darling catchment was provided by Lake (1967) who stated that at some time prior to his publication “on at least one occasion they have been seen moving up the fish ladder at Euston Weir…. in large numbers”. No other reports documented the presence of lamprey in the Lower Murray-Darling CMA catchment area, although museum specimens and sampling data exist in the Murray River both upstream (http://www.bionet.nsw.gov.au) and downstream (MDBC 2003) which suggests their presence in the Lower Murray-Darling system.

The occurrence of lamprey in the commercial fishery was very brief in the Darling River, being caught only in August 1975 from the Great Darling Anabranch and Lake Balaka (Figure 6.21). In the Murray portion of the Lower Murray-Darling catchment area, lamprey were only reported in the Murray River (general) fishery and not from either the Lower Murray or Murrumbidgee Riverina fisheries, with irregular monthly catches reported from August 1970 through until May 1978 (Figure 6.21). There were no reports in the Murray consistent with the August 1975 catches from the Darling. Further, the observed pattern in commercial catch in the Murray River also differs from that observed in the Murrumbidgee (Gilligan 2005).

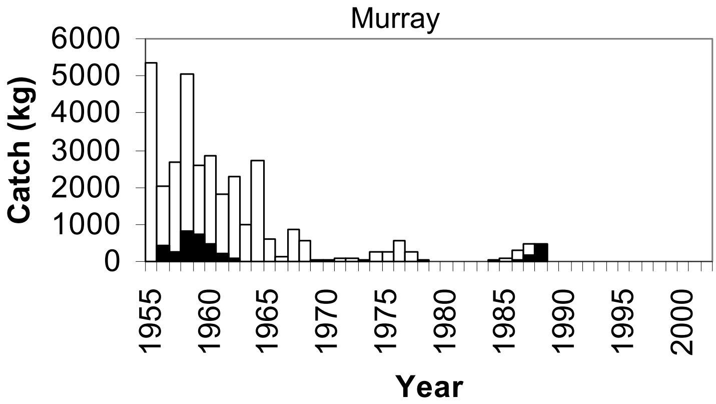


Figure 6.19. Raw commercial catch data for Macquarie perch in the Murray sections of the Lower Murray-Darling catchment. The white portion of the bars in the Murray represents the catch from the Murray River (general) fishery, which may include catch data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area. No Macquarie perch were recorded from the Darling fishery.

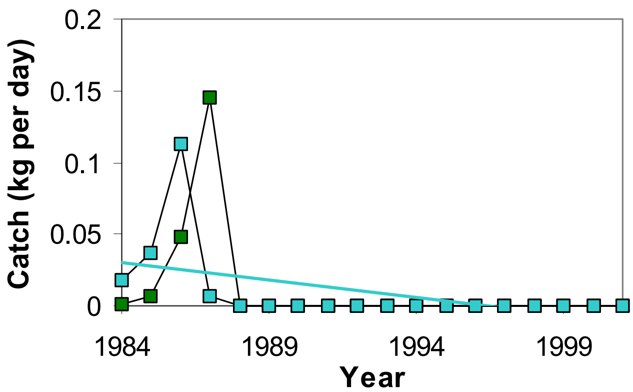


Figure 6.20. Commercial catch data for Macquarie perch standardised by fishing effort (fisher-days) for the Murray (green) fishery of the Lower Murray-Darling catchment. The Murray River (general) fishery (blue) may include data from the Murray Riverina fishery upstream of the Lower Murray-Darling catchment area. The blue trendline represents the line-of-best fit reflecting a significant decline in Macquarie perch populations of the Murray River between 1984 and 2001.

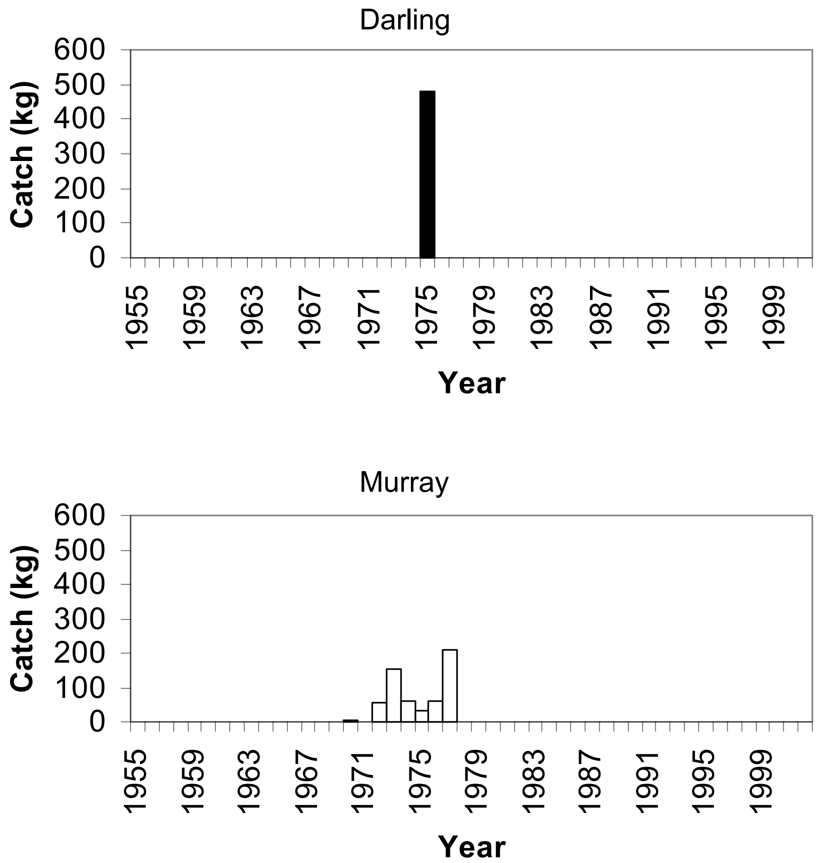


Figure 6.21. Raw commercial catch data for freshwater eels (lamprey) in the Darling and Murray sections of the Lower Murray-Darling catchment. No eels were recorded in the Lower Murray fishery and only catches from the Murray River (general) fishery are presented, which may include catch data from the Murray Riverina fishery which is upstream of the Lower Murray-Darling catchment area.

Photo: Kris Pitman (Murray cod fingerling)

7. FISH STOCKING IN THE LOWER MURRAY-DARLING CATCHMENT: 1990 -2004

7.1. 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 (NSW Fisheries 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 (NSW Fisheries 2003). The history of stocking in NSW dates back to as early as 1877 when trout acclimatisation was attempted (NSW Fisheries 2003). Management of stocking activities was assumed by the NSW government in 1960 (NSW Fisheries 2003). Native fish breeding programs in NSW did not begin until 1961 with the opening of the Narrandera Fisheries Centre. Hence, the NSW Fish Stocking Database covers all permitted stockings of native fish in the catchment. Details of fish stocking and translocation of alien fish occurring prior to 1960 are unknown. These would include the release of brown trout in the Murray as evidenced by their capture in the Euston fishway between 1940 and 1945 and near locks 8 and 9 in 1949 (Cadwallader 1977).

This chapter compiles all stocking records from the Lower Murray-Darling CMA catchment area since the first native fish stocking in 1990.

7.2. Data analysis

Stocking data were accessed from the NSW fish stocking database. This database contains data from all stocking activities undertaken in NSW 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 perch, or the illegal introduction of aquarium fishes.

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

7.3. Results and Discussion

Three species have been stocked in the Lower Murray-Darling catchment since 1990 as part of harvest stocking programs to promote recreational fishing. All three species are native to the catchment. Further stocking has been quite limited in terms of the number of species released, the number of fingerlings and the number of sites stocked. Although each stocking site referred to suggests a discrete location, in many instances fingerlings would have been released widely within a reach, rather than at one point. Further, illegal and therefore un-registered stockings may also have occurred. This is highlighted by the presence of silver perch in Imperial Lake near Broken Hill where this species is unlikely to have colonised naturally, yet there is no record of its release.

No conservation stockings of threatened species have been undertaken in the catchment area. However the Lower Murray-Darling CMA released of 33,000 Murray cod fingerlings, which are listed as vulnerable nationally, but not listed as threatened under the *NSW FM Act 1994*), at Burtundy Weir and Pooncarie in response to the February 2004 Murray cod fish kill. And therefore this could primarily be considered a conservation stocking activity.

7.3.1. Golden perch

Golden perch is the most stocked fish in the Lower Murray-Darling catchment with 251,296 fingerlings released since stocking began in 1992 (Figure 7.1). This is far lower than the number stocked in the Murrumbidgee River, which has had over 4.6 million fingerlings released since 1960 (Gilligan 2005). The first recorded stocking of golden perch in the catchment was 10,000 individuals released in the Murray River at Dareton between Wentworth and Mildura in 1992. The number of fingerlings released annually has not increased significantly since that time ($r = 0.11$, $p = 0.657$) with an average of 19,330 ± 5,912 fingerlings stocked per year (Figure 7.2).

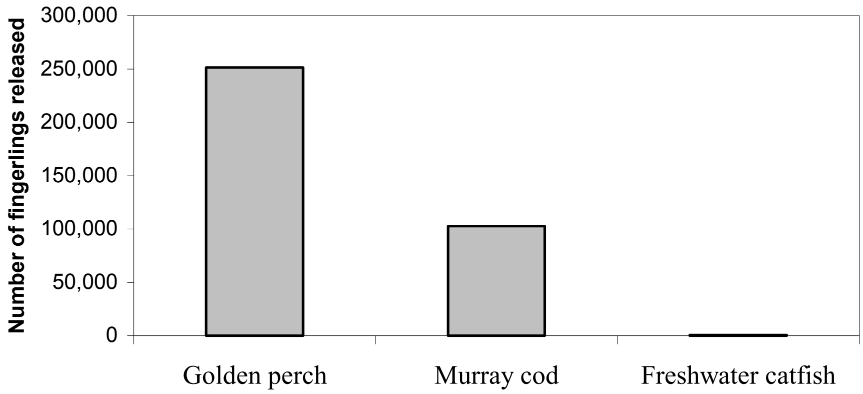


Figure 7.1. Number of fingerlings of each species stocked into the Lower Murray-Darling catchment since record keeping began in 1968.

Golden perch have been released at five sites, with 92% of fingerlings released at four locations on the Murray River (Table 7.1) and the remaining 8% in the Umberumberka Reservoir near Silverton. No golden perch have been released in the lower Darling catchment.

The increasing commercial catches of golden perch in the Lower Murray-Darling from the early 1990s corresponds with the initiation of stocking this species. Therefore, it is possible that stocking had a positive effect on local populations. This is further supported by the relative increase in commercial catches in the Murray River, which was stocked, versus the Darling River, which was not. Further, the same pattern was observed following increases in stocking activity of golden perch in the Murrumbidgee catchment in the 1970's (Gilligan 2005).

Table 7.1. Waterbodies in the Lower Murray-Darling catchment stocked with golden perch.

Stream name	Nearby Town	Dam name	Nearby town
Murray River	Wentworth	Umberumberka*	Silverton
Murray River	Dareton		
Murray River	Euston		
Murray River	Red Cliffs		

* Note: Umberumberka Dam was completely dry as of September 2005.

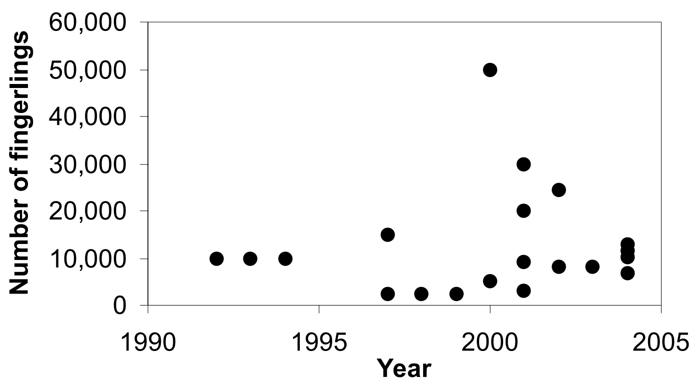


Figure 7.2. Number of golden perch fingerlings released in the Lower Murray-Darling catchment.

7.3.2. Murray cod

Murray cod stocking began in 1990 and a total of 135,674 have been released in the Lower Murray-Darling catchment. As for golden perch, this is a lower stocking density than in the Murrumbidgee catchment, where 822,161 Murray cod fingerlings have been released. The number of Murray cod released has increased significantly since stocking began in 1990 (r = 0.74, $p <$ 0.0001) (Figure 7.3).

Murray cod have been stocked at nine sites, with 70% of fingerlings being released at six sites on the Murray River (Table 7.2), 29% into the Darling River and 1% into Imperial Lake near Broken Hill.

Table 7.2. Streams, lakes or dams in the Lower Murray-Darling catchment stocked with Murray cod.

Stream name	Nearby Town	Dam name	Nearby town
Murray River	Wentworth	Imperial Lake	Broken Hill
Murray River	Dareton		
Murray River	Red cliffs		
Murray River	Colignan		
Murray River	Euston		
Darling River	Wentworth		
Darling River	Burtundy Weir		
Darling River	Pooncarie Weir		

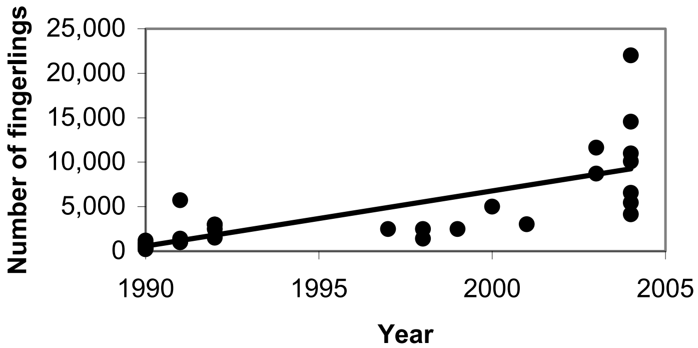


Figure 7.3. Number of Murray cod fingerlings released in the Lower Murray-Darling catchment.

7.3.3. Freshwater catfish

Freshwater catfish have only been stocked into the Lower Murray-Darling catchment on one occasion, when 500 were released into an artificial reservoir, Imperial Lake near Broken Hill in 1999. Although catfish were formally widespread throughout the Lower Murray-Darling, and contributed to the commercial fishery, this stocked reservoir was the only location where freshwater catfish were sampled in the Lower Murray-Darling catchment in 2004.

This species requires a well managed conservation stocking program in the Lower Murray-Darling catchment. Freshwater catfish are easily produced under hatchery conditions, but 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 Imperial Lake and the stocking of 500 fish in Yanco Creek (Murrumbidgee catchment) in 1995 (Gilligan 2005) both resulting in the existence of the only known current catfish populations in each of these catchments.

Photo: Ian Wooden (Murray River near Hancock Hill- Wompini)

8. GENERAL DISCUSSION AND RECOMMENDATIONS

This report presents the results of the most detailed assessment of fish species and communities undertaken across the entire Lower Murray-Darling CMA catchment area. The randomised site selection design ensures that the results collected can be inferred across all reaches of the catchment. The data and analyses presented serve three purposes:

- To benchmark the current status of fish species and fish communities.
- To determine trends in fish species and communities up until 2005 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 Lower Murray-Darling CMA catchment is degraded. Ten of the 22 native species which are known or suspected to have previously existed in the catchment are either locally extinct or survive at very low abundances. In addition to the loss of native species, the 'nativeness' of the biomass of the fish community is quite low in comparison to the neighbouring Murrumbidgee catchment (Gilligan 2005), with 56% of the total biomass being alien fish. However the 'nativeness' in terms of the proportion of alien species (23%) and alien individuals (14%) was better than observed in the neighbouring Murrumbidgee catchment, as was the proportion of sites where native fish were found (100% as compared to 75%) (Gilligan 2005).

Bony herring, Australian smelt and carp-gudgeons were three of the most abundant species in the catchment. However the fourth most abundant species in the catchment, carp, made up 49% of the total biomass of all fish sampled, with the three abundant native species only contributing 17% due to their generally small body sizes.

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; Rolls 2005). Irrespective of whether they are a cause of degradation or a response to human-induced degradation, the fact that they comprise 49% of the biomass within the catchment's rivers (as reflected by their biomass) identifies them as the single largest feature of the current poor state of the catchment's fish community and also one of the largest factors preventing recovery to a more natural state. This is supported by the coincidental decline and disappearance of olive perchlet, southern pygmy perch, southern purple spotted gudgeon and flat-headed galaxias following the invasion of Boolarra strain carp in the Murrumbidgee catchment (Gilligan 2005). In the Lower Murray-Darling catchment, 'pre-carp' records for these small species are lacking and therefore the same interpretation cannot be made, however the commercial fishery data does suggest a decline in catfish following the invasion of carp. In contrast, positive impacts were declines in the alien redfin perch and tench populations following carp invasion. The tench population is likely to have been eradicated from the Lower Murray-Darling Basin altogether, and redfin now only exist at very low abundances in the Lake Victoria area. Although tench are likely to have been quite benign, redfin perch may have had considerable negative effects on native fish communities. Redfin 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.).

The fifth most abundant species, and also the species with the fifth highest biomass was the introduced eastern gambusia. This species has been implicated in the decline of several small native fishes and numerous frog species (Lloyd 1990, McKay *et al.* 2001). Therefore gambusia also contribute substantially to the poor state of the current fish community.

Any reduction in numbers of carp or eastern gambusia is likely to result in a substantial recovery of extant populations of native fish. However this is under the proviso that declining carp populations do not result in subsequent increases in populations of redfin perch.

Analysis of trends over the 17 years between 1984 and 2001, based on commercial catch data (standardised by fishing effort), identified some significant changes in commercial fishing stocks. The golden perch stock has increased significantly since 1984 in both the Murray and Darling Rivers. Murray cod has increased significantly in the Murray but not in the Darling River. Catfish and Macquarie perch both declined significantly in the Murray River and the last population of tench in the catchment area declined significantly in the Darling River. The changes observed for Murray cod and golden perch may be partly due to stocking programs, with the increases in commercial catches coinciding with the initiation of stocking activities for both species. However this hypothesis does not apply to the golden perch population in the Darling River, which has never been stocked with this species. The declines in catfish, Macquarie perch and tench all reflect the final stages of decline in the 1980s, following declines of much greater magnitude prior to 1984. The decline of catfish and tench coincided with the invasion of Boolara strain carp in the 1970s, but the decline in Macquarie perch stocks began in the 1960s and may reflect the earlier combined impacts of the invasion of redfin perch into the catchment area and increasingly regulated flows.

Analysis of trends over the eleven years from 1994-2005, based on fish community surveys undertaken by NSW DPI (formerly NSW Fisheries) suggests very little change in fish community structure over this more recent and shorter period of time, with the only significant changes being an increase in species richness (the number of native and alien species) sampled at three of the four sites across the catchment (the exception was at Downham Farm in the very lower Darling River). These results suggest that in general, the fish community structure has remained relatively stable over this period.

Although species richness was detected to increase across the basin, the only significant change detected which suggested widespread recovery of a native species were for carp-gudgeons (which have increased in abundance). No other species showed uniform increases in abundance across the whole catchment. However Australian smelt had increased significantly in abundance in the two Murray River sites and Murray cod had increased significantly in abundance at Pooncarie on the Darling River. This site is just downstream of the reach where a large Murray cod fish-kill occurred in February 2004 (almost exactly three months prior to sampling) (Ellis and Meredith 2004). The only significant decline for any species was observed for carp at Carina Bend on the Murray River.

Comparison of the trends identified in the commercial fishery data and the scientific fish community surveys identifies some apparent inconsistencies in the two data sets. In contrast to the significant increase in the commercial stocks of golden perch observed in both the Murray and Darling fisheries, the scientific survey data indicated a non-significant decline across the catchment. Similarly, the scientific surveys did not detect a significant increase in the Murray cod population of the Murray River, but did in the Darling River, whereas the opposite was found for the commercial stocks. However if only the post-1994 commercial data are compared, the two data-sets are entirely consistent. There have been no significant increases in the Murray cod stocks of the Lower Murray River or Murray River (general) fisheries (lower Murray plus potentially data from the Murray Riverina) since 1994. Similarly, the golden perch stocks of the Darling and Murray River (general) fisheries have not increased since 1994. In fact the data from the Murray River (general) fishery suggests a non significant decline, which is the trend observed from the survey data. No analyses were possible for catfish, Macquarie perch or tench, as these three species had declined to the point of local extinction before the scientific dataset began in 1994.

Interpretation of these two datasets together suggest that Murray cod and golden perch stocks had increased between 1984 and 1994, but these increases had stabilised between 1994 and 2005. Catfish, Macquarie perch and tench populations in the Lower Murray-Darling CMA area had declined to the point of local extinction by 1990, carp-gudgeon abundance has been increasing significantly since at least 1994, Australian smelt abundance has been increasing significantly in the Murray River since 1994, and carp abundance has declined significantly since 1994 in some parts of the catchment.

Fish stocking in the Lower Murray-Darling catchment consists of harvest stocking programs for Murray cod, golden perch and catfish. The stocking programs for Murray cod and golden perch may have resulted in the significantly increased commercial fishery stock sizes observed since 1994. Further, stocking of freshwater catfish into the artificial waterway, Imperial Lake near Broken Hill, created the only population of freshwater catfish sampled in the catchment.

8.1. Recommendations

In 2005, the Murray-Darling Basin Ministerial Council began implementation of the SRA program (MDBC 2004*b*) to monitor changes in river health resulting from MDBC environmental initiatives. The SRA program builds 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 also be undertaken to monitor their status through time. Further, the SRA program excludes non-riverine habitats and as a result, fish communities in the Menindee Lakes and Lake Victoria will not be addressed. Neither will important wetland fish communities. The sampling strategy utilised for the fish survey presented in this report, incorporated three of these four important components of the fish community of the Lower Murray-Darling CMA catchment; randomly selected riverine monitoring sites; randomly selected wetland monitoring sites; and sampling of fish communities in the Menindee Lakes and Lake Victoria. The fourth component, targeted surveys of threatened species populations is yet to be undertaken.

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

8.1.1. 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, Abernethy and Rutherford 1999, Kearney *et al.* 1999, Treadwell *et al.* 1999, Lugg 2000, MDBC 2004*a*).

Within the Lower Murray-Darling catchment, the lower Darling River had moderately modified environmental conditions, the Great Darling Anabranch was predominantly substantially modified and the lower Murray was moderately modified (Norris *et al.* 2001). Norris *et al.* (2001) presents a summary of the key environmental disturbances within the Murray-Darling Basin, with each of four disturbance factors (hydrological disturbance, catchment disturbance, habitat index, and nutrient and suspended sediment loads) presented on a reach-by-reach basis. These reach-by-reach assessments should be used to guide the CMAs decisions on prioritising habitat rehabilitation actives such as rehabilitation and protection of riparian zones, revegetation with aquatic macrophytes, re-snagging, erosion control and de-silting.

8.1.2. Wetland restoration

Currently, wetlands are one of the most threatened habitats in NSW (Kingsford 2000, Treadwell 2004). Wetlands play an important role in the functioning of river ecosystems and are critical to several fish species in the Lower Murray-Darling. Many wetland fish communities across the Murray-Darling Basin are dominated by alien fish (Hillman 1987, Gehrke *et al.* 1999, Humphries *et al.* 1999, Chessman 2003, Ho *et al.* 2004; Gilligan 2005) although this is not necessarily so in the Lower Murray-Darling region, where 72% of wetlands surveyed to date have been dominated by native fish (Conallin *et al*. 2003; McCarthy *et al.* 2003; Sharpe *et al.* 2003; Ellis and Suitor 2004; Ho *et al.*, 2004; Ellis and Meredith 2005; this survey). However Murray hardyhead, flat-headed galaxias, olive perchlet, southern purple spotted gudgeon and southern pygmy perch, which are dependent on wetland habitats, have all declined or are locally extinct in the Lower Murray-Darling catchment.

Wetland condition in the Lower Murray-Darling 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. Salinisation also affects many wetlands in the Lower Murray-Darling CMA area. However wetlands with elevated salinities may be a preferred habitat of the endangered Murray hardyhead (Ellis 2005). Therefore measures to minimise salinity should be assessed on a case by case basis, to ensure that habitats of existing Murray hardyhead populations are not lost.

Under the current management regime for river systems, management of ‘natural’ wetland systems is improbable. Wetlands must be micro-managed 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 perhaps the use of fish screens on wetland inlets to prevent access by unwanted alien 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 consequently no source of recruits is available following wetting for several species. Under natural climatic conditions, as wetlands became dry through lack of rainfall, the flow in the river would also have been markedly reduced. Therefore, habitat conditions in the main river channel would have simulated wetland environments (little flow and warmer water) and the main channel provided refuge habitat for wetland fishes. However under current river regulation regimes, when low rainfall leads to the drying of wetlands, the river channel is maintained under flowing conditions less suitable for wetland fish.

It is probable that 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. Or alternatively, a captive propagation system, where fish are produced artificially for the ‘seeding’ of managed wetlands once filled.

8.1.3. Improving environmental flow management

Regulation of flows through controlled release from storages and water extraction have vastly changed the hydrology of 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 Murray (Gehrke *et al.* 1995, Gehrke and Harris 2001; Walker

2001) and Darling Rivers (Gehrke *et al.* 1995, Gehrke and Harris 2001). The major aspects of the flow regime in the Lower Murray-Darling catchment that have been modified by river regulation include the reduction in average annual and monthly flow volumes and the reduced variability of mid-range flow peaks (Maheshwari *et al.* 1995; Walker *et al.* 1995; Walker 2001).

The Lower Murray-Darling CMA board has developed a number of catchment blueprint targets specifically addressing hydrological conditions within each of the five aquatic management zones within the Lower Murray-Darling catchment (Lower Murray Darling Catchment Management Board 2003). These targets will be monitored by the CMA via a number of detailed hydrological indices (Lower Murray Darling Catchment Management Board 2003). The approach proposed by the CMA should ensure best-practice environmental flow management in the catchment and is likely to have beneficial effects for fish communities.

8.1.4. 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). Thirty-three registered barriers exist on streams in the Lower Murray-Darling CMA area (NSW DPI weirs database). Additionally seven regulators exist in the Menindee Lakes system and an inlet and outlet structure exist to regulate Lake Victoria. Of these, Locks 7, 8, 9, 10, 11 and Euston Weir on the Murray River and Menindee Main Weir, Weir 32, Pooncarie Weir and Burtundy Weir on the Darling are the structures that could significantly impact on fish passage within the catchment.

Euston Weir has had a submerged-orifice fishway installed since construction of the weir in 1937. Submerged orifice fishways have since been found to be of limited use for Australian native fishes (Mallen-Cooper 1996), as velocities and turbulence within the fishway were often too high. At Euston, the velocity through the original fishway was 2.4 ms^{-1} (Mallen-Cooper 1996). A maximum velocity of 1.4ms^{-1} is recommended for native fishes (Mallen-Cooper 1996). Despite its high velocity, some species and size classes of fish were capable of fish passage through the original fishway (Cadwallader 1977, Mallen-Cooper 1996). During its life, traps set in the Euston fishway have provided some of the most useful data on changes in fish populations in the Murray-Darling Basin (Mallen-Cooper 1996). The Euston fishway was upgraded to a denil fishway design in 2004 and fish passage efficiency is currently being monitored by NSW DPI and the MDBC.

Under its ‘Hume to the Sea’ program, the MDBC is constructing fishways on all locks and weirs within the main channel of the Murray River. Vertical-slot design fishways were constructed on Lock 8 in 2003, Lock 7 in 2004 and Lock 9 in 2005 (Baumgartner pers. com.). Monitoring of fish passage through these three structures has been ongoing since construction by the tri-state fishways monitoring program (Baumgartner pers. com.). Construction of the Lock 10 fishway has begun and will be completed in February 2006 (Baumgartner pers. com.). The Lock 11 fishway is scheduled to be the last constructed (MDBC 2005) and should also be completed under the construction program (Baumgartner pers. comm.). From that time, no fish passage barriers will exist in the main channel of the Murray River. The MDBC program may then extend to other structures within the Lower Murray-Darling catchment, including Lake Victoria and the Menindee Lakes system (MDBC 2005).

Vey (2004) reviewed the fish passage requirements of Weir 32, Pooncarie Weir and Burtundy Weir in the lower Darling River, concluding that all three posed significant barriers to fish passage. The remediation options recommended were construction of a rock-ramp fishway at Weir 32, removal of Pooncarie Weir with provision of alternative off-stream storage for the town water supply, and construction of a fishway at Burtundy Weir (Vey 2004). In response, the Lower Murray-Darling CMA is funding the installation of a fishway at Burtundy Weir in 2006, and will fund fish passage works at Pooncarie Weir following resolution of the water supply issues with the Wentworth Shire Council (Lesley Palmer pers. comm.). Environmental flows targeted at drowning-out Pooncarie Weir and Weir 32 would benefit fish passage at these structures in the interim (Vey 2004).

The NSW Weirs policy aims to halt, 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. Weir removal should be considered at each of the remaining fish passage barriers within the Lower Murray-Darling catchment.

8.1.5. 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 products and strategies program of the CRC for Invasive Animals (IA CRC) including its flagship ‘daughterless carp’ project, and the trials of William’s carp separation cages (Stuart *et al.* 2003), little is being done to actively control pest fish species in the Murray-Darling Basin. On-ground actions such as installation of William’s 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 Lower Murray-Darling. However, support of the IA CRCs freshwater products and strategies 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.

8.1.6. 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 Lower Murray-Darling 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 Lower Murray-Darling. 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 Lower Murray-Darling.

8.2. 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 Lower Murray-Darling catchment area will be collected on a three yearly basis. Sampling started in 2005 and will continue for at least 6 years, and potentially for 50 years (MDBC 2004*b*). As a result, most of the data-gathering needs for a general fish community survey of the Lower Murray-Darling catchment will be met by the SRA. However the sites sampled will not necessarily be those sampled in this survey and sites in the Lakes & Reservoirs zone will not be included. Further, the SRA program does not include sampling of wetland habitats or the targeted sampling of threatened species populations. 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 Lower Murray-Darling CMA. 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 Lower Murray-Darling catchment. The next round of SRA sampling in the Lower Murray-Darling catchment is scheduled for 2008.

Detailed assessment of any on-ground actions such as wetland rehabilitation, habitat restoration, and construction of 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 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 Lower Murray-Darling catchment.

It is suggested that the Lower Murray-Darling CMA:

- Supports SRA sampling in the Lower Murray-Darling catchment on a three yearly basis as a long-term monitoring program.
- As a minimum, the CMA should fund additional sampling at sites not incorporated into the SRA site network, plus wetland sites and targeted threatened species sites concurrently with SRA sampling ever three years (next round is scheduled for 2008). However, the CMA has allocated funds for annual fish sampling within its investment strategy. Annual sampling will provide substantially greater statistical power to detect changes in fish community structure in response to rehabilitation activities in the catchment.
- 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, sedimentation, river regulation, loss of aquatic and riparian vegetation etc.), which will enable modelling of ecosystem responses and prioritisation of rehabilitation activities.

Photo Wayne Smith: Dead Murray cod at Karoola Station (Darling River) on 17th February 2004)

9. APPENDIX 1: IMPACTS OF THE FEBRUARY 2004 FISH-KILL

A fish kill occurred in a 160km stretch of the Darling River between Weir 32 and Pooncarie between the 14th and 19th of February 2004 (Ellis and Meredith 2004). Mostly large Murray cod and only small numbers of small Murray cod and golden perch were reported to be affected (Ellis and Meredith 2004). The fish kill was suggested to have significant ecological consequences and was considered particularly detrimental to Murray cod (Ellis and Meredith 2004).

Sampling within this reach was undertaken three months after the fish kill event (11 to 13 May 2004). Sites sampled in order from upstream to downstream were:

1) Bono
2) Tolarno (UTM 54: 630000E, 6372000N)
3) Moorara
4) Karoola (UTM 54: 628000E, 6361200N)
5) Carstairs (UTM 54: 642000E, 6306000N)
6) Pooncarie
7) Lethero
8) Lelma
9) Downham Farm
10) Pomana

Of these, site 1 was upstream of the fish-kill zone, sites 2 to 5 were within the reported fish-kill zone and sites 6 to 10 were downstream. The maximum of 15 to 20 cod per river km were reported killed in the vicinity of the Tolarno site (Ellis and Meredith 2004) (Figure 9.1).

The abundance of cod sampled in May 2004 was not negatively related to the number of dead cod reported per km in February (as reported by Ellis and Meredith 2004) (Figure 9.1). An average of 1.3 Murray cod individuals were sampled at each of the sites outside of the fish-kill zone. In contrast, an average of 4.0 Murray cod weer sampled from each site within the fish kill-zone. Further, more large Murray cod (which were most affected by the fish-kill) were found at sites within the fish-kill zone (Figure 9.2).

Therefore, although a large number of large Murray cod died as a result of the fish-kill in February 2004, little evidence exists to suggest a long-term impact on the local Murray cod population, or on the ecology of fish populations within the lower Darling River.

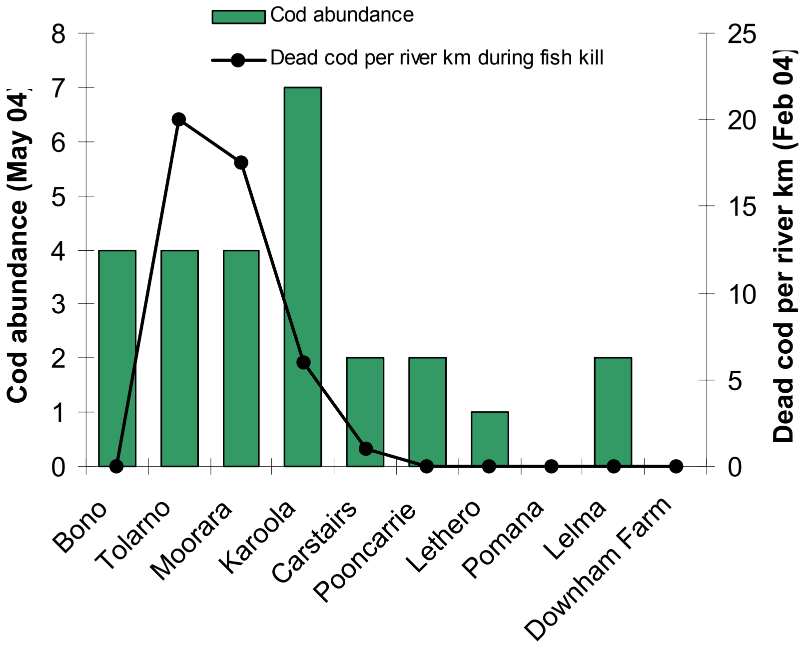


Figure 9.1. The number of Murray cod sampled from 10 sites within the lower Darling River in May 2004, three months after a major fish-kill. The bars represent the number of cod sampled. The line represents the estimated density of Murray cod killed at each site (based on data presented by Ellis and Meredith, 2004).

Figure 9.2. Murray cod sampled upstream of, within and downstream of the fish-kill zone in the Darling River three months after the February 2004 fish kill event. The size of each individual sampled is shown to scale (Drawings: Jack Hannan).

Lake Pamamaroo

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