Chowilla Icon Site
Fish Assemblage Condition Monitoring
2005 - 2008

B. P. Zampatti, S. J. Leigh and J. M. Nicol

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Executive Summary

The Chowilla Anabranch system is the largest remaining area of undeveloped floodplain habitat in the lower Murray River and has been listed as a wetland of international importance under the Ramsar Convention. The Chowilla floodplain system, however, has become increasingly degraded as a consequence of changes to the natural flow regime, grazing and drought.

In order to enhance and restore the environmental values of the Chowilla Floodplain, the Department of Water Land Biodiversity and Conservation (DWLBC) developed an Asset Environmental Management Plan (AEMP) as part of the Chowilla Integrated Natural Resource Management Project (DWLBC 2006). Within the AEMP four preliminary targets were developed for fish:

Target 10. Maintain the diversity and extent of distribution of native fish species.
Target 11. Reduce barriers to fish passage.
Target 12. Maintain successful recruitment of small-bodied native fish every year.
Target 13. Maintain successful recruitment of large-bodied fish at least once every five years.

In order to assist with condition monitoring of targets 10, 12 and 13, quantitative fish surveys were undertaken in the Chowilla Anabranch system in March/April 2005 - 2008. Sites were chosen to represent all aquatic mesohabitats present within the Chowilla region (i.e. fast flowing anabranches, slow flowing anabranches, backwaters and the Murray River main channel).

A total of 38942 fish were captured representing 15 species (11 native and 4 exotic) over the 4 years. The total catch was similar each year but slightly higher in 2008 due to greater numbers of bony herring. The most abundant fish were the native species bony herring, unspecked hardyhead and Australian smelt. The most abundant exotic species were common carp and goldfish.

The survey data suggest that targets 10, 12 and 13 are being met. The distribution and diversity of species was similar across years. Many species were widespread throughout the available mesohabitats and were captured in similar abundances each year. Some species, however, were only collected in specific mesohabitats (e.g. Murray cod in fast flowing and Murray River habitats). Length frequency distributions indicate that successful recruitment occurred each year for the small to medium-bodied species (i.e. bony herring, unspecked hardyhead, Murray rainbowfish and Australian smelt). Furthermore, recruitment of large bodied native species (i.e. golden perch and Murray cod) was evident for at least one of the 4 years sampled. Annual recruitment was evident for the two most abundant exotic species (common carp and goldfish) although common carp recruitment strength (at least to young-of-the year) appeared related to flow.

Introduction

The Chowilla floodplain system covers a total area of 17, 700 ha (MDBC 2006) and is the largest remaining region of floodplain habitat in the lower Murray River. It is comprised of a series of anabranching creeks, backwaters and wetland systems that bypass Lock and Weir No. 6 on the Murray River. The floodplain and the associated anabranch system is part of the Riverland Ramsar site, a wetland of international importance for migratory waterbirds.

River regulation has resulted in a shift in flowing water habitats from the main channel of the Murray River to the Chowilla Anabranch system. Due to the head differential (~ 3 m) created by Lock and Weir No. 6 on the River Murray, 20 – 90% of Murray River flows are now diverted through the Chowilla Anabranch system under low flow conditions (i.e. < 10,000 ML/d) (Stace and Greenwood 2004). Consequently, the Chowilla Anabranch system exhibits permanent lotic habitats in what previously would have been a combination of perennial and ephemeral streams. Lotic habitats in Chowilla can be generally classified as fast or slow flowing depending primarily on the distance over which the upstream/downstream head differential is dissipated.

The diversity of aquatic habitats available within Chowilla is now rare within the lower Murray River and supports a wide range of aquatic organisms (O'Malley and Sheldon 1990) and significant native fish populations (Lloyd 1990; Pierce 1990; Zampatti *et al.* 2006). The Chowilla floodplain system, however, has become increasingly degraded as a consequence of changes to the natural flow regime, grazing and drought (MDBC 2006).

In order to enhance and restore the environmental values of the Chowilla Floodplain, the Department of Water Land Biodiversity and Conservation (DWLBC) developed an Asset Environmental Management Plan (AEMP) as part of the Chowilla Integrated Natural Resource Management Project (DWLBC 2006). Within the AEMP four preliminary targets were developed for fish:

Target 10. Maintain the diversity and extent of distribution of native fish species.
Target 11. Reduce barriers to fish passage.
Target 12. Maintain successful recruitment of small-bodied native fish every year.
Target 13. Maintain successful recruitment of large-bodied fish at least once every five

years.

The aim of this report is to assess the condition of the fish community within the Chowilla Anabranch system in reference to three of the management targets (10, 12 and 13, above). In order to achieve this we investigated the spatial and temporal variation in fish assemblages in the Chowilla Anabranch system over 4 years (Target 10) and determined the recruitment of small-bodied (Target 12) and large-bodied (Target 13) fish using length and, in the case of golden perch (*Macquaria ambigua*), age frequency data.

Methods

Sixteen sites were surveyed annually from 2005 - 2008 in the Chowilla Anabranch system and adjacent Murray River (Figure 1). Sites were surveyed in March/April in order to detect young-of-the-year (YOY) individuals from the preceding spring/summer spawning season. Sites were chosen to represent all aquatic habitats (mesohabitats) present in the Chowilla anabranch system i.e. fast flowing anabranches, slow flowing anabranches, backwaters and the Murray River main channel, as described by Sheldon and Lloyd (1990) (Table 1). These mesohabitats were quantified and revised following the measurement of cross-sectional velocity profiles (based on six cross sections) at all sites in March 2007. Fast flowing habitats were characterised as having mean velocities of > 0.18 ms^{-1}, slow flowing habitats 0.05 - 0.18 ms^{-1}, backwaters < 0.05 ms^{-1} and Murray River main channel < 0.1 ms^{-1}.

Fish were sampled using a boat mounted 5kW Smith Root Model GPP electrofishing system. At each site electrofishing incorporated 12 (6 on each bank) x 90 second (power on time) electrofishing shots during daylight hours. All fish were dip netted and placed in holding tanks. Any positively identified fish unable to be dip netted were recorded as "observed" and included in the total catch. Fish from each shot were identified, enumerated and measured for length (± 1 mm, caudal fork length, L_F or total length, L_T). Where large numbers of an individual species were collected a sub sample of 20 individuals was measured for length.

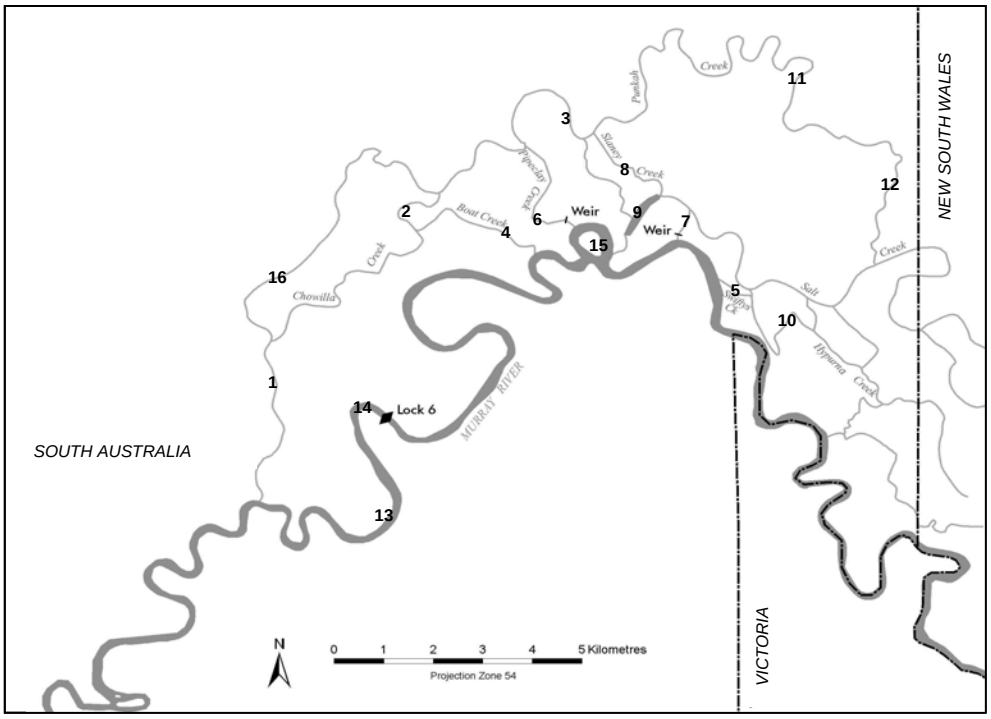

Figure 1. Map of the Chowilla Anabranch system and adjacent Murray River showing the location of the 16 fish survey sites.

Table 1. Site number, location and corresponding aquatic mesohabitat type.

Site No.	Location	Mesohabitat Type
1	Chowilla Creek d/s Monoman Creek	Slow Anabranch
2	Chowilla Creek u/s of Boat Creek	Fast Anabranch
3	Chowilla Creek d/s Slaney Creek	Fast Anabranch
4	Boat Creak u/s vehicle bridge	Fast Anabranch
5	Swiftys Creek d/s Bank I	Fast Anabranch
6	Pipeclay Creek d/s Pipeclay Weir	Slow Anabranch*
7	Slaney Creek d/s Slaney Weir	Fast Anabranch
8	Slaney Creek d/s Salt Creek junction	Fast Anabranch
9	Slaney Billabong	Backwater
10	Hypurna Creek at Wilkadene	Slow Anabranch
11	Punkah Creek d/s Punkah Island ford	Slow Anabranch
12	Punkah Creek at Lake Littra	Slow Anabranch
13	Murray River 10 km d/s Lock 6	Main River Channel
14	Murray River immediately d/s Lock 6	Main River Channel
15	Isle of Mann backwater	Backwater
16	Monoman Creek at campsite 29	Backwater

*the Pipeclay Creek site was classified as a fast anabranch in 2005 but was reclassified as a slow flowing anabranch in 2006 following a reduction in discharge in this creek.

Although the abundance of each fish species is not defined as a target for fish in the AEMP, changes in abundance may in some cases reflect environmental condition. As such we investigated the abundance of fish species in each mesohabitat over the four sampling events. Sites were grouped into mesohabitat types as individual mesohabitats have been previously shown to contain significantly different fish assemblages (Zampatti *et al.* 2006). Analysis of Similarities (ANOSIM) and indicator species analysis (Dufrene and Legendre 1997) were performed on unpooled relative abundance data using the packages Primer version 5.2.9 (Clarke and Gorley 2001) and PCOrd version 5.12 (McCune and Mefford 2006). Bray-Curtis distances were used to calculate the similarity matrix for all multivariate analyses (Bray and Curtis 1957).

In order to investigate the diversity and distribution of native fish species between years (Target 10) sites were also grouped into mesohabitats for each year. The diversity of species was determined by the number of individual species in each mesohabitat and was compared between years. The presence or absence of individual species in a mesohabitat type was considered to be a representation of species distribution over the Chowilla Anabranch system and was compared between years.

To investigate recruitment of large and small to medium-bodied fish species in the Chowilla Anabranch system (Targets 12 and 13) we plotted the length distributions of golden perch and Murray cod (*Maccullochella peelii peelii*) (large bodied native species), and bony herring (*Nematalosa erebi*), unspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*), Murray rainbowfish (*Melanotaenia fluviatilis*) and Australian smelt (*Retropinna semoni*) (small to medium-bodied native species). The recruitment pattern of the two most abundant exotic species common carp (*Cyprinus carpio*) and goldfish (*Carrasius auratus*) were also investigated.

Using length to estimate age was considered an appropriate method to investigate recruitment for all species with the exception of golden perch. In the Murray-Darling Basin golden perch exhibits considerable variability in length at age (Anderson *et al.* 1992; Mallen-Cooper and Stuart 2003). Therefore to more accurately assess the recruitment of golden perch we used length frequency graphs and thin sectioned otoliths to determine age. Golden perch otoliths exhibit a clear incremental pattern of opaque and translucent zones, which form annually (Anderson *et al.* 1992; Mallen-Cooper and Stuart 2003) and are therefore considered reliable for age determination.

A sub sample of golden perch was sacrificed from each electrofishing survey (2005 – 2008). Each fish was measured to the nearest millimetre and the otoliths were removed. Whole sagittae were embedded in clear casting resin and a single 400 to 600 μm transverse section, incorporating the primordium, was prepared (Anderson *et al.* 1992). Sections of sagittae were examined using a dissecting microscope (x 25) under transmitted light. Estimates of age were determined independently by three readers by counting the number of complete or clearly discernable opaque zones from the primordium to the otolith edge. A suitable birth date was assigned by considering the timing of the formation of a new annulus (opaque zone) and back calculated spawning dates of post larval fish (Zampatti and Leigh unpublished data). To describe the age structure of golden perch captured from the Chowilla Anabranch age frequency plots were generated for each survey year. Murray cod may also show variability in length at age (Ye and Zampatti 2007) but due to the conservation status of this species we elected not to use a destructive ageing technique to investigate recruitment.

Results

Abundance

A total of 38942 fish representing 15 species (11 native and 4 exotic) were sampled over four sampling events in March/April 2005 - 2008 (Table 2, Appendix 1 - 4). Three species with conservation significance were captured during the survey period, namely Murray cod (*Maccullochella peelii peelii*), freshwater catfish (*Tandanus tandanus*) and silver perch (*Bidyanus bidyanus*). Murray cod is listed as threatened under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 and freshwater catfish and silver perch are protected under the South Australia *Fisheries Management Act 2007*.

The total catch was similar each year but slightly higher in 2008 due mainly to greater numbers of bony herring (*Nematolosa erebi*) (Table 2). The most abundant species each year were small to medium-bodied species bony herring, unspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*) and Australian smelt (*Retropinna semnoi*) (Table 2). The abundance of Australian smelt, however, was considerably lower in 2006. Common carp (*Cyprinus carpio*) and goldfish (*Carassius auratus*) were the most abundant exotic species and the abundance of both of these species was higher in 2006 than other years (Table 2). Low numbers of the large-bodied species Murray cod and golden perch (*Maquaria ambigua*) were sampled with golden perch being most abundant in 2007 (Table 2). Silver perch, dwarf flat-headed gudgeon (*Phylipnodon macrostomus*), freshwater catfish and exotic redfin perch (*Perca fluviatilis*) were captured in low abundances each year (Table 2). The abundance of Murray rainbowfish (*Melanotaenia fluviatilis*) and carp gudgeons (*Hypseleotris* spp) decreased over the four years (Table 2).

Table 2. Total numbers of fish sampled from 16 sites in the Chowilla Anabranch system and adjacent Murray River in March/April 2005 to 2008.

Species	2005	2006	2007	2008	Grand Total
Golden perch	75	75	114	90	**354**
Murray cod	12	11	14	7	**44**
Silver perch	5	5	1	10	**21**
Bony herring	3970	6233	6320	7783	**24306**
Australian smelt	546	192	756	734	**2228**
Murray rainbowfish	436	396	125	199	**1156**
Flat-headed gudgeon	59	7	20	18	**104**
Dwarf flat-headed gudgeon	2	0	0	11	**13**
Unspecked hardyhead	2600	1673	1595	1976	**7844**
Carp gudgeon spp.	254	107	107	74	**542**
Freshwater catfish	0	0	2	0	**2**
Carp	223	469	279	184	**1155**
Gambusia	157	52	128	54	**391**
Goldfish	177	300	177	145	**799**
Redfin perch	0	0	9	3	**12**
Total species	**13**	**13**	**14**	**14**	**15**
Total fish	**8514**	**9493**	**9647**	**11288**	**38942**

The relative abundance of fishes in all four mesohabitats varied significantly across years although differences were not uniform across mesohabitat types (Table 3). Slow anabranch mesohabitats were characterised by greater relative abundances of Australian smelt in 2005 and goldfish, common carp and bony herring in 2006 (Table 4). In backwater mesohabitats the relative abundance of carp gudgeons was greater in 2005, common carp in 2006, redfin perch in 2007 and Australian smelt and goldfish in 2008 (Table 4). Murray River mesohabitats had greater relative abundances of unspecked hardyhead, Murray rainbowfish, carp gudgeons, flat-headed gudgeon in 2005 and goldfish and bony herring in 2006 (Table 4). The relative abundance of fishes in fast flowing mesohabitats also varied between years. Sliver perch, Australian smelt, bony herring and unspecked hardyhead were significantly more abundant in fast flowing mesohabitats in 2008. The relative abundance of Golden perch was greater in fast flowing mesohabitats in 2007 while carp gudgeons and flat-headed gudgeons were captured in greater abundances in 2005 (Table 4).

Table 3. One-way ANOSIM results testing for the effect of year on fish assemblages in four aquatic mesohabitats of the Chowilla Anabranch system and adjacent Murray River. Significant differences ($P \leq 0.05$) are highlighted in bold.

		Mesohabitat			
Comparison		**Fast Anabranch**	**Slow Anabranch**	**Backwater**	**Murray River**
Global test					
Among years	R-statistic	0.077	0.031	0.054	0.031
	P-value	**0.001**	**0.006**	**0.019**	**0.006**
Pairwise tests					
2005 v 2006	R-statistic	0.003	0.043	0.074	0.043
	P-value	0.383	**0.049**	**0.013**	**0.049**
2005 v 2007	R-statistic	0.052	0.028	0.079	0.028
	P-value	**0.003**	0.051	**0.022**	0.051
2005 v 2008	R-statistic	0.147	<0.001	-0.143	<0.001
	P-value	**0.001**	0.430	0.908	0.430
2006 v 2007	R-statistic	0.039	0.064	0.091	0.064
	P-value	**0.020**	**0.001**	**0.014**	**0.001**
2006 v 2008	R-statistic	0.198	0.021	-0.071	0.021
	P-value	**0.001**	0.158	0.766	0.158
2007 v 2008	R-statistic	0.032	0.006	-0.082	0.006
	P-value	**0.011**	0.285	0.705	0.285

Table 4. Indicator species analyses comparing the relative abundance of fish over four years (2005, 2006, 2007 and 2008) in each of the four aquatic mesohabitats. A significant difference ($P < 0.05$) indicates that a species occurs in a higher relative abundance in a specific mesohabitat in a particular year. Values that are not significant indicate that a species was either sampled in low numbers in a single group (uncommon) or was sampled in similar numbers in more than one group (widespread).

	Mesohabitat							
	Fast Anabranch		**Slow Anabranch**		**Backwater**		**Murray River**	
Species	***Year***	***P-value***	***Year***	***P-value***	***Year***	***P-value***	***Year***	***P-value***
Unspecked hardyhead	**2008**	**0.012**	2005	0.075	2005	0.113	**2005**	**<0.001**
Murray rainbowfish	2006	0.591	**2005**	**0.003**	2006	0.236	**2005**	**<0.001**
Bony herring	**2008**	**<0.001**	**2006**	**0.001**	2006	0.900	**2006**	**0.001**
Carp gudgeons	**2005**	**0.034**	2006	0.057	**2005**	**0.046**	**2005**	**<0.001**
Flat-headed gudgeon	**2005**	**<0.001**	2005	0.078	2007	0.648	**2005**	**0.002**
Dwarf flat-headed gudgeon	2008	0.099	2008	0.126	2005	1.000	**2008**	**0.021**
Murray cod	2007	0.744	2006	1.000	-	-	2007	0.675
Golden perch	**2007**	**0.041**	2008	0.154	2007	0.720	2006	0.264
Silver perch	**2008**	**0.020**	2005	0.659	2005	1.000	2006	0.249
Australian smelt	**2008**	**0.017**	**2005**	**<0.001**	**2008**	**0.001**	2007	0.786
Freshwater catfish	2007	0.165	-	-	-	-	-	-
Goldfish	2008	0.578	**2006**	**0.049**	**2008**	**<0.001**	**2006**	**0.002**
Common Carp	2006	0.148	**2006**	**<0.001**	**2006**	**0.023**	2006	0.381
Gambusia	**2005**	**0.003**	2008	0.568	2005	0.060	2005	0.129
Redfin perch	2008	0.464	-	-	**2007**	**0.023**	2007	0.178

Diversity and distribution of fish species (Target 10)

Most species were widespread throughout mesohabitats with the exception of Murray cod, silver perch, dwarf flat-headed gudgeon, freshwater catfish and exotic redfin perch. Murray cod and silver perch were only captured in fast flowing mesohabitats and the Murray River (Table 5) although one silver perch was collected from a backwater mesohabitat (the Isle of Mann, site 15, in 2005) (Appendix 1). Freshwater catfish were captured in low numbers (n = 2) and only in fast flowing mesohabitats in Slaney Creek (site 8) and Boat Creek (site 4) in 2007 (Appendix 3). Dwarf flat-headed gudgeon were captured in low numbers (n = 2) in Slaney Billabong (site 9) and the Murray River (site 13) in 2005 (Appendix 1). In 2008 this species was captured at more sites but only in low numbers (n = 18) (Appendix 4). Redfin perch were captured in the Murray River (sites 13 and 14), the Isle of Mann backwater (site 15) and Monoman Creek (site 16) in 2007 (Appendix 3). In 2008 they were captured from the Murray River at Lock 6 (site 14) and Slaney Creek downstream of the weir (site 7) (Appendix 4).

Species richness and diversity in each mesohabitat was relatively consistent over time (Table 5). Fast flowing mesohabitats were characterised by the same fish community in 2005 and 2006, however in 2007 silver perch were not captured and freshwater catfish were (Table 5). Redfin perch and dwarf flat-headed gudgeon were only captured in fast flowing mesohabitats in 2008. The fish community in slow flowing mesohabitats remained the same from 2005 to 2007 and varied slightly in 2008 with the presence of dwarf flat-headed gudgeon. The fish community of backwater mesohabitats varied slightly between years with silver perch only captured in 2005 and redfin perch only in 2007. Golden perch, Murray rainbowfish, flat-headed gudgeon and gambusia were absent from backwater sites in 2008 (Table 5). In the Murray River, dwarf flat-headed gudgeon were only present in 2005 and 2008, Murray cod were only captured in 2007, redfin perch in 2007 and 2008, and silver perch in 2005 and 2006 (Table 5).

Table 5. Presence/absence of fish species in each mesohabitat type from 2005 - 2008.

	Fast				Slow				Backwater				Murray River			
Species	2005	2006	2007	2008	2005	2006	2007	2008	2005	2006	2007	2008	2005	2006	2007	2008
Golden perch	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*
Murray cod	*	*	*	*											*	
Silver perch	*	*		*	*	*	*	*	*				*	*		
Bony herring	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Australian smelt	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Murray rainbowfish	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*
Flathead gudgeon	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*
Dwarf flathead gudgeon				*				*					*			*
Unspecked hardyhead	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Carp gudgeon spp	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Freshwater catfish			*													
Carp	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Gambusia	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*
Goldfish	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Redfin perch				*							*				*	*

Recruitment of fish species (Target 12 and 13)

The length distribution of golden perch (Figure 2a) shows a unimodal distribution in 2005 with fish ranging from 250 - 450 mm. Ageing data indicate that this mode was comprised of three strong year classes, namely 4, 6 and eight year olds (Figure 2b). In 2006 a small cohort of fish < 100 mm appears. The ages of these fish were determined to be < 1 year old (Zampatti and Leigh unpublished data). In 2007 a bi-modal distribution is present, consisting of two distinct groups of fish, which includes a strong group of 1 year old fish with a range of approximately 120 - 280 mm. In 2008 the length frequency distribution is again unimodal as the group of small fish progresses to 2 year olds.

The length distribution of Murray cod varies over the survey period (Figure 3). Fish < 400 mm were collected in low numbers (1 - 2 fish) in 2005 and 2006 but were absent in 2007 and 2008. The length distribution, however, is broad with fish in most years ranging from 450 - 1200 mm.

Length distributions were similar between years (2005 - 2008) for bony herring (Figure 4a) and the three small-bodied species, unspecked hardyhead (Figure 4b), Murray rainbowfish (Figure 5a) and Australian smelt (Figure 5b). All species show a strong annual cohort of small fish.

Common carp length frequency distributions (Figure 6a) show recruitment of YOY fish (~ 100 mm long) in low numbers in 2005 and 2007 and large numbers of fish YOY in 2006. Fish of this size were absent from the 2008 length frequency distribution although there were a small number fish present at 150 - 200 mm in length. The length distribution for goldfish (Figure 6b) ranges from 40 - 220 mm and is similar each year (2005 - 2008).

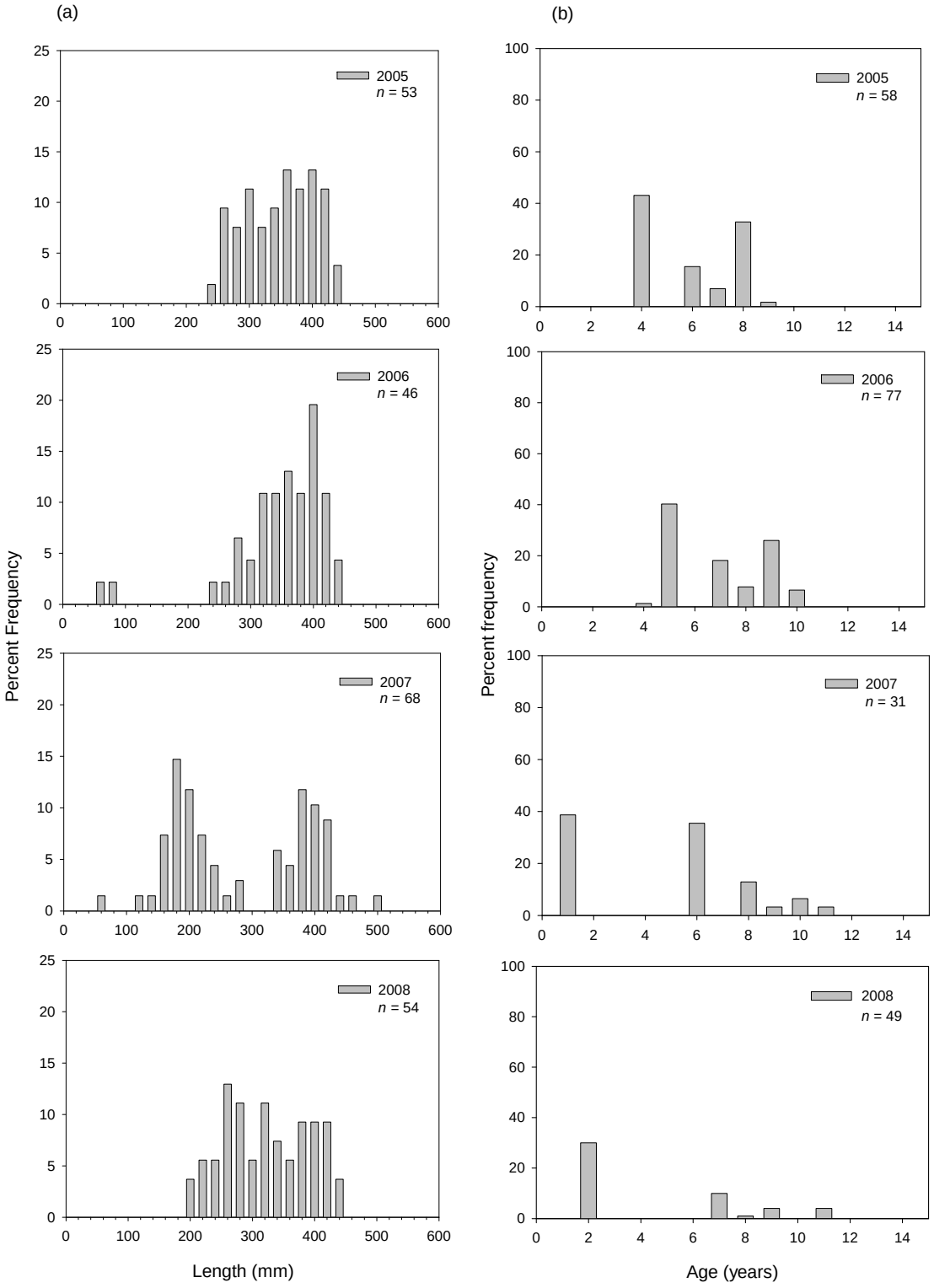

Figure 2. The length distribution (a) and age structure (b) of golden perch captured at sites within the Chowilla Anabranch system in March/April 2005 - 2008.

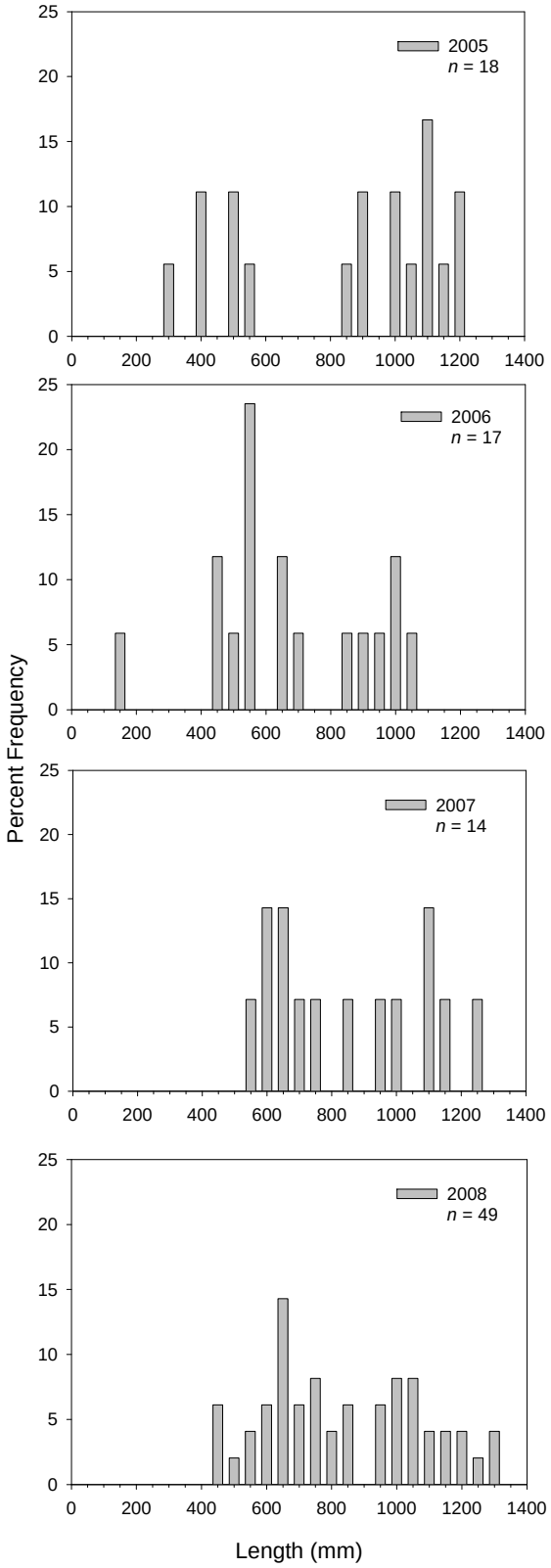

Figure 3. The length distribution of Murray cod captured at sites within the Chowilla Anabranch system in March/April 2005 - 2008.

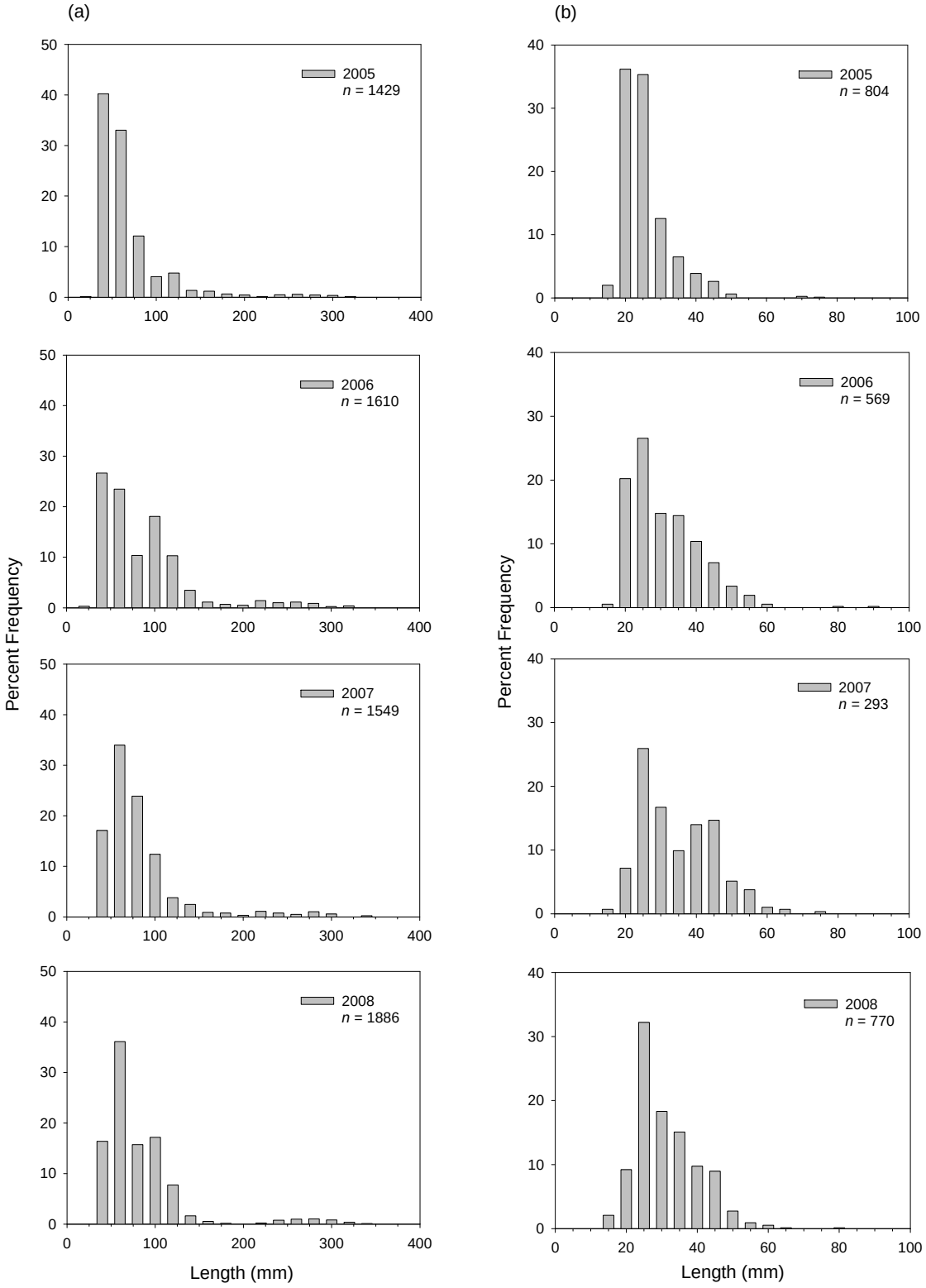

Figure 4. The length distribution of a) bony herring and b) unspecked hardyhead captured at sites within the Chowilla Anabranch system in March/April 2005 - 2008.

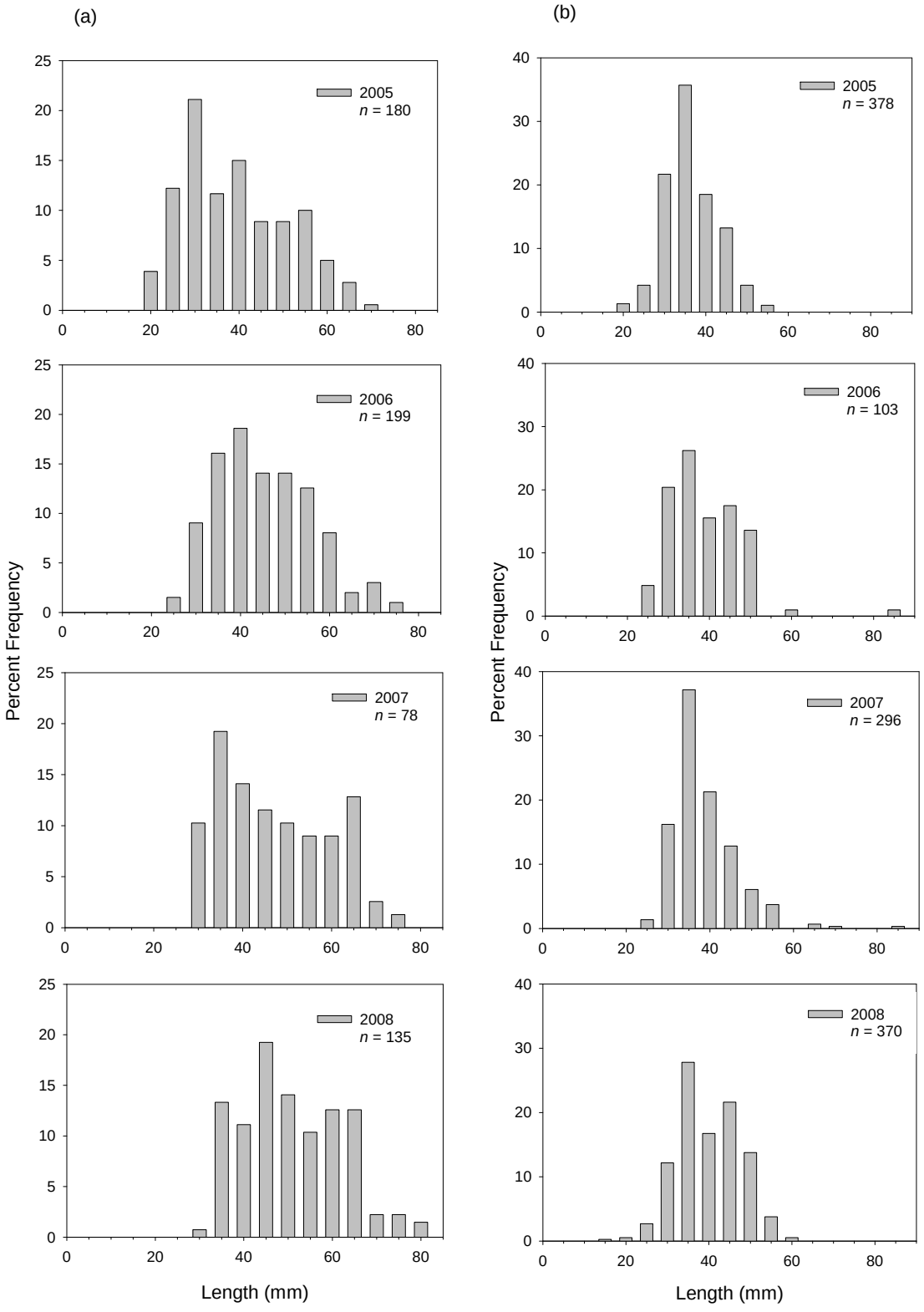

Figure 5. The length distribution of a) Murray rainbowfish and b) Australian smelt captured at sites within the Chowilla Anabranch system in March/April 2005 - 2008.

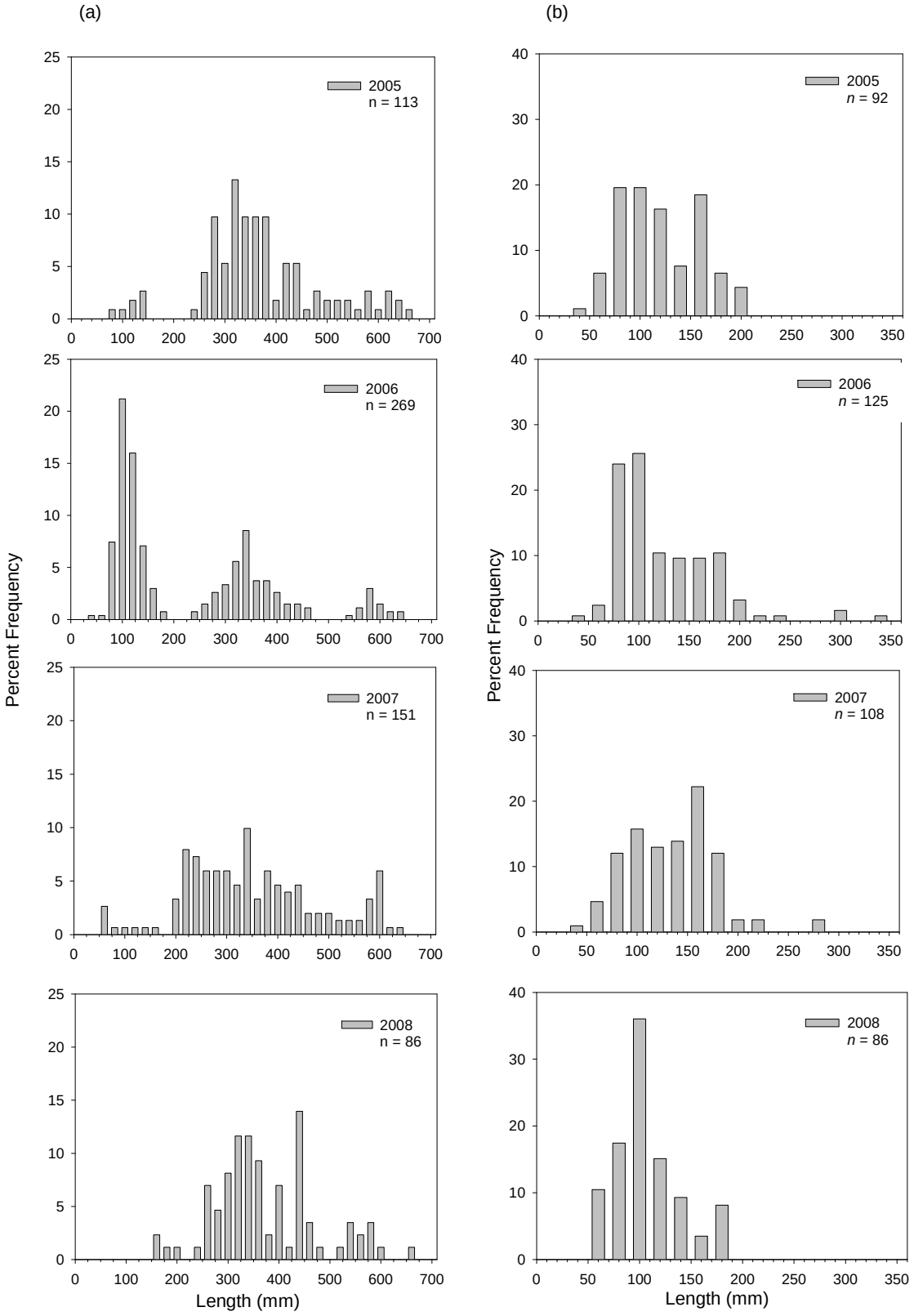

Figure 6. The length distribution of a) common carp and b) goldfish captured at sites within the Chowilla Anabranch system in March/April 2005 - 2008.

Discussion

Abundance

15 fish species (11 native and 4 exotic) were sampled over four sampling events in March/April 2005 - 2008. Only 13 - 14 fish species, however, were captured in any one year due to the absence of species such as freshwater catfish, dwarf flat-headed gudgeon and redfin perch from the catch in one or more years. These three species were captured in low abundances and differences in the presence of these species between years and mesohabitats may be explained by their low abundance in the lower Murray River. The total catch was similar each year but slightly higher in 2008 compared to previous years due to greater numbers of bony herring. Bony herring was also the most abundant species each year followed by the small-bodied species, unspecked hardyhead and Australian smelt.

The abundance of some species varied over the four years and may be related to variability in discharge. Golden perch abundance increased in 2007 mainly due to age 1+ fish while similarly, the abundance of common carp and goldfish (YOY fish) increased in 2006. These fish would have been spawned in the spring/summer of 2005 in association with a small (3,800 - 15,000 ML/d) but prolonged (3 months) increase in discharge to South Australia. For golden perch in particular there is no evidence of spawning/recruiment in any other year during the study period. These observations suggest that the spawning and/or recruitment mechanism for golden perch, common carp and goldfish may be influenced by increased discharge.

The increase in flow during 2005/06 may have also caused a decrease in the abundance of some species. For example, Australian smelt, a short-lived species (1-2 years) that requires slow flowing environments to enhance recruitment, was collected in significantly lower abundances in 2006. This may result from the flow event in 2005 leading to decreased availability of recruitment habitats suitable for Australian smelt. The variable responses to flow by individual species highlight the importance of hydrological heterogeneity in maintaining fish populations in the Murray Darling Basin.

Diversity and distribution of fish species (Target 10)

The distribution and diversity of fish species in the Chowilla Anabranch system were similar across years and most species were widespread throughout the available mesohabitats. Nevertheless, a small number of species were specific to one or more mesohabitat types (e.g. freshwater catfish, dwarf flat-headed gudgeon, redfin perch and Murray cod). Generally these species were captured in low abundances and this may explain some of the variation in their presence/absence from one or more mesohabitat types. Dwarf flat-headed gudgeon was captured in low abundance (n = 1 - 5) in the Murray River in 2005 as well as in fast and slow flowing macrohabitats, and the Murray River, in 2008. Nevertheless, the variation in the distribution of species in the Chowilla Anabranch system may simply reflect the patchy distribution of this species in the Murray-Darling Basin (Lintermans 2007).

Freshwater catfish were captured in fast flowing mesohabitats and only in 2007 in low abundance (n = 2). The distribution and abundance of freshwater catfish in the Murray Darling Basin has declined significantly since 1970/1980's (Clunie and Koehn 2001; Lintermans 2007). Although some aspects of their habitat requirements are not clearly understood this species is considered to prefer a diverse range of structural habitats such as undercut banks, root masses and aquatic vegetation (Clunie and Koehn 2001; Lintermans 2007). This preference for diverse structural habitat may explain why they were captured from only fast flowing creeks in the Chowilla anabranch system (e.g. Slaney and Boat Creek). These creeks are characterised by having diverse and abundant instream habitat including woody debris, aquatic vegetation and variable hydraulic environments (Zampatti and Leigh 2005).

Exotic redfin perch also had a patchy distribution and were only captured in 2007 and 2008. They were present in fast, slow and Murray River mesohabitats in low abundance. Little is documented on the species ecology in the lower Murray River and the low number of individuals captured from the Murray River and Chowilla anabranch over the past four years suggests that they are in low abundance in this region. Due to the scarcity of freshwater catfish, dwarf flat-headed gudgeon and redfin perch over the survey period it is difficult to detect changes in abundance and distribution and thus difficult to assess these species in respect to Target 10.

Murray cod were only captured from fast flowing mesohabitats and the Murray River (2007 only) and, like the freshwater catfish, the limited distribution of this species maybe explained by their habitat requirements. Murray cod prefers habitats with abundant large woody debris (snags) (Koehn and Nicol 1998; Crook and Robertson 1999; Boys and Thoms 2006; Zampatti *et al.* 2006; Jones and Stuart 2007) and has also been positively associated with relatively high water velocities (Koehn and Harrington 2006; Zampatti *et al.* 2006). These factors are likely to limit the distribution of Murray cod in the Chowilla Anabranch system and Murray River main channel.

Fast flowing mesohabitats exhibited the greatest species richness. These mesohabitats are characterised by heterogeneous hydraulic environments and diverse and abundant structural habitat including woody debris and aquatic vegetation (Zampatti and Leigh 2005). This structural complexity is likely to explain the greater species richness in these mesohabitats compared to less complex main channel, slow flowing and backwater habitats (Gorman and Karr 1978; Merigoux *et al.* 1998). Due to time constraints, two out of the three backwater sites were not sampled in 2008, namely the Isle of Mann (site 15) and Monoman Creek (site 16). The observed decrease in species richness in backwater mesohabitats in this year can therefore be largely attributed to the reduced sample size. Overall, the results on fish species diversity and distribution suggest that Target 10 of the Chowilla AEMP is being met.

Recruitment of fish species (Target 12 and 13)

Length frequency data indicate that most small-bodied fish species and bony herring recruited annually from 2005 - 2008. Furthermore, there has been recruitment of golden perch and Murray cod (large-bodied native species) in at least one of the past 5 years in the Chowilla Anabranch system. These data suggest that Targets 12 and 13 of the Chowilla AEMP are being met for these species.

The small-bodied native species and bony herring show consistent recruitment each year. These species are generally short-lived (Milton and Arthington 1983; Humphries *et al.* 1999; Leigh 2002) and consequently have a high turn over of older fish in the population. To ensure the survival of the population in a variable flow environment these species have evolved a life history strategy enabling them to recruit strongly each year regardless of the flow environment (Humphries *et al.* 1999). In comparison, the recruitment pattern of medium-large bodied native species (e.g. golden perch and Murray cod) is more variable

(Anderson *et al.* 1992; Mallen-Cooper and Stuart 2003; Ye and Zampatti 2007). Recruitment of these species does not occur at the same magnitude every year as a result of lack of spawning and/or poor survival of eggs and/or larvae.

Recruitment of Murray cod is difficult to determine in this study, as young fish were generally captured in low abundances and difficult to detect until approximately 300 mm in length. Fish from 200 - 400 mm in length are likely to be approximately two to three years old and four year old fish may range from 500 mm to 700 mm according to available length-at-age data for Murray cod from the lower Murray River (Ye and Zampatti 2007). As several individuals < 500 mm were captured in this study it is likely that low-level recruitment has occurred within the last 5 years in the Chowilla Anabranch system.

The timing and duration of occurrence of Murray cod larvae has been well documented in the main stem and several tributaries of the mid reaches of the Murray River (Humphries *et al.* 2002; Humphries 2005; King *et al.* 2005; Koehn and Harrington 2006) and more recently in the lower Murray River (Leigh *et al.* 2008). Murray cod spawn annually; regardless of flow, therefore the survival of larvae is likely to determine recruitment success (Rowland 1983; Humphries *et al.* 2002; Koehn and Harrington 2006; Leigh *et al.* 2008). Consequently the environmental conditions present during the larval stage may influence the level of recruitment to the adult population. The environmental conditions required to enhance the recruitment of Murray cod are poorly understood (Humphries *et al.* 2002). Recent studies in the Chowilla Anabranch system, however, indicate that flow, particularly small-scale hydraulics, maybe important for the survival of Murray cod larvae (Leigh *et al.* 2008). Since low-level recruitment has been undetectable from the main channel of the lower Murray River during the current low flow period (Ye and Zampatti 2007) we suggest that the Chowilla Anabranch system has provided a diversity of flow and physical habitats that have facilitated the recruitment of Murray cod.

Golden perch and common carp both show a clear recruitment event that corresponds with the small but prolonged within-channel increase in discharge in spring/summer of 2005/06. Nevertheless, the mechanisms promoting recruitment may differ between these species. Golden perch are considered to be a flow-cued spawner (Humphries *et al.* 1999; Mallen-Cooper and Stuart 2003). Larval fish sampling within the Chowilla Anabranch system indicates that increased discharge during the spring/summer 2005/06 is likely to have been a trigger for spawning (Leigh *et al.* 2008). The subsequent survival of larvae to 1+ recruits in

2007 suggests that this increase in discharge may have also facilitated recruitment of this species.

Common carp were significantly more abundant in slow anabranch and backwater sites in 2006 when a strong cohort of 0+ fish was collected. In contrast to golden perch, common carp spawn annually independently of flow (Humphries *et al.* 2002). Consequently increased discharge in 2005 may have increased the number of suitable spawning sites and/or enhanced the survival of eggs and/or larvae (Brown *et al.* 2005). A similar mechanism would also explain the increased abundance of YOY goldfish in 2006.

Conclusions

Condition monitoring of fish assemblages in the Chowilla Anabranch system from 2005 - 2008 indicates that management targets 10, 12 and 13 in the Chowilla AEMP are being met. Nevertheless, extended low flow periods or droughts (such as that occurring from 2001 until present) can increase stress on populations of aquatic species and lead to decreased ability to recover post drought (Bond *et al.* 2008). The persistence of fish through these periods is dependent on refugia, which afford suitable habitat and may also provide conditions appropriate for recruitment (Magoulick and Kobza 2003). In comparison to the main channel of the Murray River in South Australia, the Chowilla Anabranch system supports significantly higher relative abundances of Murray cod and has facilitated recruitment of Murray cod during the current low flow period (Ye and Zampatti 2007). These factors highlight the importance of the Chowilla Anabranch system as a refuge habitat.

As the current low-flow period continues, the diversity, distribution and recruitment of native and exotic fish in the Chowilla Anabranch system and Murray River main channel should be closely monitored. Furthermore, any alteration to the hydrodynamics of the Chowilla system (e.g. changes to discharge via operation of existing and proposed regulatory structures) should be considered and assessed with respect to the maintenance and rehabilitation of native fish populations and the control of exotic species.

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Appendices

Appendix 1. Total number of fish captured at each site in 2005.

	Site Number																
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Total**
Golden perch	7	10	2	5	1	9	10	10	-	6	1	3	2	4	2	3	**75**
Murray cod	-	2	-	1	2	1	2	4	-	-	-	-	-	-	-	-	**12**
Silver perch	1	-	-	-	1	-	-	-	-	-	-	-	2	-	1	-	**5**
Bony herring	503	100	183	27	390	296	462	100	61	184	164	148	124	397	104	727	**3970**
Australian smelt	35	11	36	5	166	25	56	34	29	19	26	20	48	18	1	17	**546**
Murray rainbowfish	15	23	1	17	46	16	30	22	-	13	6	7	124	94	17	4	**435**
Flat-headed gudgeon	2	1	10	-	2	4	4	3	-	3	-	4	10	13	-	2	**58**
Dwarf flat-headed gudgeon	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	**2**
Unspecked hardyhead	131	13	166	20	57	381	76	18	34	79	23	34	413	754	300	101	**2600**
Carp gudgeon spp	3	-	24	5	4	27	14	6	3	7	-	8	24	24	-	97	**254**
Freshwater catfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0**
Common carp	13	-	15	17	19	10	8	11	3	14	12	13	6	16	36	19	**223**
Gambusia	-	-	26	53	10	11	1	2	3	8	-	11	3	6	4	16	**157**
Goldfish	4	-	27	1	-	10	1	1	40	17	19	28	7	1	4	16	**177**
Redfin perch	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0**
Total species	**10**	**11**	**10**	**10**	**11**	**11**	**11**	**11**	**8**	**10**	**7**	**10**	**12**	**10**	**9**	**10**	**13**
Total fish/site	**714**	**183**	**490**	**151**	**698**	**790**	**664**	**211**	**174**	**350**	**251**	**276**	**764**	**1327**	**469**	**1002**	**8527**

Appendix 2. Total number of fish captured at each site in 2006.

	Site Number																
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Total**
Golden perch	3	14	1	10	4	7	6	6	-	1	-	-	6	14	2	1	**75**
Murray cod	-	3	-	2	2	-	1	3	-	-	-	-	-	-	-	-	**11**
Silver perch	1	-	1	-	1	-	-	-	-	-	-	-	2	-	-	-	**5**
Bony herring	640	147	889	98	183	129	889	85	104	209	184	216	695	661	138	966	**6233**
Australian smelt	3	9	5	1	74	15	27	12	1	6	3	1	27	7	-	1	**192**
Murray rainbowfish	5	21	4	12	73	29	84	21	-	3	23	5	40	42	5	29	**396**
Flat-headed gudgeon	-	-	1	1	-	1	1	-	-	1	-	-	1	-	-	1	**7**
Dwarf flat-headed gudgeon		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0**
Unspecked hardyhead	30	53	124	38	113	524	119	28	93	76	16	26	227	132	10	64	**1673**
Carp gudgeon spp	4	6	11	2	3	22	15	1	1	9	5	1	3	9	2	13	**107**
Freshwater catfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0**
Common carp	3	6	57	9	24	26	20	11	13	47	52	48	25	30	47	51	**469**
Gambusia	-	1	1	23	-	5	-	4	-	5	-	7	5	-	1	-	**52**
Goldfish	14	1	13	3	-	21	3	-	14	27	40	24	27	68	8	37	**300**
Redfin perch	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0**
Total species	**9**	**10**	**11**	**11**	**9**	**10**	**10**	**9**	**6**	**10**	**7**	**8**	**11**	**8**	**8**	**9**	**12**
Total fish/site	**703**	**261**	**1107**	**199**	**477**	**779**	**1165**	**171**	**226**	**384**	**323**	**328**	**1058**	**963**	**213**	**1163**	**9520**

Appendix 3. Total number of fish captured at each site in 2007 (site 9 was not sampled).

	Site Number																
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Total**
Golden perch	5	10	17	7	4	9	18	9		5	7	5	8	6	2	2	**114**
Murray cod	-	3	-	1	1	-	1	7		-	-	-	1	-	-	-	**14**
Silver perch	1	-	-	-	-	-	-	-		-	-	-	-	-	-	-	**1**
Bony herring	201	191	170	133	2104	275	935	483		237	170	87	183	90	51	1010	**6320**
Australian smelt	5	49	5	11	142	98	319	45		12	-	-	55	9	-	6	**756**
Murray rainbowfish	6	13	13	15	14	4	26	7		6	-	1	8	7	2	3	**125**
Flat-headed gudgeon	-	-	4	2	-	1	-	-		2	1	1	3	3	2	1	**20**
Dwarf flat-headed gudgeon	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	**0**
Unspecked hardyhead	12	37	15	89	100	158	353	17		34	5	5	298	158	215	99	**1595**
Carp gudgeon spp	6	4	2	5		17	50			7	2	-	5	2	-	7	**107**
Freshwater catfish	-	-	-	1	-	-	-	1		-	-	-	-	-	-	-	**2**
Common carp	19	13	24	9	23	11	12	23		16	26	10	21	13	42	17	**279**
Gambusia	-	2	3	56	2	35	7	-		8	2	4	-	-	2	7	**128**
Goldfish	3	2	10	3	1	6	1	1		35	20	16	1	5	12	61	**177**
Redfin perch	-	-	-	-	-	-	-	-		-	-	-	1	4	2	2	**9**
Total species	**9**	**10**	**10**	**12**	**9**	**10**	**10**	**9**		**10**	**8**	**8**	**11**	**10**	**9**	**11**	**14**
Total fish/site	**258**	**324**	**263**	**332**	**2391**	**614**	**1722**	**593**		**362**	**233**	**129**	**584**	**297**	**330**	**1215**	**9647**

Appendix 4. Total number of fish captured at each site in 2008 (sites 12, 15 and 16 were not sampled).

	Site Number																
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Total**
Golden perch	9	9	3	3	4	13	25	3	-	3	5		3	10			**90**
Murray cod	-	1	-	-	1	-	3	2	-	-	-		-	-			**7**
Silver perch	1	-	-	-	6	-	1	2	-	-	-		-	-			**10**
Bony herring	193	284	391	311	2573	447	1495	783	231	172	246		192	465			**7783**
Australian smelt		63	39	20	274	47	127	63	19	33	9		15	25			**734**
Murray rainbowfish	14	33	-	17	42	5	40	12	-	4	4		15	13			**199**
Flat-headed gudgeon	4	-	4	1	-	1	-	-	-	3	1		1	3			**18**
Dwarf flat-headed gudgeon	1	1	2	-	-	1	-	-	-	-	-		1	5			**11**
Unspecked hardyhead	40	114	53	274	220	376	523	23	23	56	7		103	164			**1976**
Carp gudgeon spp	8	4	3	6	5	6	17	1	1	10	-		2	11			**74**
Freshwater catfish	-	-	-	-	-	-	-	-	-	-	-		-	-			**0**
Common carp	18	12	8	16	29	13	11	24	5	8	14		3	23			**184**
Gambusia	4	2	3	12	1	18	1	1	-	5	2		3	2			**54**
Goldfish	8	2	21	1	-	-	3	7	49	24	25		2	3			**145**
Redfin perch	-	-	-	-	-	-	1	-	-	-	-		-	2			**3**
Total species	**11**	**11**	**10**	**10**	**10**	**10**	**12**	**11**	**6**	**10**	**9**		**11**	**12**			**14**
Total fish/site	**300**	**525**	**527**	**661**	**3155**	**927**	**2247**	**921**	**328**	**318**	**313**		**340**	**726**			**11288**