Inland Waters & Catchment Ecology

Chowilla Icon Site

Fish Assemblage Condition Monitoring

2011

S. J. Leigh and B. P. Zampatti

SARDI Publication No. F2008/000907-3
SARDI Research Report Series No. 597

SARDI Aquatic Sciences
PO Box 120 Henley Beach SA 5022

January 2012

Government of South Australia

Australian Government

MURRAY–DARLING BASIN AUTHORITY

Government of South Australia
Department for Water

Chowilla Icon Site
Fish Assemblage Condition Monitoring
2011

S. J. Leigh and B. P. Zampatti

SARDI Publication No. F2008/000907-3
SARDI Research Report Series No. 597

January 2012

This Publication may be cited as:
Leigh, S. J. and Zampatti, B. P (2012). Chowilla Icon Site – Fish Assemblage Condition Monitoring 2011. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2008/000907-3. SARDI Research Report Series No. 597. 31pp.

South Australian Research and Development Institute
SARDI Aquatic Sciences
2 Hamra Avenue
West Beach SA 5024

Telephone: (08) 8207 5400
Facsimile: (08) 8207 5406
http://www.sardi.sa.gov.au

Printed in Adelaide: January 2012

SARDI Publication No. F2008/000907-3
SARDI Research Report Series No. 597

Author(s): S. J. Leigh and B. P. Zampatti

Reviewer(s): S. Gehrig (SARDI) and J. Whittle (DfW)

Approved by: Dr J. Nicol
A/ Principal Scientist – Inland Waters & Catchment Ecology

Signed:

Date: 30 January 2012

Distribution: DFW, MDBA, SAASC Library, University of Adelaide Library, Parliamentary Library, State Library and National Library

Circulation: Public Domain

Table of Contents

List of Figures

List of Tables

Acknowledgements

Many thanks to the SARDI staff who assisted with field sampling and laboratory processing for the 2011 condition monitoring surveys; namely, Ian Magraith, Paul Jennings, Chris Bice, Neil Wellman, Arron Strawbridge and Phillipa Wilson. We also thank Jason Nicol for his advice and assistance in undertaking the statistical analyses presented in this report.

Robbie Bonner, Darryl Jones, Warren Beer and Tony Waye from SA Water provided space for us to live at Lock 6 and generous hospitality. Thanks to Phil Strachan (Department of Environment and Natural Resources, DENR), Erin Lenon (Department for Water, DFW) and Scott Jaensch (Department of Natural Resources, DNR NSW) for facilitating access to various parts of the Chowilla Game Reserve, and Jock and James Robertson for access to the Chowilla lease.

Thanks to Susan Gehrig (SARDI) and Jan Whittle (DFW) who constructively reviewed a draft of this report. Funding for the 2011 condition monitoring survey was provided by the Murray-Darling Basin Authority (MDBA) Living Murray Initiative through the Department for Water and the project was managed by Mark Schultz (DFW).

Executive Summary

The Chowilla Anabranch and Floodplain system is the largest remaining area of undeveloped floodplain habitat in the lower Murray River. The range of aquatic habitats available within Chowilla is now rare in the region and supports a diverse native fish community. Nevertheless, the Chowilla Floodplain has become increasingly degraded as a consequence of changes to the natural flow regime, grazing and an extended period (2001 – 2010) of low flows in the Murray-Darling Basin. In order to 'enhance and restore' the environmental values of the Chowilla Floodplain, the Department of Water, Land and Biodiversity Conservation developed an Asset Environmental Management Plan as part of the Chowilla Integrated Natural Resource Management Project. Four 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.

To assist with condition monitoring of Targets 10, 12 and 13, annual quantitative fish surveys have been undertaken in the Chowilla system since 2005. Due to variation in sampling efficiency during high water levels in 2011 we have not quantitatively compared 2011 data with that collected during relatively stable water levels from 2005 – 2010.

Results from the 2011 surveys indicate that Targets 10, 12 and 13 are being met. A total of 21,296 fish were captured representing 15 species (11 native and 4 non-native). The most abundant species were non-native common carp and goldfish, followed by native bony herring and golden perch. Previously defined aquatic mesohabitat types were characterised by significantly different fish assemblages. Most species were widespread across mesohabitats, however some species were not captured from all mesohabitats (i.e. Murray cod were not captured from backwaters). Species richness in fast-flowing, slow-flowing and main channel mesohabitats was the same, although species composition in each mesohabitat varied. Backwater mesohabitats had the lowest species richness.

Length-frequency distributions indicate that recruitment occurred for the small-bodied species unspecked hardyhead, Murray rainbowfish and bony herring. Recruitment for Australian smelt, however, was indistinct. For the large-bodied native species golden perch and Murray cod, and non-native common carp and goldfish, recruitment was evident at least once in the last five years.

Introduction

The Chowilla Anabranch and Floodplain system contains the largest remaining area of undeveloped floodplain habitat in the lower Murray River. It is comprised of a series of anabranching creeks, backwaters, wetlands and terminal lakes that bypass Lock and Weir No. 6 on the Murray River. The floodplain and associated anabranch system is part of the Riverland Ramsar site, a wetland of international importance for migratory waterbirds.

Due to approximately 3 m of head differential created by Lock and Weir No. 6, 20 – 90% of Murray River main channel flow is now diverted through the Chowilla system under low flow conditions (i.e. < 10,000 ML/d) (Stace and Greenwood 2004). Consequently, Chowilla exhibits a range of permanent lotic (flowing water) habitats in what previously would have been a combination of perennial and ephemeral streams. As such, river regulation has resulted in a shift in flowing water habitats from the main channel of the Murray River to the Chowilla system.

Due to the loss of lotic habitats in the Murray River main channel, the diversity of aquatic habitats available within Chowilla is now rare within the lower Murray River. As such Chowilla supports a wide range of aquatic organisms (O'Malley and Sheldon 1990) and a diverse native fish community (Lloyd 1990; Pierce 1990; Zampatti *et al.* 2011). The floodplain system, however, has become increasingly degraded as a consequence of changes to the natural flow regime, grazing and drought (MDBC 2006). In response to this and in order to 'enhance and restore' the environmental values of the Chowilla Floodplain system, the Department of Water, Land and Biodiversity Conservation (DWLBC) developed an Asset Environmental Management Plan (AEMP) as part of the Chowilla Integrated Natural Resource Management Project (DWLBC 2006) in which 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 the condition monitoring program is to assess the fish community within the Chowilla system in reference to management targets 10, 12 and 13. In order to achieve this annual quantitative (standardised electrofishing) fish surveys have been undertaken in the Chowilla system since 2005. Data from these surveys are used to investigate spatial and temporal variation in the fish assemblage within the Chowilla system (Target 10) and to determine the recruitment of small-bodied (Target 12) and large-bodied (Target 13) fish. This report summarises the results of the fish condition monitoring surveys undertaken in 2011 with reference to results from 2005 – 2010. In 2010/11, the most significant overbank floods since 1993 occurred in the lower Murray River and, despite delaying fish surveys for approximately 2 months, sampling was undertaken when water levels remained approximately 1.5 m higher than 'normal' regulated pool level. Due to the potential for altered sampling efficiency and effort during high water levels, we have not quantitatively compared data from 2011 to data collected from 2005 – 2010. We have, however, presented abundance and length-frequency data from 2005 – 2010 for qualitative comparison.

Methods

Fish condition monitoring at the Chowilla Icon Site was initially undertaken in 2005 (Zampatti *et al.* 2008). Eighteen sites were identified, representing the range of permanent aquatic mesohabitats present within Chowilla (i.e. fast-flowing anabranches, slow-flowing anabranches, backwaters and the Murray River main channel) as described by Sheldon and Lloyd (1990) (Figure 1). These sites were initially assigned to a mesohabitat category based on visual assessments (Table 1) and were later quantified and, if necessary, revised following the measurement of cross-sectional velocity profiles (based on six cross sections) 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} (Zampatti *et al.* 2008). Four additional sites were surveyed in the New South Wales section of the Chowilla system in 2008 and 2009 (Leigh *et al.* 2010).

In 2011, 21 of the 22 previously defined fish condition monitoring sites were sampled (Table 1 and Figure 1). Fish condition monitoring from 2005 – 2010 was conducted in March/April in order to maximise the likelihood that young-of-year (YOY) individuals from the preceding spring/summer spawning season were represented in the catch, enabling the recruitment of individual fish species to be assessed. These surveys were undertaken following low (i.e. below entitlement) flows (< 7,500 ML/d, 2006/07, 2007/08 and 2008/09) and two small within-channel increases (i.e. above entitlement) in flow (~ 15,000 ML/d, 2005/06 and ~ 10,000 ML/d, 2009/10). The 2011 fish surveys followed a year of significant overbank flow into South Australia (peaking at ~ 93,000 ML/d in February 2011). Due to high river levels and extensive floodplain inundation, surveys were delayed until May 2011 when flow had decreased substantially (~ 45,000 ML/d) in an effort to ensure that a comparable (standard) area was sampled at each site to previous surveys (2005 – 2010). Nevertheless, at the time of the surveys flow was still bankfull and water levels remained ~1.5 m higher than levels previously experienced.

Fish surveys were conducted using a boat mounted 5kW Smith Root Model GPP electrofishing system. At each site 12 (6 on each bank) x 90 second (power on time) electrofishing shots during daylight hours were undertaken. 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, counted 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 and Floodplain system and the adjacent Murray River main channel showing the fish condition monitoring sites 1 – 22.

Table 1 Site number, location and mesohabitat type of fish condition monitoring sites surveyed within the Chowilla Anabranch system and adjacent Murray River main channel from 2005 – 2011. Asterisks denote years when sites were surveyed.

Site No.	Location	Mesohabitat type	2005	2006	2007	2008	2009	2010	2011
1	Chowilla Creek d/s Monoman Creek	Slow-flowing	*	*	*	*	*	*	*
2	Chowilla Creek u/s of Boat Creek	Fast-flowing	*	*	*	*	*	*	*
3	Chowilla Creek d/s Slaney Creek	Fast-flowing	*	*	*	*	*	*	*
4	Boat Creek u/s vehicle bridge	Fast-flowing	*	*	*	*	*	*	*
5	Swiftys Creek d/s Bank I	Fast-flowing	*	*	*	*	*	*	*
6	Pipeclay Creek d/s Pipeclay Weir	Fast-flowing	*	*	*	*	*	*	*
7	Slaney Creek d/s Slaney Weir	Fast-flowing	*	*	*	*	*	*	*
8	Slaney Creek d/s Salt Creek junction	Fast-flowing	*	*	*	*	*	*	*
9	Slaney Billabong	Backwater	*	*		*	*	*	*
10	Hypurna Creek at Wilkadene	Slow-flowing	*	*	*	*	*	*	*
11	Punkah Creek d/s Punkah Island ford	Slow-flowing	*	*	*	*	*	*	*
12	Punkah Creek at Lake Littra	Slow-flowing	*	*	*		*	*	*
13	Murray River 5-7 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 9	Backwater	*	*	*		*	*	*
17	Salt Creek at cliffs (NSW)	Slow-flowing					*	*	*
18	Murray River at Border Cliffs (NSW)	Main River Channel	*				*	*	*
19	Salt Creek d/s Bank K (NSW)	Fast-flowing				*	*	*	*
20	Salt Creek at NSW border (NSW)	Slow-flowing					*	*	*
21	Salt Creek near Tareena Billabong (NSW)	Slow-flowing					*	*	
22	Pilby Billabong	Backwater	*					*	*
		Total number of sites	**18**	**16**	**15**	**14**	**21**	**22**	**21**

Abundance

The abundance of fish is not a specific target set out within the AEMP; nevertheless, changes in abundance may reflect environmental conditions. As such, total and standardised abundances were calculated for each species captured during the 2011 condition monitoring surveys. Total abundances for each fish species were calculated as the number of fish captured in addition to the number of fish observed. Standardised abundances were calculated by dividing the total abundance calculated for each species by the number of sites sampled in that year.

To determine if fish assemblages captured in 2011 were significantly different between aquatic mesohabitats (fast-flowing, slow-flowing, backwater and Murray River main channel) sites were grouped into previously defined mesohabitats (Table 1). A two factor permutational multivariate analysis of variance (PERMANOVA) (Anderson 2001; Anderson and Ter Braak 2003) was performed to investigate if there were differences in the fish community (species and relative abundances) between mesohabitats. Further pair-wise comparisons were undertaken to determine whether there were differences in the fish community between individual mesohabitat types. Indicator species analysis (Dufrene and Legendre 1997) was used to calculate the indicator value (site fidelity and relative abundance) of species between mesohabitats using the package PCOrd v. 5.12 (McCune and Mefford 2005). A perfect indicator remains exclusive to a particular mesohabitat and exhibits strong site fidelity during sampling (Dufrene and Legendre 1997). Statistical significance was determined for each species indicator value using the Monte Carlo (randomisation) technique.

Diversity and distribution of fish species (Target 10)

Sites were grouped into aquatic mesohabitat categories (Table 1) and the diversity and distribution of fish species were described for each mesohabitat. Diversity was defined as the number of fish species (species richness) present within each mesohabitat. Distribution was defined as the number of mesohabitats that each fish species was present in during the 2011 surveys.

Recruitment of fish species (Target 12 and 13)

Length-frequency distributions were considered to be an appropriate method to investigate the recruitment of individual fish species (with the exception of golden perch, *Macquaria ambiguia ambigua*). Length data was used to generate length-frequency histograms for the native small-bodied species (Target 12) unspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*), Murray rainbowfish (*Melanotaenia fluviatilis*) and Australian smelt (*Retropinna semoni*) and bony herring (*Nematalosa erebi*), and large-bodied species (Target 13) golden perch and Murray cod (*Maccullochella peelii*). Although not defined as a target for the AEMP length-frequency histograms were also generated for the non-native species common carp (*Cyprinus carpio*) and goldfish (*Carassius auratus*).

Golden perch exhibit considerable variation in length-at-age in the Murray Darling Basin (Anderson *et al.* 1992; Mallen-Cooper and Stuart 2003). Therefore, to more accurately assess the recruitment of golden perch, we investigated both length and age-frequency distributions. To determine the age of golden perch, thin sectioned otoliths were prepared from a sub sample of fish (n = 62) representing the size range of fish captured during the 2011 survey (adults and juveniles). Individuals were measured (to the nearest millimetre) and the otoliths (sagittae) removed. Whole sagittae were embedded in clear casting resin and a single 400 to 600 μm transverse section 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 discernable opaque zones (annuli) from the primordium to the otolith edge. Young-of-year (YOY, < 1 year old) fish were defined as individuals lacking a clearly discernable annuli.

Murray cod may also show variability in length-at-age (Ye and Zampatti 2007) but due to the conservation status of this species (listed as vulnerable species under the *Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act 1999*) we elected not to use a destructive ageing technique to investigate recruitment. In order to increase the number of individuals for length frequency analysis, length data from Murray cod collected in the Chowilla region for the Sustainable Rivers Audit (SRA) were included in the sample.

Results

Abundance

A total of 21,296 fish from 15 species (11 native and 4 non-native), were captured in the 2011 condition monitoring surveys (Table 2). Total and standardised abundances were similar to 2010 and slightly higher than 2005 – 2009 surveys. Three species of conservation significance were collected, namely Murray cod (*EPBC Act 1999*), freshwater catfish (*Tandanus tandanus*, protected under the South Australia *Fisheries Management Act 2007*) and silver perch (*Bidyanus bidyanus*, protected under the South Australia *Fisheries Management Act 2007*). One spangled perch (*Leiopotherapon unicolour*), a native species not previously collected at Chowilla, was also captured.

The most abundant species were non-native common carp (*n* = 11,602) and goldfish (*n* = 3,945) followed by the native species bony herring (*n* = 2,521) and golden perch (*n* = 802) (Table 2). With the exception of bony herring, these species were captured in greater abundances (total and standardised) than during monitoring undertaken from 2005 – 2010 (Table 2). Increased abundances of Murray rainbowfish and gambusia (*Gambusia holbrooki*) were also observed compared to other years, whilst unspecked hardyhead and Australian smelt were captured in lower abundances (Table 2).

Table 2 Total (captured + observed) and standardised (fish site^{-1}) abundances of fish captured from condition monitoring sites sampled in the Chowilla Anabranch system and adjacent Murray River 2005 – 2011.

Species	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Grand Total**
Golden perch	69	75	112	94	174	114	802	**1440**
(*Macquaria ambigua ambigua*)	(3.8)	(4.7)	(7.5)	(6.7)	(8.3)	(5.2)	(38.2)	
Murray cod	13	11	14	15	21	15	7	**96**
(*Maccullochella peelii*)	(0.7)	(0.7)	(0.97)	(1.1)	(1.0)	(0.7)	(0.3)	
Silver perch	5	5	1	14	8	20	30	**83**
(*Bidyanus bidyanus*)	(0.3)	(0.3)	(0.1)	(1.0)	(0.4)	(0.9)	(1.4)	
Bony herring	3849	6229	6251	7782	10629	17948	2521	**55209**
(*Nematalosa erebi*)	(213.8)	(389.3)	(416.7)	(555.9)	(506.1)	(815.8)	(114.6)	
Australian smelt	526	189	740	803	1067	589	484	**4398**
(*Retropinna semoni*)	(29.2)	(11.8)	(49.3)	(57.4)	(50.8)	(26.8)	(22.0)	
Murray rainbowfish	458	378	123	213	231	240	686	**2329**
(*Melantaenia fluviatilis*)	(25.4)	(23.6)	(8.2)	(15.2)	(11.0)	(10.9)	(31.2)	
Flat-headed gudgeon	93	6	20	18	70	21	11	**239**
(*Philypnodon grandicepts*)	(5.2)	(0.4)	(1.3)	(1.3)	(3.3)	(1.0)	(0.5)	
Dwarf flat-headed gudgeon	2	0	0	11	2	6	0	**21**
(*Philynodon macrostomus*)	(0.1)	0	0	(0.8)	(0.1)	(0.3)	0	
Unspecked hardyhead	2659	1602	1574	1786	2145	1687	455	**11908**
(*Craterocephalus stercusmuscarum fulvus*)	(147.7)	(100.1)	(104.9)	(127.6)	(102.1)	(76.7)	(20.7)	
Carp gudgeon spp.	398	113	104	73	84	153	92	**1017**
(*Hypseleotris* spp.)	(22.1)	(7.1)	(6.9)	(5.2)	(4.0)	(7)	(4.2)	
Freshwater catfish	0	0	1	0	3	2	8	**14**
(*Tandanus tandanus*)	0	0	(0.1)	0	(0.1)	(0.1)	(0.4)	
Common carp*	234	466	277	185	400	357	11602	**13521**
(*Cyprinus carpio*)	(13.0)	(29.1)	(18.5)	(13.2)	(19.1)	(16.2)	(527.4)	
Gambusia*	200	61	125	60	107	490	647	**1690**
(*Gambusia holbrooki*)	(11.1)	(3.8)	(8.3)	(4.3)	(5.1)	(22.3)	(29.4)	
Goldfish*	202	296	177	156	551	217	3945	**5544**
(*Carassius auratus*)	(11.2)	(18.5)	(11.8)	(11.1)	(26.2)	(9.9)	(179.3)	
Redfin perch*	0	0	9	3	7	8	5	**32**
(*Perca fluviatilis*)	0	0	(0.6)	(0.2)	(0.3)	(0.4)	(0.2)	
Spangled perch^	0	0	0	0	0	0	1	**1**
(*Leipotherapon unicolour*)	0	0	0	0	0	0	(0.05)	
Total species	**13**	**12**	**14**	**14**	**15**	**15**	**15**	**16**
Total number of sites	**18**	**16**	**15**	**14**	**21**	**22**	**21**	**22**
Total number of fish	**8708**	**9431**	**9528**	**11213**	**15499**	**21867**	**21296**	**97542**
Standardised total abundance	**483.7**	**589.4**	**635.2**	**800.9**	**738.0**	**934.0**	**969.7**	

*Denotes non-native species, ^ denotes native species captured outside its 'normal' distribution range.

The fish assemblage (species composition and relative abundances) differed between mesohabitats in 2011 (PERMANOVA Psuedo-F = 10.581, df = 3,248, P = 0.001). Pair-wise tests indicate significant differences between the relative abundance of fish species in each mesohabitat type (Table 3).

With the exception of fast-flowing sites, aquatic mesohabitats were characterised by significant indicator species (Table 4). Slow-flowing mesohabitats were characterised by common carp and goldfish. Backwater mesohabitats were characterised by unspecked hardyhead, gambusia, bony herring and carp gudgeon (*Hypseleotris spp*), and Murray River main channel sites by Murray rainbowfish, flat-headed gudgeon (*Philypnodon grandiceps*), Murray cod, golden perch and silver perch.

Table 3 PERMANOVA pair-wise tests comparing the relative abundances of fish species between mesohabitat types. Significant values where Bonferroni corrected $P \leq 0.008$ are highlighted in bold.

Pair-wise	***t***	***P***
Slow vs fast	3.863	**0.001**
Slow vs backwater	3.502	**0.001**
Slow vs Murray River	3.661	**0.001**
Fast vs backwater	3.167	**0.001**
Fast vs Murray River	2.423	**0.002**
Backwater vs Murray River	2.727	**0.001**

Table 4 Indicator species analysis comparing the relative abundance (CPUE) of fish species between mesohabitats. Significant values (where $P \leq 0.05$, highlighted in bold) indicate that a species occurs in a higher relative abundance in a specific mesohabitat type. Values that are not significant indicate that species was either sampled in similar abundance (widespread) or was captured in low abundance (uncommon). NS = not sampled.

	2005 – 2010 surveys		2011 surveys	
Species	**Mesohabitat**	***P* – value**	**Mesohabitat**	***P* – value**
Golden perch	Fast	**0.001**	River	**0.003**
Murray cod	Fast	**<0.001**	River	**0.046**
Silver perch	Fast	**0.003**	River	**0.003**
Bony herring	Backwater	**0.003**	Backwater	**0.035**
Australian smelt	Fast	**<0.001**	Fast	0.112
Murray rainbowfish	River	**<0.001**	River	**<0.001**
Flat-headed gudgeon	Backwater	**0.006**	River	0.6067
Dwarf flat-headed gudgeon	River	**0.034**	NS	NS
Unspecked hardyhead	River	**<0.001**	Backwater	**<0.001**
Carp gudgeon spp.	Backwater	**<0.001**	Backwater	**<0.001**
Freshwater catfish	River	0.272	Backwater	0.181
Common carp*	Backwater	**<0.001**	Slow	**0.040**
Gambusia*	River	**<0.001**	Backwater	**<0.001**
Goldfish*	Backwater	**<0.001**	Slow	**<0.001**
Redfin perch*	River	**<0.001**	River	0.7973
Spangled perch^	NS	NS	Slow	0.6246

Diversity and distribution of fish species (Target 10)

Backwater mesohabitats were characterised by lower species richness (n = 11) than fast-flowing, slow-flowing and Murray River main channel mesohabitats (n = 14). Most species were widespread across all mesohabitat types (Table 5) although, Murray cod, silver perch, and redfin perch (*Perca fluviatilis*) were not captured from backwater mesohabitats. Freshwater catfish were not captured from slow-flowing mesohabitats and the one spangled perch collected was captured at site 12 (Punkah Creek at Lake Littra), a slow-flowing mesohabitat.

Table 5 Number of fish species present in each mesohabitat type for the 2011 fish condition monitoring surveys.* denotes presence.

Common names	Fast-flowing	Slow-flowing	Backwater	Main channel
Golden perch	*	*	*	*
Murray cod	*	*		*
Silver perch	*	*		*
Bony herring	*	*	*	*
Australian smelt	*	*	*	*
Murray rainbowfish	*	*	*	*
Flat-headed gudgeon	*	*	*	*
Dwarf flat-headed gudgeon				
Unspecked hardyhead	*	*	*	*
Carp gudgeon spp.	*	*	*	*
Freshwater catfish	*		*	*
Common carp*	*	*	*	*
Gambusia*	*	*	*	*
Goldfish*	*	*	*	*
Redfin perch*	*	*		*
Spangled perch^		*		
Total species	**14**	**14**	**11**	**14**

Recruitment of small-bodied native species (Target 12) and bony herring

The length-frequency distributions for small-bodied species (i.e. unspecked hardyhead, Murray rainbowfish, Australian smelt) and bony herring show broad ranges in size distribution and modes that are likely to represent an annual cohort of young-of-year fish (Figures 2 – 5). Compared to length frequency distributions from 2005 – 2010, the mode for all species is larger due to the delayed timing of surveys and consequent growth of fish.

Recruitment of large-bodied native (Target 13) and non-native species

The length-frequency distribution of golden perch from the 2011 surveys consists of two modes, individuals ranging in length (TL) from ~ 80 – 300 mm and ~ 300 – 500 mm (Figure 6a). The age structure data indicate that three dominate age classes exist, YOY (0+), 1 and 5 year olds (Figure 6b). YOY and 1 year old fish, represented by the mode of fish ranging from ~ 80 – 300 mm TL, contributed to ~ 82 % of the sample (29 % and 53 % respectively).

Murray cod length-frequency distribution from the 2011 survey consists of individuals ranging in length from ~ 280 – 1200 mm TL (Figure 7). The proportion of the sample < 700 mm is 50 %. Common carp and goldfish both exhibited broad size ranges with a high proportion (~ 78 and 42 % respectively) of small (most likely YOY) individuals (Figure 8 and 9).

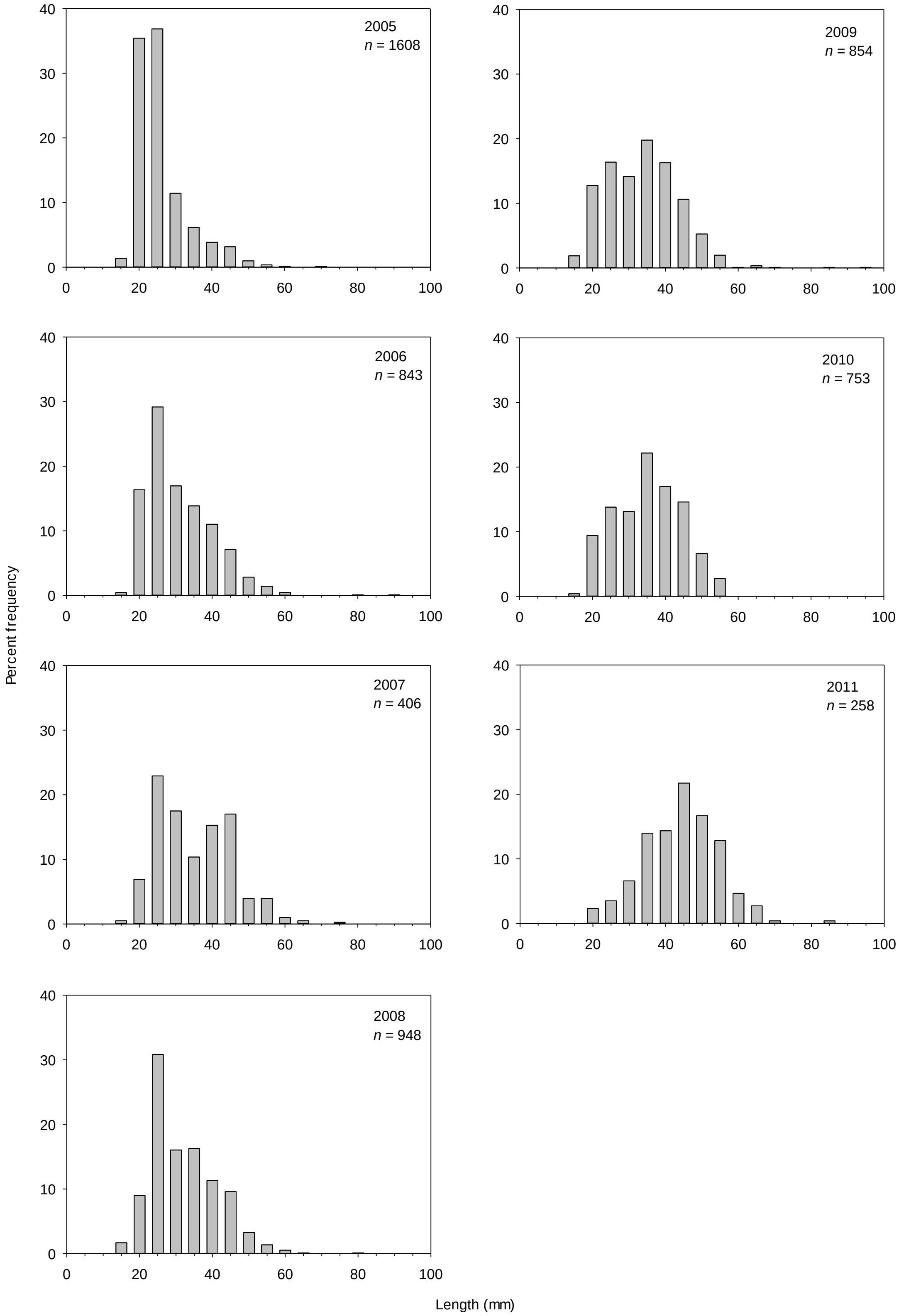

Figure 2 Length distribution of unspecked hardyhead captured at all sites sampled within the Chowilla Anabranch system and adjacent Murray River main channel from 2005 – 2011.

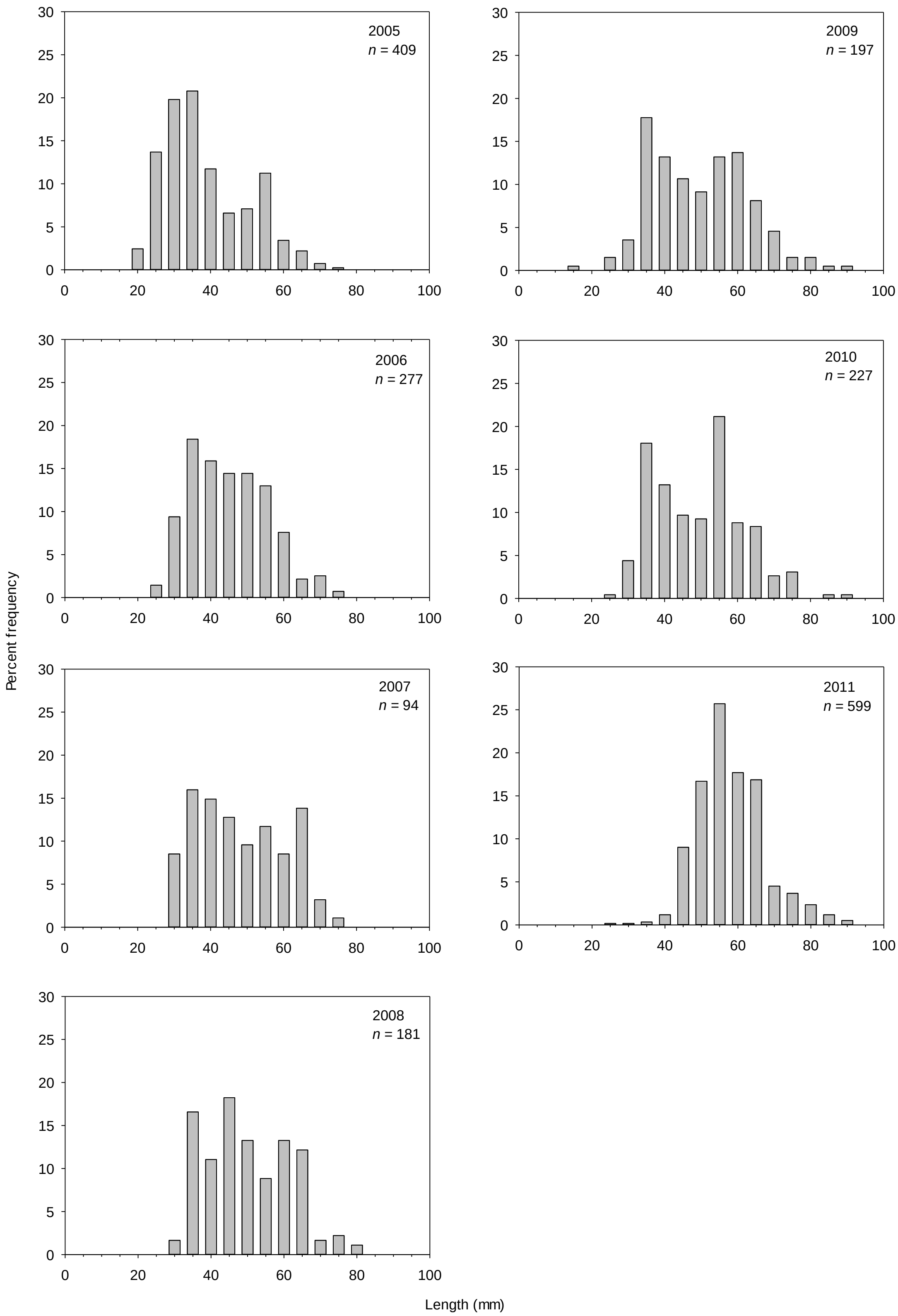

Figure 3 Length distribution of Murray rainbowfish captured at all sites sampled within the Chowilla Anabranch system and the adjacent Murray River main channel from 2005 – 2011.

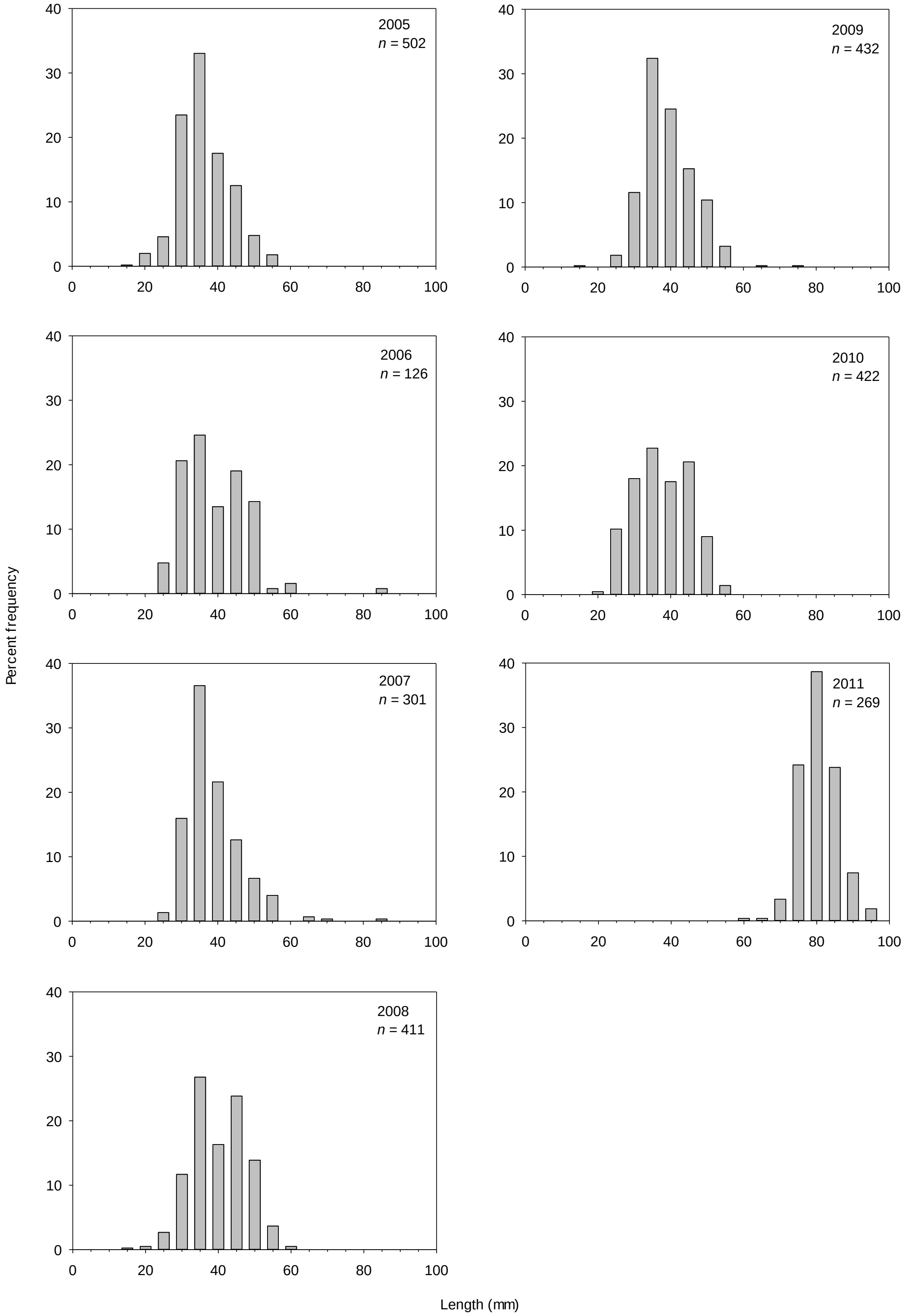

Figure 4 Length distribution of Australian smelt captured at all sites sampled within the Chowilla Anabranch system and the adjacent Murray River main channel from 2005 – 2011.

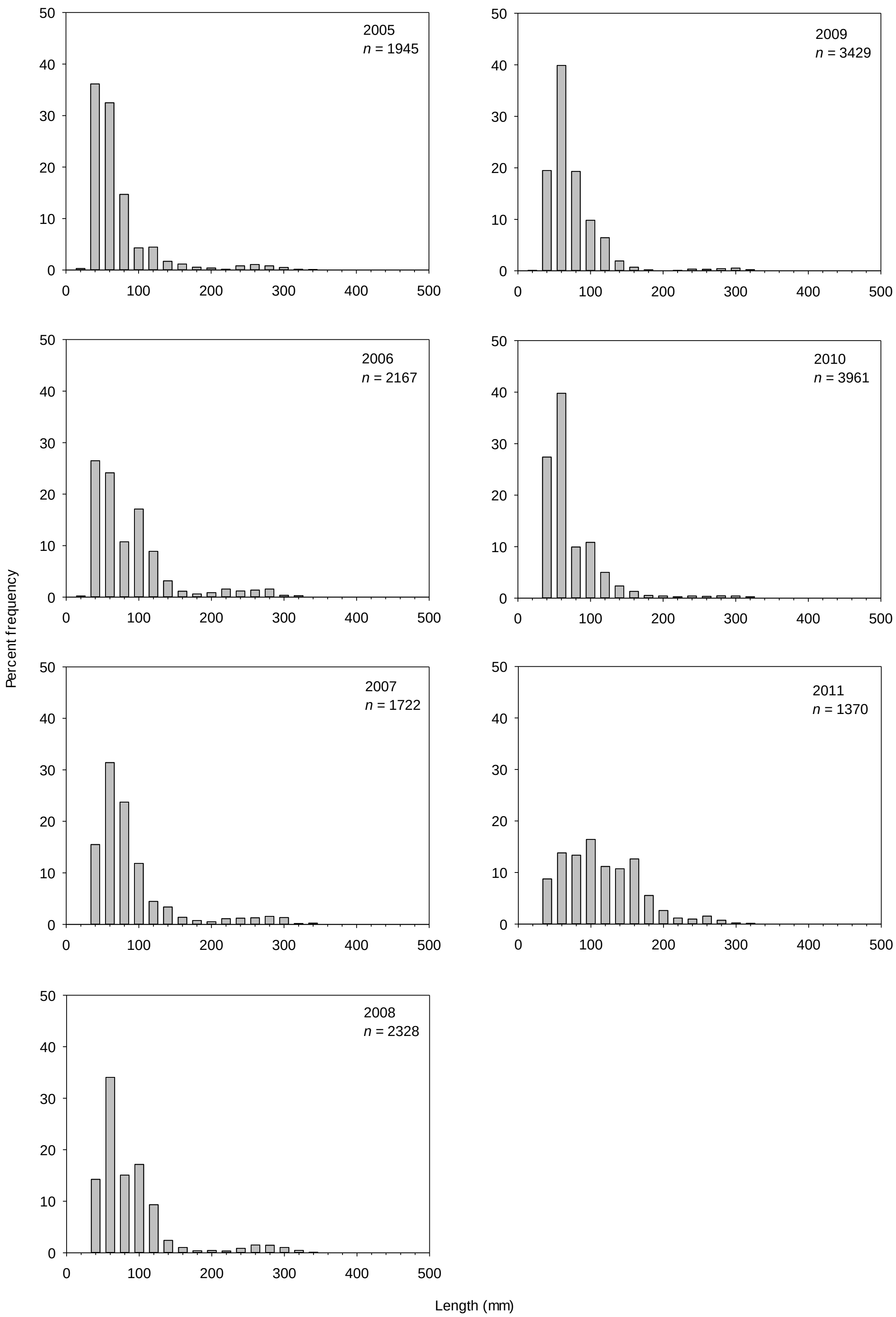

Figure 5 Length distribution of bony herring captured at all sites sampled within the Chowilla Anabranch system and the adjacent Murray River main channel from 2005 – 2011.

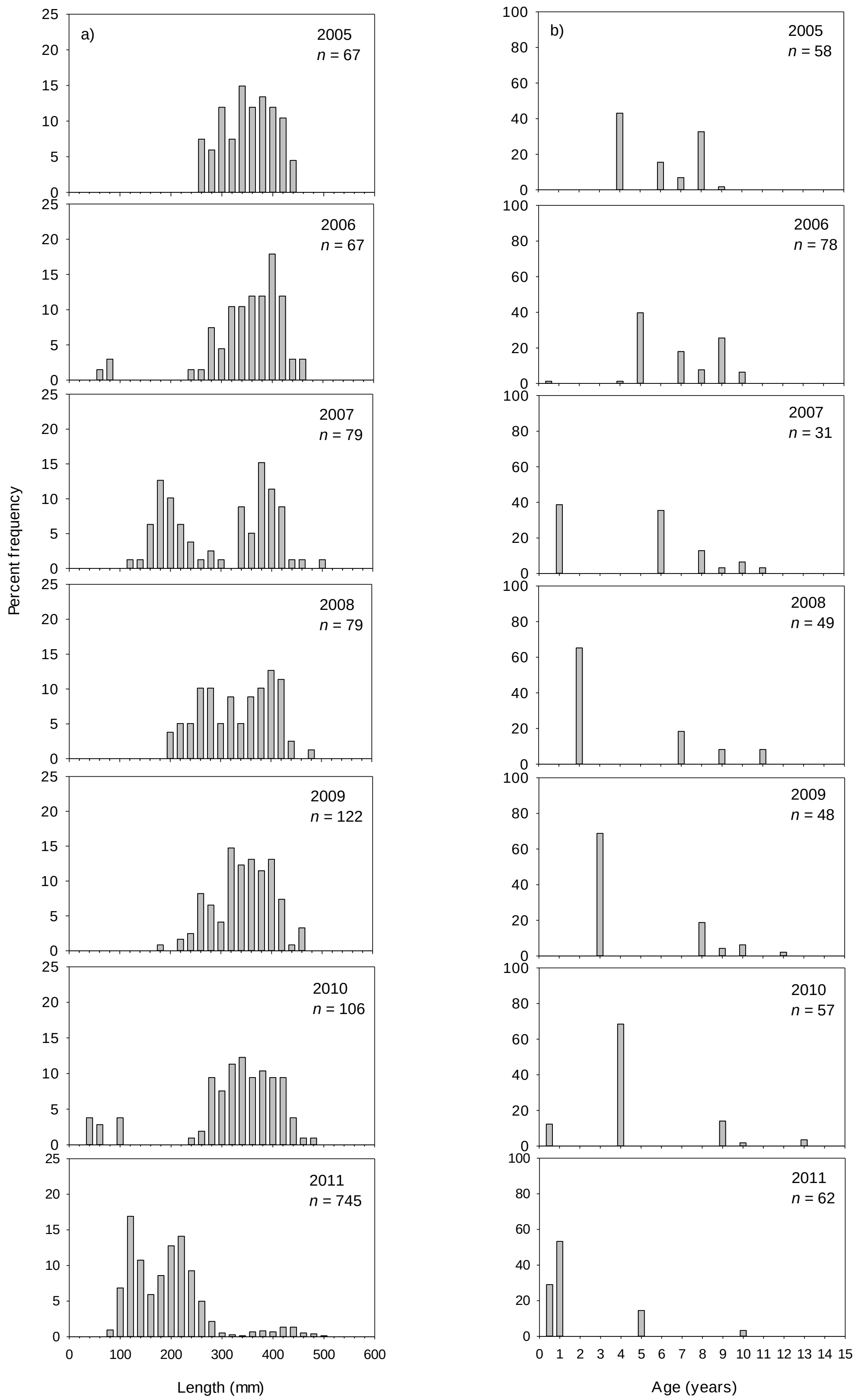

Figure 6 Length distribution (a) and age structure (b) of golden perch captured at all sites sampled within the Chowilla Anabranch system and the adjacent Murray River main channel from 2005 – 2011.

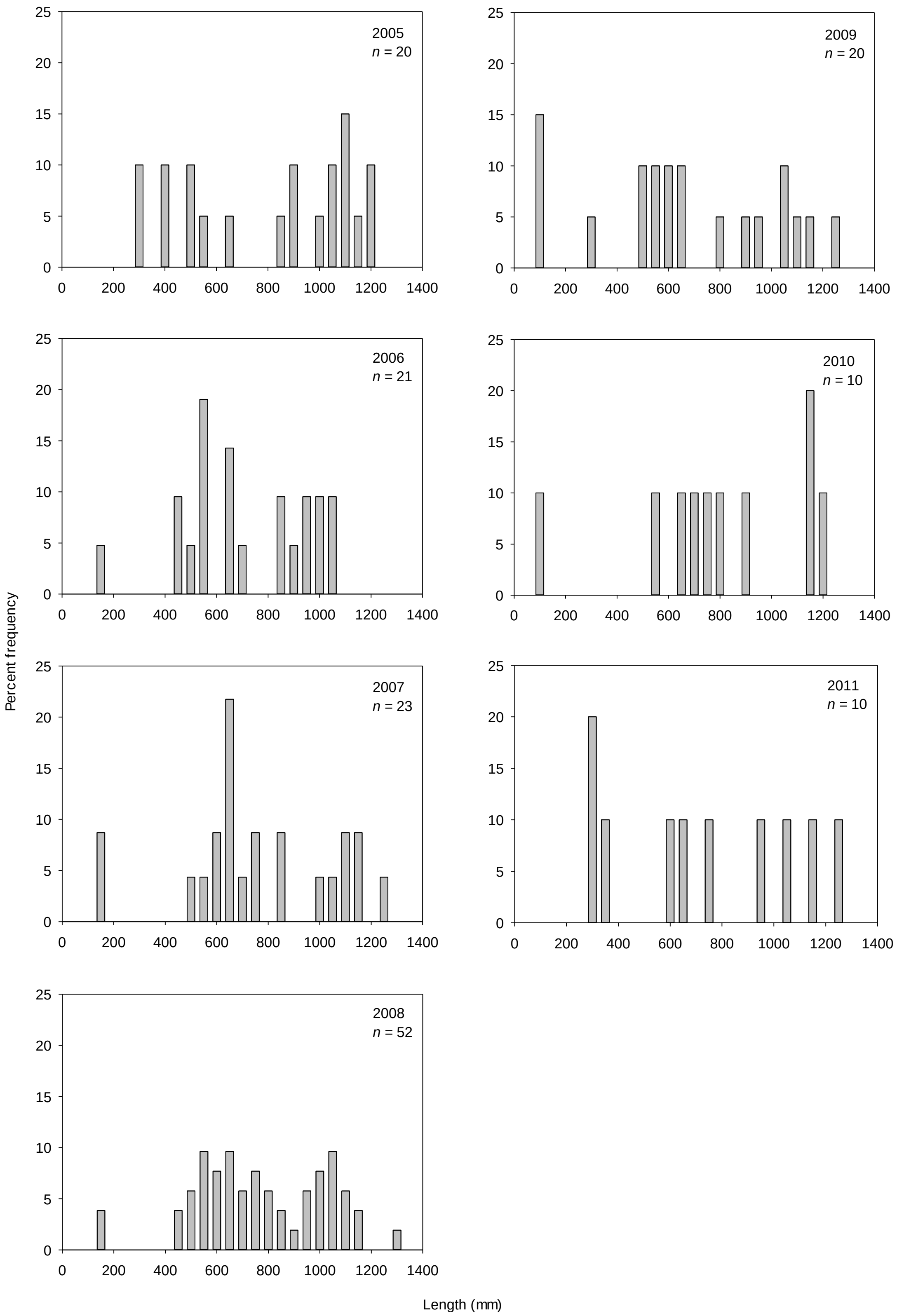

Figure 7 Length distribution of Murray cod captured at all sites sampled within the Chowilla Anabranch system and the adjacent Murray River main channel from 2005 – 2011.

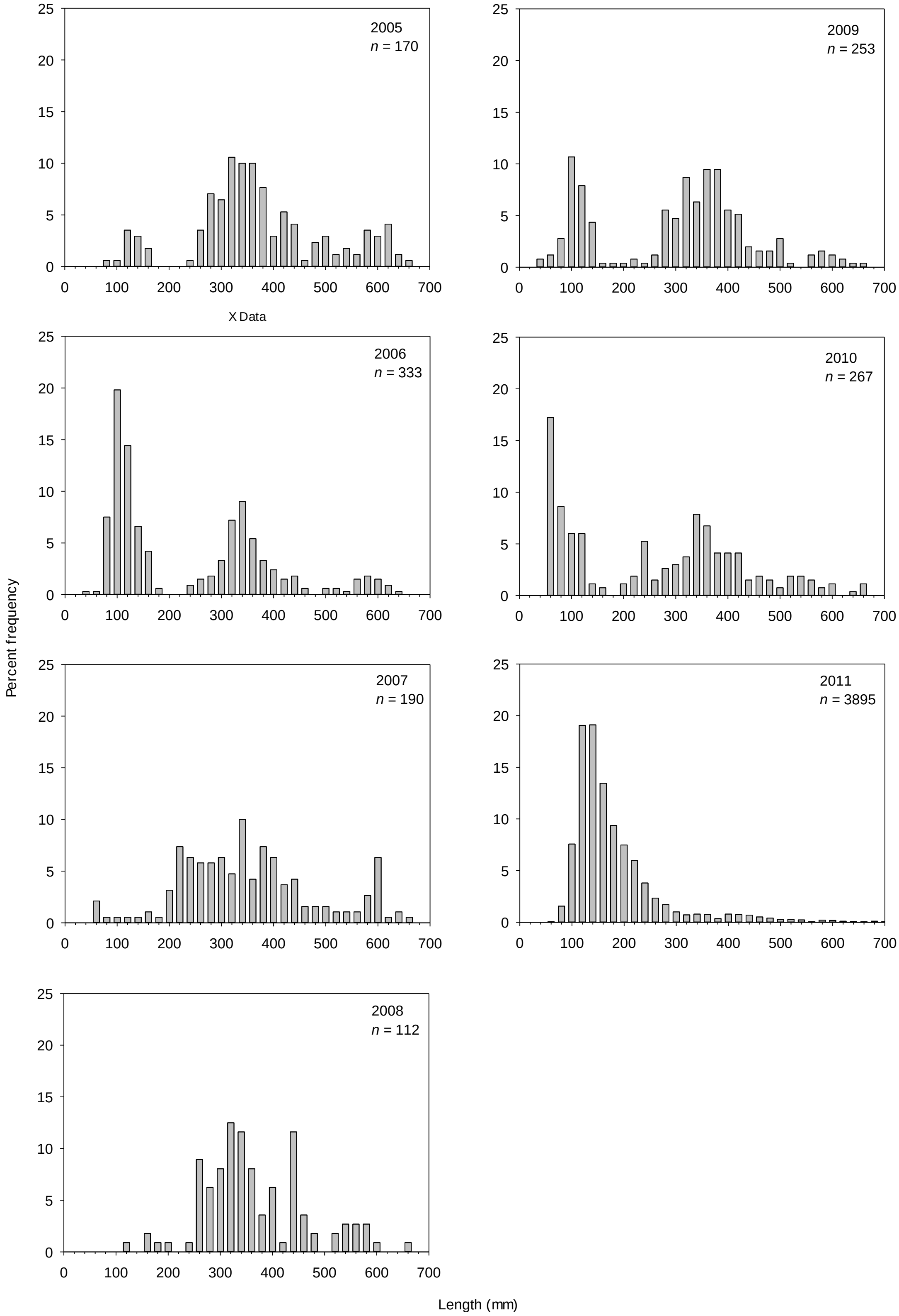

Figure 8 Length distribution of common carp captured at all sites sampled within the Chowilla Anabranch system and the adjacent Murray River main channel from 2005 – 2011.

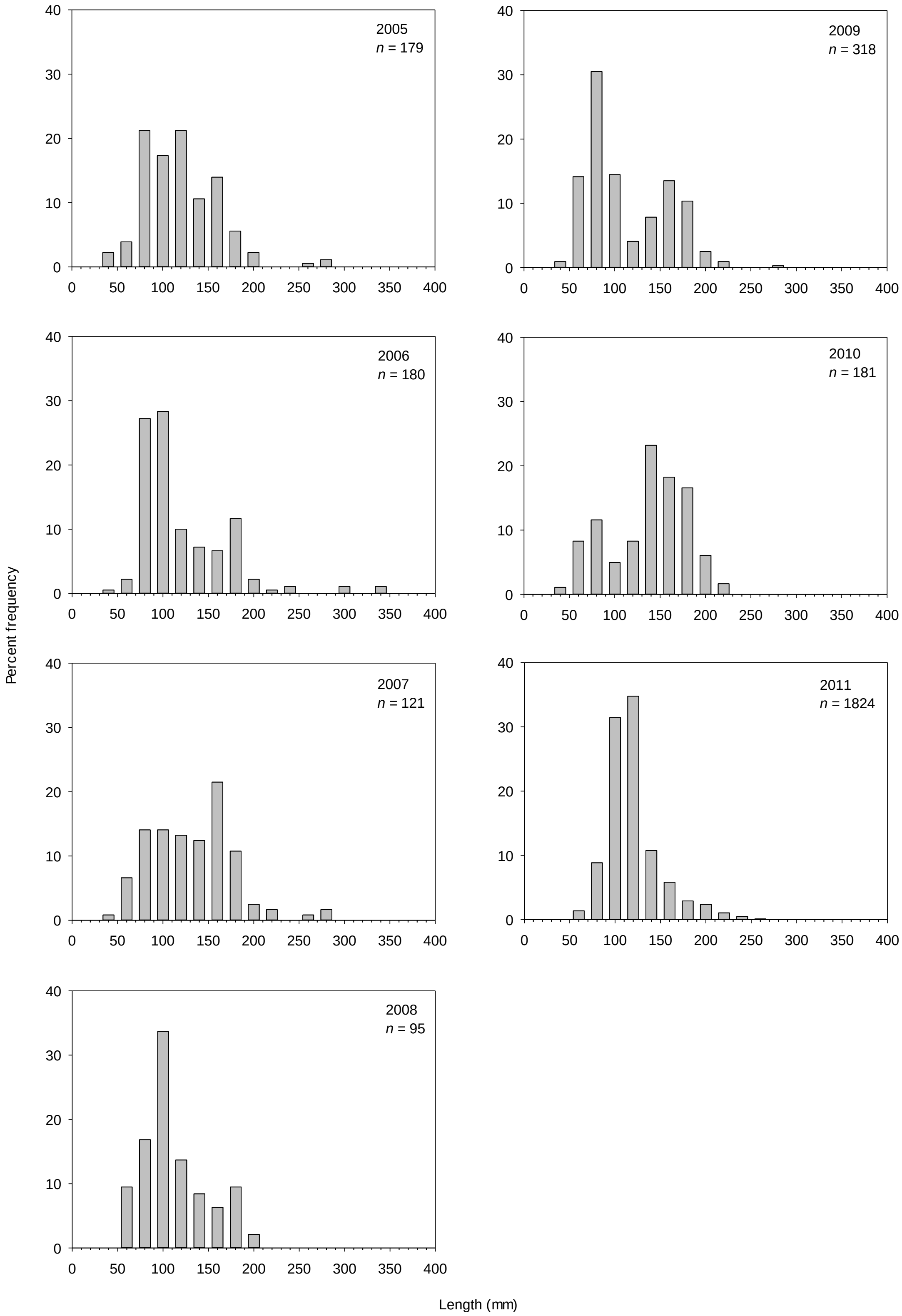

Figure 9 Length distribution of goldfish captured at all sites sampled within the Chowilla Anabranch system and the adjacent Murray River main channel from 2005 – 2011.

Discussion

The 2011 fish condition monitoring followed the most significant overbank flow event (~ 93,000 ML/d) in the lower Murray River since 1993 and delayed fish surveys at the Chowilla Icon Site until May 2011 (~ 2 months later than previous years). At this time, flow in the Murray River was still bankfull (~ 45,000 ML/d) and water levels were approximately 1.5 m higher than 'normal' regulated pool level. Electrofishing under these conditions is likely to result in dissimilar fishing effort (i.e. electrofishing effectiveness and efficiency) to monitoring undertaken at 'normal' regulated pool levels in March/April 2005 – 2010. Consequently, quantitative temporal comparisons of data from 2011 to data collected from 2005 – 2010 have not been undertaken.

Abundance

A total of 21,296 fish were captured during the 2011 survey. Standardised total abundance (970 fish site^{-1}) was similar to the 2010 survey (934 fish site^{-1}) and greater than 2005 – 2009 surveys (484, 589, 635, 801 and 738 fish site^{-1} respectively). Fifteen species of fish were captured (11 native and 4 non-native) including spangled perch a native species not previously recorded in fish condition monitoring surveys.

Non-native common carp and goldfish were the most abundant species followed by the native species bony herring and golden perch. This is in contrast to bony herring, unspecked hardyhead and Australian smelt and non-native common carp being the most abundant species from 2005 – 2010. The high abundances of common carp and goldfish were dominated by large proportions (~ 78 and 42 % respectively) of YOY fish which is likely to be a response to increased spawning and rearing habitat created by extensive overbank flooding. A similar response was observed from non-native gambusia.

The native species golden perch, silver perch and Murray rainbowfish, increased in abundance compared to 2005 – 2010. Golden and silver perch are flow-cued spawners that spawn and exhibit increased recruitment under increased flows (Humphries *et al.* 1999; Mallen-Cooper and Stuart 2003). The abundance of Murray rainbowfish also increased markedly in 2011 and this species was a significant indicator of Murray River main channel sites. Murray rainbowfish are generally regarded to inhabit slow-flowing rivers, wetlands and billabongs (Lintermans 2007) consequently their high abundances in the relatively fast-flowing but hydraulically complex main channel habitats of the Murray River in 2011 offers new insights into the ecology and population dynamics of this species.

The abundance (total and standardised) of unspecked hardyhead, bony herring and Australian smelt decreased in 2011 compared to previous years. From 2005 – 2010 these species were significantly more abundant in lentic habitats (backwater and Murray River mesohabitats) and the decline in relative abundance in 2011 may be due to reduced availability of such habitats during increased flows. Decreased abundances of Australian smelt were recorded in years following periods of increased flow (within-channel, 2006 and 2010 and overbank, 2011) and is consistent with decreases in the abundance of Australian smelt larvae in the lower Murray River during years of increased flow (Cheshire *et al.* 2011).

Murray cod are generally captured in low abundances (range 7 – 21 individuals) in the Chowilla condition monitoring surveys and the standardised abundance of Murray cod captured during the 2011 surveys was slightly lower than previous years. Murray cod have previously been captured from fast-flowing and Murray River main channel mesohabitats in the Chowilla region (Leigh *et al.* 2010; Zampatti *et al.* 2011). As the area and extent of flowing habitat increased as a result of the increased flow in 2010/11, it is possible that Murray cod were more widespread than in previous surveys and not as concentrated in core fast-flowing habitats, making them less susceptible to capture at established sampling sites. There is also the potential that the large-scale blackwater event, which occurred as a result of widespread flooding in the upper and mid Murray catchments in late spring/summer 2010, may have caused extensive mortalities and subsequently reduced abundances of Murray cod.

Spangled perch were captured for the first time in the 2011 condition monitoring surveys (n = 1) and from floodplain and wetland habitats of the Chowilla and Katarapko anabranch systems (authors unpublished data). Spangled perch are widespread throughout the arid northern and central regions of the MDB and the adjacent Lake Eyre and Bulloo catchments (McDowall 1996). The presence of this species at Chowilla highlights the magnitude of the 2010/11 flood event and the scale at which ecological processes occur in the MDB.

Previously quantified aquatic mesohabitats in the Chowilla system and adjacent Murray River main channel (i.e. fast-flowing, slow-flowing, backwater and Murray River main channel) were characterised by significantly different fish assemblages in 2011, however the species contributing to the differences in mesohabitats differed from previous years. In 2011 slow-flowing mesohabitats were characterised by significantly higher abundances of common carp and goldfish. Previously (2005 – 2010) there were no significant indicators of slow-flowing mesohabitats. Backwater mesohabitats in 2011 were characterised by higher abundances of unspecked hardyhead, gambusia, bony herring and carp gudgeon. Backwaters were previously characterised by higher abundances of common carp, goldfish, carp gudegon, flat-headed gudgeon and bony herring.

In 2011, Murray rainbowfish, flat-headed gudgeon, Murray cod, golden perch and silver perch were significant indicators of Murray River main channel sites which had previously been characterised by Murray rainbowfish, dwarf flat-headed gudgeon, unspecked hardyhead, gambusia and redfin perch. Murray cod, golden perch and silver perch were previously indicators of fast-flowing mesohabitats but in 2011 there were no significant indicators of fast-flowing mesohabitats. These differences may be explained by the hydraulic characteristics of mesohabitats in 2011 being substantially different to those measured during relatively stable, low within-channel flows in 2007. Although not quantified in the 2011 surveys, previously distinct aquatic mesohabitats, with the exception of backwaters, could all be described (based on visual observations) as fast-flowing habitats. As such, mesohabitats were homogenised resulting in increased area and extent of flowing habitats compared to previous years. Furthermore the increased water velocities across all mesohabitat types are likely to have resulted in increased hydraulic complexity at the microhabitat scale, particularly in the Murray River main channel.

Diversity and distribution (Target 10)

Fifteen fish species (11 native and 4 non-native) were captured during the 2011 survey. Species richness was the same in fast-flowing, slow-flowing and main channel mesohabitat types (n = 14) however the species composition in each mesohabitat varied. This difference was generally due to the presence or absence of species typically sampled in low abundances (e.g. freshwater catfish, dwarf flat-headed gudgeon and redfin perch). Backwater mesohabitats exhibited the lowest species richness (n = 11). Backwater habitats are generally characterised by shallow, uniform depths and a lack of flow, consequently they are less physically complex than other mesohabitats and this is likely to support a less diverse range of species (Gorman and Karr 1978; Schlosser 1982; Mérigoux *et al.* 1998).

The distribution of species across mesohabitats at Chowilla in 2011 was similar to that recorded from 2005 – 2010; with a few exceptions. From 2005 – 2010 Murray cod were only captured from fast-flowing and main channel sites. In 2011, however, one individual was also captured from a slow-flowing mesohabitat (site 12, Punkah Creek at Lake Littra). Similarly, freshwater catfish were captured for the first time from two backwater sites (Pilby and Slaney Billabongs) in 2011. The broader distribution of species observed in 2011, which were previously only captured from particular habitats, highlights the importance of increased flow in providing spatial and temporal habitat diversity. The presence of dwarf flat-headed gudgeon in previous condition monitoring surveys (2005 – 2010) has been patchy with this species generally being captured in low abundance (range 0 – 11 fish annum^{-1}) and the absence from the catch in 2011 is likely to reflect this.

Recruitment of native species (Target 12 and 13)

Length-frequency distributions for individual species indicated that YOY recruits were generally larger than in previous years due to the 2011 condition monitoring surveys being delayed by approximately 2 months. Despite this, recruitment was observed for the small-bodied species unspecked hardyhead and Murray rainbowfish, and medium-bodied bony herring. Recruitment of Australian smelt, however, was indistinct and may reflect an increase in the size of recruits due to either the timing of surveys or increased growth associated with flood conditions, or may reflect a decrease in spawning and/or recruitment success. Increased growth rates have been observed in fish in response to floods due to increased productivity and availability of food and/or increased foraging area (Jones and Noltie 2007; Gutreuter *et al.* 1999). Nevertheless, coupled with the observed decreases in relative abundance of Australian smelt in 2011 the absence of a distinct YOY cohort more likely reflects decreased spawning and/or recruitment. A similar explanation may apply for the decrease in recruitment of bony herring in 2011.

Recruitment of golden perch and Murray cod would have been expected following flooding in 2010/11 (Mallen-Cooper and Stuart 2003; Ye and Zampatti 2007). Strong recruitment (i.e. presence of YOY fish) was observed for golden perch but YOY Murray cod were not captured. For golden perch, both length and age data suggests that Target 13 is being met. The increased relative abundance observed in 2011 is likely to have resulted following increased recruitment in both the 2009/10 small within-channel (~ 10,000 ML/d) and 2010/11 overbank (~ 93,000 ML/d) flow events, as 1 year olds (2009/10) and YOY (2010/11) contributed a large proportion of the catch in 2011 (53 % and 29 % respectively).

The absence of YOY Murray cod in the 2011 survey suggests that the overbank flows in 2010/11 did not promote strong recruitment. Murray cod spawn annually regardless of flow conditions (Humphries 2005; Koehn and Harrington 2006) and strong recruitment in the lower Murray River is associated with years of high within-channel and overbank flows (Ye and Zampatti. 2007). The absence of YOY Murray cod suggests that some aspect/s of the 2010/11 flow event and/or the extensive black water event in early 2011 were not conducive to the survival of early life history stages. Nevertheless, the presence of Murray cod < 700 mm suggests that a low level of recruitment has occurred in the Chowilla system within the last 5 years and that Target 13 is being met.

Assessing the recruitment of Murray cod based on condition monitoring data alone is challenging and has been highlighted in previous reports (Zampatti *et al.* 2008; Leigh *et al.* 2010). Young fish are difficult to detect until ~400 mm in length (Zampatti *et al.* 2011) and it is possible that YOY were simply not detected. Furthermore the number of Murray cod collected during the fish condition monitoring surveys is generally low. To effectively assess annual variation in Murray cod recruitment, we suggest increasing sampling effort and targeting specific habitats for Murray cod in addition to standardised condition monitoring surveys. Also, the specific aspects of the flow regime that promote recruitment of Murray cod in the lower Murray River remain unclear and we suggest that investigations of recruitment mechanisms need to be conducted under a range of hydrological conditions.

Recruitment of non-native species

Strong recruitment was observed for both common carp and goldfish following the overbank flow event in 2010/11. Increased recruitment was also observed following years of increased discharge and water level that occurred at both the catchment scale (i.e. 100s – 1000 kms) in 2006 and 2010, and at the local scale (i.e. <10 km) during the Slaney Creek flow manipulation in 2009 (Leigh and Zampatti 2011). These observations indicate that increases in water level may enhance recruitment opportunities for common carp and goldfish by increasing spawning effort and/or the availability of appropriate spawning and/or recruitment habitat.

Conclusions

Condition monitoring surveys from 2005 – 2010 were undertaken following low or small within-channel increases in flow. The 2011 surveys followed the most significant overbank flow (~93,000 ML/d) since 1993. Despite delaying surveys by ~ 2 months, flow during the 2011 surveys was ~45,000 ML/d and resulted in homogenisation of previously well delineated aquatic mesohabitats and an increase in the area and extent of flowing (lotic) habitats, particularly within the Murray River main channel.

The results from the 2011 condition monitoring survey indicate that management targets 10, 12 and 13 (as defined in the Chowilla AEMP) are being met. Qualitative comparisons of relative abundance and recruitment data highlight that ecological responses to flow are complex and species specific, reflecting the diversity of life history strategies of fish in the MDB. Strong recruitment was observed for golden perch, common carp and goldfish in 2011, whilst it appears that recruitment of Murray cod, as indicated by the presence of YOY fish, was minimal. Furthermore, recruitment and abundance of Australian smelt and bony herring was lower compared to low flow years. The range of responses observed suggests that environmental flow management strategies may not elicit the same response from all fish species. Therefore consideration of the life histories of native and non-native fish is required in order to successfully manage fish populations in the lower Murray River.

Condition monitoring provides valuable information on the spatial and temporal patterns in fish assemblages. Nevertheless, in order to effectively assess spatial and temporal changes in abundance and recruitment for species which are generally captured in low abundance during condition monitoring surveys (i.e. Murray cod and freshwater catfish), targeted sampling is recommended. Similarly the use of temporary floodplain and wetland habitats by native species is not assessed within the current condition monitoring program.

Based on condition monitoring data alone, the underlying casual mechanisms of observed responses are speculative. Therefore hypothesis based manipulative experiments should be used in conjunction with condition monitoring to test and refine our current conceptual understanding of fish ecology in the lower Murray River. This process is essential in order to effectively manage fish populations, particularly in light of management interventions planned for the Chowilla Icon Site.

References

Anderson, J. R., Morison, A. K. and Ray, D. J. (1992). Validation of the use of thin-sectioned otoliths for determining the age and growth of golden perch, *Macquaria ambigua* (Perciformes : Percichthyidae), in the lower Murray Darling Basin, Australia. *Australian Journal of Marine and Freshwater Research* **43**, 1103-1128.

Anderson, M. J. (2001). A new method for non-parametric analysis of variance. *Austral Ecology* **26**, 32-46.

Anderson, M. J. and Ter Braak, C. J. F. (2003). Permutation tests for multi-factorial analysis of variance. *Journal of Statistical Computation and Simulation* **73**, 85-113.

Cheshire K. M., Ye, Q., Wilson, P. and Bucater, L. (2011). *From drought to flood: Annual variation in larval fish assemblages in a heavily regulated lowland river*. SARDI Aquatic Sciences, Adelaide, 25 pp.

DWLBC (2006). *Asset Environmental Management Plan: Chowilla Floodplain (excluding Lindsay – Wallpolla) Significant Environmental Asset*. Department of Water, Land and Biodiversity Conservation.

Dufrene, M. and Legendre, P. (1997). Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs* **67**, 345-366.

Gorman, O. T. and Karr, J. R. (1978). Habitat structure and stream fish communities. *Ecology* **59(3)**, 507–515.

Gutreuter, S., Bartels, A. D., Irons, K. and Sandheinrich, M. B. (1999). Evaluation of the flood-pulse concept based on statistical models of growth of selected fishes of the Upper Mississippi River system. *Canadian Journal of Fisheries and Aquatic Sciences* **56(12)**, 2282–2291.

Humphries, P., King, A. J. and Koehn, J. D. (1999). Fish, flows and floodplains: links between freshwater fishes and their environment in the Murray-Darling River system, Australia. *Environmental Biology of Fishes* **56**, 129-151.

Humphries, P. (2005). Spawning time and early life history of Murray cod, *Maccullochella peeli peeli* (Mitchell) in an Australian River. *Environmental Biology of Fishes* **72**, 393-407.

Jones, B. D. and Noltie, D. B. (2007). Flooded flathheads: evidence of increased growth in Mississippi River *Pylodictis olivaris* (Pisces: Ictaluridae) following the Great Midwest Flood of 1993. *Hydrobiologia* **592,** 183–209.

Koehn, J. D. and Harrington, D. J. (2006). Environmental conditions and the timing for the spawing of Murray cod (*Maccullochella peelii peelii*) and the endangered trout cod (*M. macquariensis*) in southeastern Australian rivers. *River Research and Applications* **22**, 327–342.

Leigh, S. J., Zampatti, B. P. and Nicol, J. M. (2010). *Chowilla Icon Site – Fish Assemblage Condition Monitoring 2005 - 2010*. South Australian Research and Development Institute (Aquatic

Sciences), Adelaide, 32 pp. SARDI Publication No. F2008/000907-2. SARDI Research Report Series No.517.

Leigh, S. J. and Zampatti B. P. (2011). *Movement and spawning of Murray cod (*Maccullochella peelii*) and golden perch (*Macquaria ambigua ambigua*) in response to a small-scale flow manipulation in the Chowilla Anabranch system*. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, 45 pp. SARDI Publication No. F2010/000646-1. SARDI Research Report Series No. 536.

Lintermans, M. (2007). *Fishes of the Murray-Darling Basin: An introductory guide*. Murray-Darling Basin Commission, Canberra, 157 pp.

Lloyd, L. (1990). Fish communities. In: *Chowilla Floodplain Biological Study* (O'Malley, C. & Sheldon, F., eds), pp. 183–193. Nature Conservation Society of South Australia, Adelaide.

Mallen-Cooper, M. and Stuart, I. (2003). Age, growth and non-flood recruitment of two potamodromous fishes in a larage semi-arid/temperate river system. *River Research and Applications* **19**, 697–719.

McCune, B. and Mefford, M.J. (2005). *PC-ORD Multivariate Analysis of Ecological Data, Version 5*. (MjM Software Design: Glendon Beach, Oregon, USA).

McDowall, R. M. (1996). *Freshwater fishes of south-eastern Australia*. Chatswood, NSW, Reed Books.

MDBC (2006). *The Living Murray Foundation Report on the significant Ecological Assets Targeted in the First Step Decision*. pp 329. Murray-Darling Basin Commission.

Mérigoux, S., Ponton, D. and Mérona, B. (1998). Fish richness and species-habitat relationships in two coastal streams of French Guiana, South America. *Environmental Biology of Fishes* **51,** 25–39.

O'Malley, C. and Sheldon, F. (1990). *Chowilla Floodplain Biological Study*. pp 224. Nature Conservation Society of South Australia, Adelaide.

Pierce, B. E. (1990). *Chowilla Fisheries Investigations*. South Australian Department of Fisheries, Adelaide.

Schlosser, I. J. (1982). Fish community structure and function along two habitat gradients in a headwater stream. *Ecological Monographs* **52(4)**, 395–414.

Sheldon, F. and Lloyd, L. (1990) *Physical limnology and aquatic habitats*. In: Chowilla Floodplain Biological Study (O'Malley, C. and Sheldon, F., eds) pp 121-135. Nature Conservation Society of South Australia, Adelaide.

Stace, P. and Greenwood, A. (2004). *Chowilla Anabranch System Surface Water Information Summary*. Pg 88. Department of Water, Land and Biodiversity Conservation.

Ye, Q. and Zampatti, B. (2007). *Murray cod stock status: the Lower River Murray, South Australia. Stock status report to PIRSA Fisheries*. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, 32 pp. SARDI Publication No. F20007-000211-1.

Zampatti, B. P., Leigh, S. J and Nicol, J M. (2008). *Chowilla Icon site – fish assemblage condition monitoring 2005 – 2008*. South Australian research and development institute (Aquatic Sciences), Adelaide, 38 pp. SARDI Publication No. F2008/000907-1. SARDI Research Report Series Number 319.

Zampatti, B.P., Leigh, S.J. and Nicol, J.M. (2011). *Fish and Aquatic macrophyte communities in the Chowilla Anabranch system, South Australia: A report on investigations from 2004 – 2007*. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, 180 pp. SARDI Aquatic Sciences Publication Number: F2010/000719-1. SARDI research report series number: 525.