Inland Waters & Catchment Ecology

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Intervention monitoring of fish and fish habitats within the Katarapko Anabranch system ('Katfish' Demonstration Reach): Before intervention surveys 2010 and 2011

S. J. Leigh, S.L. Gehrig, P. J. Wilson, B. P. Zampatti and J. M. Nicol

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Executive Summary

The Katarapko Anabranch and Floodplain system bypasses Lock and Weir No. 4 generating a head differential of ~ 3.5 m between the main inlet through Eckert Creek (Bank J) and the confluence of Katarapko Creek and the Murray River. As such Katarapko contains hydraulically diverse aquatic habitats which are now uncommon in the lower Murray River. The diverse aquatic habitats available within Katarapko, supports a diverse fish community.

In 2007 the 'Katfish Reach' initiative was developed to facilitate community involvement and provide a holistic approach to the management of the health of the Katarapko system and its associated floodplain. In order to achieve this, the 'Katfish Reach' Investment proposal describes seven management interventions that are proposed for the site. An intervention monitoring program was developed and implemented to assess the effects of interventions 1 (regulated inundation of the Eckert Island system) and 2 (drying of parts of the Eckert Island system) on fish and fish habitat within the Katarapko system.

This report summarises the intervention data collected in 2010 and 2011. In order to assess the fish community structure (fish abundance, species composition and diversity), habitat (diversity and abundance), fish-habitat associations and recruitment success, fish surveys were carried out using boat electrofishing surveys and fyke netting/box trapping in conjunction with habitat assessments (percentage cover of available habitat types).

Fish abundance, species composition, species richness and recruitment were found to vary between years and can be attributed to different flow conditions experienced between years (small within-channel flow event 2009/2010, overbank flows in 2010/2011). Similarly habitat availability (aquatic macrophyte species and abundance) and fish-habitat associations varied between years.

The variable nature of the responses observed between 2010 and 2011 highlights the importance of collecting 'before' intervention data under a wide range of flow conditions.

Introduction

The Katarapko Anabranch and Floodplain system is one of three large anabranch systems (Chowilla, Katarapko and Pike) in the lower Murray River, South Australia (SA). These anabranch systems bypass Lock and Weir structures on the Murray River main channel and due to the head differential created contain hydraulically diverse aquatic habitats. The Katarapko Anabranch and Floodplain system bypasses Lock and Weir No. 4 generating a head differential of ~3.5 m between the main inlet through Eckert Creek (Bank J) and the confluence of Katarapko Creek and the Murray River. Katarapko is hydraulically diverse, comprising an array of fast-flowing, slow-flowing, backwater and main channel mesohabitats. This diversity contrasts markedly with the Murray River main channel, where water regulation and extraction for irrigation purposes has created a largely lentic habitat in what once was a more heterogeneous (lotic and lentic habitats) system. As such the diversity of aquatic habitats available within these anabranch systems is now uncommon in the lower Murray River (Zampatti *et al.* 2011).

The diverse aquatic habitats available within the Katarapko system, supports a diverse fish community (Leigh *et al.* 2009; Beyer *et al.* 2011). However, fish passage for medium-large bodied species in particular (i.e. golden perch and Murray cod) is likely to be limited during low flow conditions due to three major flow control structures i.e. the Eckert Creek Weir (Bank J), Eckert Creek Log Crossing and Katarapko Stone Weir. These structures are 'overtopped' at ~45,000, 42,000 and 8,000 ML/d respectively suggesting that connectivity is limited for ~7 kms of Eckert Creek at flow < 45,000 ML/d (Leigh *et al.* 2009). This is demonstrated by low abundances of golden perch captured between Bank J and the Log Crossing in 2007 and 2009. Furthermore, during low flow into SA, these structures restrict flow in Eckert and Katarapko creeks decreasing the water velocities experienced in the system. Low velocities in Katarapko Creek in particular may explain the low abundance of Murray cod captured in Katarapko despite the abundance of suitable physical habitat (i.e. large woody debris).

In 2007 the 'Katfish Reach' initiative was developed to facilitate community involvement and provide a holistic approach to the management of the health of the Katarapko Anabranch system and its associated floodplain (Katfish Reach Steering Group 2008a). The 'Katfish Reach' Implementation Plan (Katfish Reach Steering Group 2008a) outlined five key ecological objectives to be undertaken within the Katarapko Anabranch system:

1. Improving the connectivity between river, creek, wetland, and floodplain environments (e.g. the removal of barriers to fish passage and flows)

2. improving environmental flow management for in-channel, wetland and floodplain environments
3. Improving the condition of riparian and aquatic habitats
4. Increasing the population and abundance of native flora and fauna
5. Reducing the impacts from pest plant, animal and native species where applicable

The 'Katfish Reach' Investment proposal describes seven management actions (interventions) that are proposed in order to achieve the ecological objectives outlined (Katfish Reach Steering Group 2008b):

1. Improve spring/summer inundation of Eckert Island at low river flows
2. Temporarily partial dry and vary pool level of Eckert Creek anabranch system
3. Achieve fish passage and increased in-stream flow for Eckert Creek anabranch system
4. Achieve fish passage and increased in-stream flow for Katarapko Creek
5. Improve flows, carp control and fish passage at Ngak Indau Wetland
6. Improve opportunities for wetland inundation frequency and duration at temporary wetlands 1541, 408, 399 & 900 and the Katarapko Island Saline Water Disposal Basin
7. Reduce and control carp populations in the Katfish Reach area.

In order to assess the response of fish and fish habitats to the interventions proposed for Katarapko, a hypothesis-based fish ecology monitoring program was developed (Beyer *et al.* 2009a). Within this plan, conceptual models based on the current understanding of fish ecology within the Katarapko system and the lower Murray River, and details of the proposed operating regime provided in the Katfish Reach investment proposal (Katfish Reach Steering Group 2008b) were developed in order to assist in predicting the fish and habitat response to the management interventions proposed.

In 2010 an intervention monitoring program (Beyer *et al.* 2009b) was developed and implemented for interventions 1 and 2 with funding from the Murray-Darling Basin Authority's (MDBA) Native Fish Strategy (NFS). The overall objective of the intervention monitoring is to assess the effects of interventions 1 and 2 on fish and fish habitat within the Katarapko system. Specifically the aims are to assess changes over time in: 1) the fish community structure (fish abundance, species composition and diversity); 2) habitat diversity, abundance and fish-habitat associations; and 3) recruitment success for individual fish species, in response to intervention 1 (artificial inundation of the Eckert Island system) and intervention 2 (artificial drying of parts of the Eckert Island system).

This report summarises 'before' intervention data collected in 2010 and 2011. Assessment of the response of fish and fish habitats to interventions 1 and 2 can only be undertaken after the interventions are implemented and 'after' intervention monitoring data are collected.

Methods

Site selection and mesohabitat classification

As part of initial investigations of the fish assemblage structure within the Katarapko system, twelve sites (sites 1 – 12) were surveyed in 2007 within the Katarapko system and adjacent Murray River main channel (Leigh *et al.* 2007). The twelve original sites and two additional sites (sites 1 – 14) were surveyed in 2009 for fish and fish habitat condition monitoring (Leigh *et al.* 2009).

In order to assess the response of fish and fish habitats to intervention 1 and 2, and to provide sufficient replication required for the Before-After-Control-Impact-Paired (BACIP) design chosen for the monitoring program (Beyer *et al.* 2009), some additional sites were chosen. To account for the variation in fish community structure and habitat association in different aquatic mesohabitat types within the Katarapko system (Leigh *et al.* 2009), the system was divided into mesohabitat types based on visual assessments. For each intervention, reaches potentially unaffected by the intervention were chosen as 'control' sites, whilst reaches potentially affected by the intervention were chosen as 'impact' sites. A total of 22 sites were selected (Figure 1).

The first year of 'before' intervention monitoring was undertaken in April 2010. In 2011 'before' intervention surveys were delayed until May/June due to high river levels and three sites were unable to be surveyed due to access problems (Table 1).

Table 1. Details of intervention monitoring sites, fish survey method used, mesohabitat type and year sampled (*). Eboat: boat electrofishing survey.

Site	Name	Fishing method	Mesohabitat	2010	2011
1	Eckert Creek d/s Weir (~1 km)	Eboat	Fast-flowing	*	
2	Eckert Wide Water d/s	Eboat	Backwater	*	*
3	Eckert Creek u/s Log Crossing	Eboat	Slow-flowing	*	*
4	Eckert Creek d/s Log Crossing	Eboat	Fast-flowing	*	*
5	The Splash Upstream	Eboat	Backwater	*	*
6	Katarapko d/s Weir	Eboat	Slow-flowing	*	*
7	Katarapko Creek u/s (Katarapko Island)	Eboat	Slow-flowing	*	*
8	Katarapko Creek mid (campsite 16)	Eboat	Slow-flowing	*	*
9	Katarapko Creek d/s (campsite 30)	Eboat	Slow-flowing	*	*
10	Murray 3.5 km d/s of Lock 4	Eboat	Murray River	*	*
11	Murray 10 km d/s of Lock 4	Eboat	Murray River	*	*
12	Murray d/s of Katarapko Junction	Eboat	Murray River	*	*
13	Eckert Creek d/s Ford	Eboat	Slow-flowing	*	*
14	Murray u/s of Lock 4	Eboat	Murray River	*	*
16	The Splash d/s	Eboat	Backwater	*	*
17	Eckert Creek d/s	Fyke net/box trap	Fast-flowing	*	*
18	Eckert Creek u/s	Eboat	Fast-flowing	*	*
19	Sawmill Creek	Fyke net/box trap	Slow-flowing	*	*
20	Eckert Wide Water u/s	Eboat	Backwater	*	
22	Eckert Creek immed d/s Eckert Weir	Eboat	Fast-flowing	*	
23	Eckert Northern Arm	Fyke net/box trap	Slow-flowing	*	*
24	Eckert Southern Arm	Fyke net/box trap	Slow-flowing	*	*

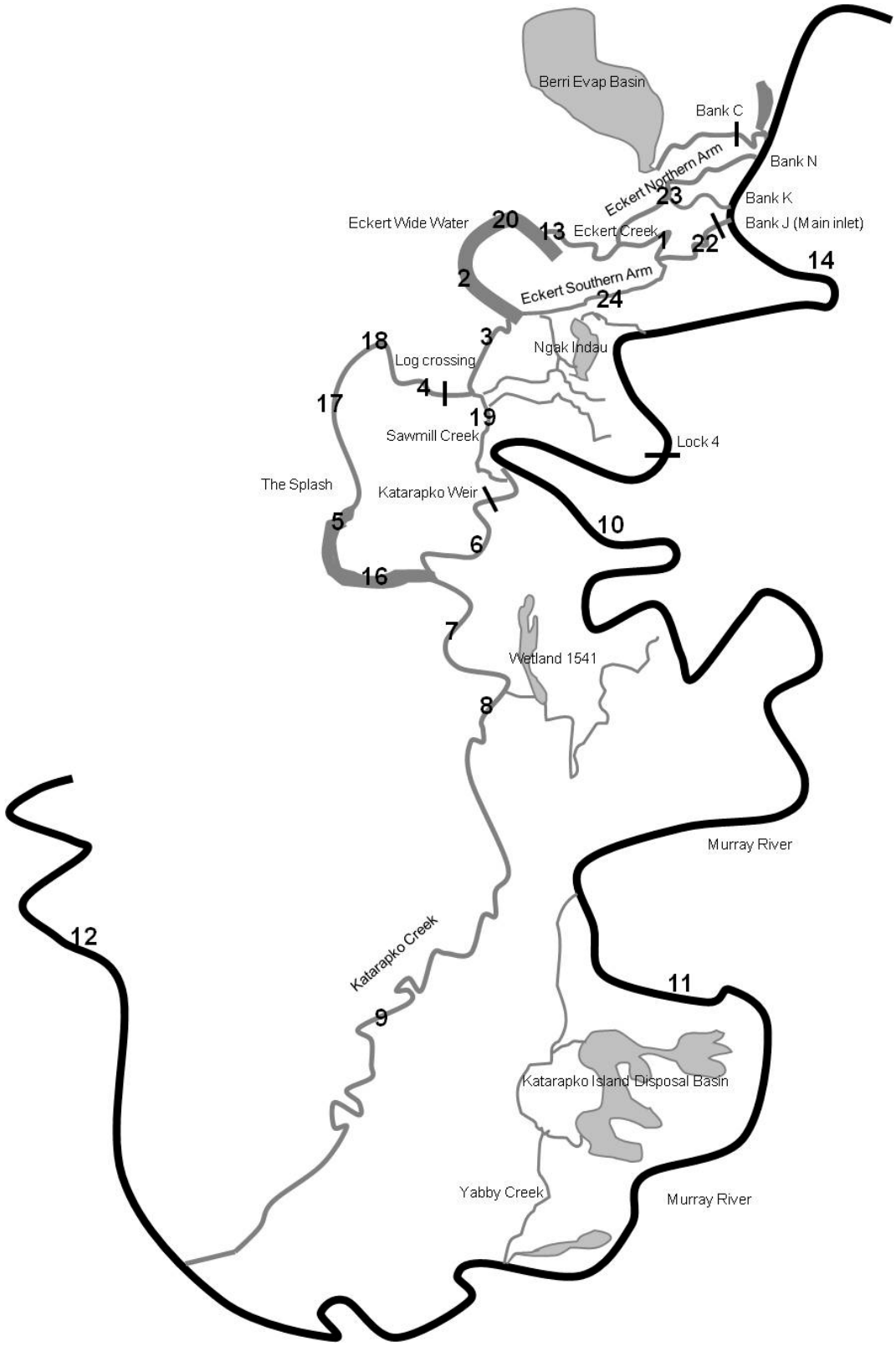

Figure 1. Map of the 22 intervention monitoring sites surveyed as part of the before intervention monitoring of the Katarapko Anabranch system in 2010 and 2011.

Data collection

Fish community structure (abundance, composition and richness) and recruitment success

Boat electrofishing surveys were used to assess the fish community structure and the recruitment success of individual species. Surveys were conducted using a boat mounted 5kW Smith-Root electrofishing system. At each site, 12 (six on each bank) x 90 second (power on time) electrofishing shots were conducted during daylight hours. All fish were dip-netted and placed in a recirculating well. Fish from each shot were identified and a sub-sample of 20 individuals measured for length (fork or total length, mm). Any positively identified fish unable to be dip-netted were recorded as "observed".

Where efficient electrofishing from a boat was not possible (n = 4), a combination of fyke netting and box trapping was used to assess the fish community structure and recruitment success. At each fyke net/box trap site, three single-winged fyke nets (wing length 6 m, stretched mesh size 3 mm) and two unbaited box traps (stretched mesh 1 mm, 24 x 24 x 40 cm) were set overnight. Where possible, fyke nets were positioned perpendicular to the bank. Box traps were set randomly amongst the fyke nets.

The relationship between length and age for golden perch (*Macquaria ambigua ambigua*) is highly variable (Anderson *et al.* 1992; Mallen-Cooper and Stuart 2003). Therefore, to assess recruitment for this species a sub-sample of fish was euthanized and age was determined using thin sectioned otoliths. Otoliths were prepared using the methodology described in Anderson *et al.* (1992). 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. Otoliths were accepted if two or more readers agreed on the number of annuli. If all three readers differed in the estimate of age for an individual then the otolith was rejected. Young-of-year (YOY) fish (individuals < 1 year old) were defined as fish lacking a clearly discernable annulus.

Habitat assessments (microhabitat)

Simultaneously to the fish surveys (electrofishing and fyke net/box trap), quantitative assessments of the percentage cover of microhabitat types present within the site were carried out. These included individual aquatic and riparian plant species (i.e. aquatic emergent, submergent and floating species, overhanging or inundated riparian species), species complexes (i.e. mixed plant species) and physical structure (i.e. coarse woody debris (CWD), tree roots). Assessment methods varied slightly between electrofishing sites and fyke net/box trap sites. At electrofishing sites (Table 1) habitat assessments were carried out within the effective fishing area for each 90 second shot (Zampatti *et al.* 2011). For fyke net/box trap sites (Table 1) habitat was assessed within a 10 m radius around individual fyke nets and box traps. Submerged vegetation

was sampled using a van Veen grab to verify identification to species, where necessary. Microhabitat types were also categorised into relevant functional groups (e.g. emergent, submergent, structural and/or complex).

Data analysis

For the purpose of describing the before intervention monitoring data, data collected from the electrofishing and fyke net/box trap sites were combined. However, to assess the response of fish and fish habitats following the interventions, data from sites sampled using different fishing methods were treated separately.

Fish community structure (abundance, species richness and distribution)

Despite flow conditions differing between the two survey years (2010 and 2011), sites were grouped into mesohabitat categories as per their original assignment (Table 1) in order to investigate changes in fish and fish habitat within the system. Total and standardised abundance was calculated for individual species captured in 2010 and 2011 for each mesohabitat. Total abundance was calculated as the captured + observed. Standardised abundance was calculated as the total abundance divided by the number of sites sampled in each year. Species richness was determined as the number of species captured in each mesohabitat type. Species distribution was assessed by determining the presence or absence of individual species in each mesohabitat type.

Recruitment success

Where a sufficient number of individuals were captured, length frequency distributions were generated to assist in describing recruitment patterns. The presence, absence and characteristics of length modes were used to describe recruitment. For golden perch (which exhibit considerable variation in length at age) age frequency distributions were also generated from age data collected by interpretation of otolith microstructure.

Habitat assessments (diversity, abundance and habitat associations)

Habitat diversity and abundance was described by interpreting data collected from habitat assessments at each site. Micro-mesohabitat associations were investigated using two factor permutational multivariate analysis of variance (PERMANOVA) (Anderson 2001; Anderson and Ter Braak 2003) performed on unpooled data to investigate if there were differences in microhabitat (individual aquatic and riparian plant species:. aquatic emergent, submergent and floating species, overhanging or inundated riparian species), species complexes (mixed plant species) and physical structure (CWD, tree roots) between years (2010 and 2011) and between mesohabitats (fast-flowing, slow-flowing, backwater and Murray River main channel). Indicator species analysis (Dufrene and Legendre 1997) using the package PCOrd version 5.12 (McCune

and Mefford 2006) was used to investigate if a specific microhabitat type was significantly associated with a particular mesohabitat type for each year (2010 and 2011).

Habitat use

Fish-mesohabitat associations

A two factor PERMANOVA was performed on unpooled data to investigate if there were differences in the fish community (species and abundances) between years (2010 and 2011) and between mesohabitats (fast-flowing, slow-flowing, backwater and Murray River main channel). Indicator species analysis was used to investigate if a specific fish species was significantly associated with a particular mesohabitat type for each year (2010 and 2011).

Fish-microhabitat associations

A two factor PERMANOVA was performed on unpooled data to investigate if there were differences in fish abundance between years (2010 and 2011) and between microhabitats. Indicator species analysis was then used to investigate if a specific fish species was significantly associated (positively or negatively) with a particular microhabitat type (aquatic vegetation type or CWD category) for each year (2010 and 2011).

Results

Fish community structure

Abundance

A total of 43,235 fish were captured during the 'before' intervention monitoring surveys in 2010 and 2011 (Table 2). Both total abundance and total standardised abundances were greater in 2011 than in 2010. In 2010, the native species bony herring, unspecked hardyhead and Australian smelt were most abundant. In 2011, the most abundant species were the non-native common carp and goldfish. The abundances of golden perch, Murray rainbowfish, carp gudgeon, common carp, Gambusia and goldfish were greater in 2011, whereas the abundance of Australian smelt and bony herring was greater in 2010.

Species richness and distribution

A total of 16 species were captured over the two years and species richness (number of species) was greater in Murray River main channel sites (Table 3 and Table 4). Fifteen species were captured in 2010, whilst all 16 species were captured in 2011. In 2010, the number of species captured in fast-flowing sites ranged between 8 and 11 species. Species richness ranged between 7 and 11 species in slow flowing sites, 5 and 9 species in backwater sites and 9 and 12 species per site in the Murray River main channel. In 2011, the number of species captured at fast-flowing sites was 11. Between 7 and 11 species were found at slow-flowing sites, and between 9 and 10 species and 10 and 14 species per site were captured at backwater sites and the Murray River main channel respectively.

Most species were widespread across sites and mesohabitat types (Table 3 and 4). However, Murray cod, freshwater catfish, sliver perch, flat-headed gudegon, dwarf flat-headed gudegon, redfin perch and spangled perch were not captured in all mesohabitats. Murray cod were only captured from Murray River main channel sites. Catfish and silver perch were not captured from backwater sites. Flat-headed gudgeon, dwarf flat-headed gudgeon and redfin perch were captured in low abundances each year (n <20 per year). Spangled perch was only captured in 2011 (n = 4) (Table 2).

Table 2. Total (captured + observed) and standardised (total / number of sites samples in each year) abundances for species captured in 2010 and 2011 before intervention monitoring surveys.

Species	**2010**	**2011**	**Total**
Golden perch	138	598	**736**
(*Macquaria ambigua ambigua*)	(6.3)	(31.5)	
Murray cod	2	1	**3**
(*Maccullochella peelii*)	(0.1)	(0.1)	
Silver perch	19	26	**45**
(*Bidyanus bidyanus*)	(0.9)	(1.4)	
Spangled perch	0	4	**4**
(*Leiopotherapon unicolour*)		(0.2)	
Bony herring	9208	1280	**10488**
(*Nematalosa erebi*)	(418.5)	(67.4)	
Australian smelt	849	426	**1275**
(*Retropinna semoni*)	(38.6)	(22.4)	
Murray rainbowfish	245	1978	**2223**
(*Melanotaenia fluviatilis*)	(11.1)	(104.1)	
Flat-headed gudgeon	20	56	**76**
(*Philypnodon grandiceps*)	(0.9)	(2.9)	
Dwarf flat-headed gudgeon	1	1	**2**
(*Philypnodon macrostomus*)	(0.04)	(0.1)	
Unspecked hardyhead	1627	1017	**2644**
(*Craterocephalus stercusmuscarum fulvus*)	(74.0)	(53.5)	
Carp gudgeon spp.	376	810	**1186**
(*Hypseleotris spp.*)	(17.1)	(42.6)	
Freshwater catfish	10	22	**32**
(*Tandanus tandanus*)	(0.5)	(1.2)	
Common carp	306	17298	**17604**
(*Cyprinus carpio*)	(13.9)	(910.4)	
Gambusia	248	1482	**1730**
(*Gambusia holbrooki*)	(11.3)	(78.0)	
Goldfish	473	4711	**5184**
(*Carassius auratus*)	(21.5)	(247.9)	
Redfin perch	1	2	**3**
(*Perca fluviatilis*)	(0.04)	(0.1)	
Total # species	**15**	**16**	**16**
Total # of sites	**22**	**19**	**22**
Total abundance	**13523**	**29712**	**43235**
Total standardised abundance	**614.7**	**1563.8**	

Table 3. Number of fish captured at each site in 2010. F = fast-flowing, S = slow-flowing, B = backwater and M = Murray River main channel mesohabitats.

Site number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**16**	**17**	**18**	**19**	**20**	**22**	**23**	**24**	
Mesohabitat type	**F**	**B**	**S**	**F**	**B**	**S**	**S**	**S**	**S**	**M**	**M**	**M**	**S**	**M**	**B**	**F**	**F**	**S**	**B**	**F**	**S**	**S**	**Total**
Species																							
Golden perch	2	1	1	8	7	14	7	14	8	29	9	6	-	6	-	7	2	1	-	2	-	14	**138**
Murray cod	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	**2**
Silver perch	-	-	-	1		1	1	1	2	7	3	-	-	-	-	1	-	-	-	-	1	1	**19**
Bony herring	700	80	804	402	498	473	379	824	1155	548	826	422	98	404	247	264	238	96	99	628	14	9	**9208**
Australian smelt	125	-	4	63	48	16	21	15	17	99	79	19	10	28	25	130	18	36	19	73	4	-	**849**
Murray rainbowfish	1	1	3	5	1	7	7	66	55	12	11	19	3	40	-	-	1	2	-	10	1	-	**245**
Flat-headed gudgeon	-	1	12	-	-	-	-	-	-	-	-	-	-	2	2	3	-	4	-	-	1	4	**20**
Dwarf flat-headed gudgeon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	**1**
Unspecked hardyhead	277	9	11	67	49	30	59	21	33	195	70	270	43	87	77	134	6	70	7	110	-	2	**1627**
Carp gudgeon spp	9	-	-	6	3	10	-	2	2	11	3	2	5	-	3	16	-	96	-	20	29	159	**376**
Freshwater catfish	4	-	-	-	-	-	-	-	-	1	-	-	-	2	-	-	-	1	-	2	-	-	**10**
Common carp	5	8	10	18	16	12	8	13	12	20	23	49	9	12	15	2	23	10	19	15	-	7	**306**
Gambusia	6	-	-	4	1	9	8	-	-	5	-	1	-	-	6	5	1	54	-	13	112	23	**248**
Goldfish	17	47	30	33	41	1	3	13	19	39	4	30	21	17	44	2	25	3	54	20	3	7	**473**
Redfin perch	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**
Total # species	**11**	**7**	**8**	**11**	**9**	**10**	**9**	**9**	**9**	**12**	**10**	**9**	**7**	**9**	**8**	**10**	**8**	**11**	**5**	**10**	**8**	**10**	**15**
Total # fish/site	**1147**	**147**	**864**	**609**	**664**	**573**	**493**	**969**	**1303**	**967**	**1029**	**818**	**189**	**598**	**419**	**564**	**314**	**373**	**198**	**893**	**165**	**227**	**13523**

Table 4. Number of fish captured at each site in 2011. F = fast-flowing, S = slow-flowing, B = backwater and M = Murray River main channel mesohabitat.

Site number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**16**	**17**	**18**	**19**	**20**	**22**	**23**	**24**	
Mesohabitat type	**F**	**B**	**S**	**F**	**B**	**S**	**S**	**S**	**S**	**M**	**M**	**M**	**S**	**M**	**B**	**F**	**F**	**S**	**B**	**F**	**S**	**S**	**Total**
Species																							
Golden perch		29	65	57	17	25	26	57	47	27	54	49	30	54	5	7	16	30			2	1	**598**
Murray cod		-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-			-	-	**1**
Silver perch		-	-	1	-	2	7	3	4	2	4	-	-	3	-	-	-	-			-	-	**26**
Spangled perch		-	-	-	-	-	-	-	-	-	2	-	-	2	-	-	-	-			-	-	**4**
Bony herring		55	21	316	42	368	30	30	14	74	41	41	30	18	25	6	154	12			1	2	**1280**
Australian smelt		4	7	17	51	80	13	18	33	37	36	18	27	39	15	3	17	-			2	9	**426**
Murray rainbowfish		73	114	147	62	107	92	149	144	99	194	364	171	47	86	4	86	-			16	23	**1978**
Flat-headed gudgeon		-	2	8	-	-	-	-	-	-	1	3	1	-	1	4	4	2			1	29	**56**
Dwarf flat-headed gudgeon		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-			-	-	**1**
Unspecked hardyhead		120	128	108	36	8	24	21	3	26	35	47	54	5	169	133	13	-			10	77	**1017**
Carp gudgeon spp		8	3	12	3	-	-	7	-	16	12	8	5	3	3	98	4	3			8	617	**810**
Freshwater catfish		-	1	-	-	-	-	1	-	1	1	-	-	-	-	15	-	3			-	-	**22**
Common carp		1477	1092	851	1211	1347	535	2738	366	576	377	1009	2189	464	462	442	1671	348			100	43	**17298**
Gambusia		9	11	35	40	1	7	22	6	1	2	19	11	4	92	754	18	-			15	435	**1482**
Goldfish		169	69	1075	322	392	306	471	103	125	142	339	172	74	267	13	595	40			27	10	**4711**
Redfin perch		-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-			-	1	**2**
Total # species		**9**	**11**	**11**	**9**	**10**	**9**	**11**	**9**	**11**	**14**	**10**	**10**	**11**	**10**	**11**	**11**	**7**			**10**	**11**	**16**
Total # fish/site		**1944**	**1513**	**2627**	**1784**	**2331**	**1040**	**3517**	**720**	**984**	**902**	**1897**	**2690**	**713**	**1125**	**1479**	**2579**	**438**			**182**	**1247**	**29712**

Recruitment success

For the small-bodied species, unspecked hardyhead, carp gudegon, Murray rainbowfish, Australian smelt and flat-headed gudgeon broad size ranges of individuals were captured suggesting recruitment occurred in 2010 and 2011 (Figure 2, Figure 3, Figure 4, Figure 5 and Figure 6). However, the size ranges observed in 2011 were slightly larger than for 2010. The size distribution for Australian smelt differed more between years compared to other species ranging between ~20 – 60 mm in 2010 and ~35 – 65 mm in 2011 (Table 5).

The size distribution of bony herring also varied between years. In 2010 a large proportion of bony herring ranged between ~20 – 100 mm with a smaller proportion of larger fish ~100 – 300 mm (Figure 7). In 2011 the size range shifted slightly where the majority of fish were between 20 – 180 mm and larger fish between 180 – 380 mm. In both years the smaller size range (i.e. 20 – 180 mm) is likely to be comprised of young-of-year (YOY) individuals.

Silver perch exhibited two length modes in 2010: smaller fish ~50 – 100 mm and larger fish ~200 – 400 mm (Figure 8). In 2011 three modes were present, with fish ranging between ~50 – 100 mm, ~180 – 250 mm and a single fish ~380 mm. Individuals ranging from ~50 – 100 mm are likely to be YOY fish and were captured in both years. Distinct length modes also exist for golden perch (Figure 9). In 2010, two modes existed comprising small fish ranging from ~20 – 60 mm (YOY) and larger fish ~180 – 480 mm. Larger fish are likely to be 4, 9, 11 and 14 year olds (Figure 9). In 2011, three less distinct modes were present: smaller fish ~60 – 160 mm (which are likely to be YOY individuals), 160 – 260 (1 year olds) and 340 – 480 mm (5, 10 and 12 year olds). Low numbers of freshwater catfish were captured (Figure 10) and the presence of individuals ~100 mm in 2010 and 2011 suggests that recruitment occurred in both years.

Recruitment was evident for the non-native species for both years. A larger proportion of YOY common carp (~40 – 140 mm) and goldfish (~20 – 100 mm) in 2011 suggests that recruitment was greater in 2011 (Figure 11 and Figure 12, respectively). The size distribution of Gambusia in both years was similar ranging from ~20 – 50 mm (Figure 13).

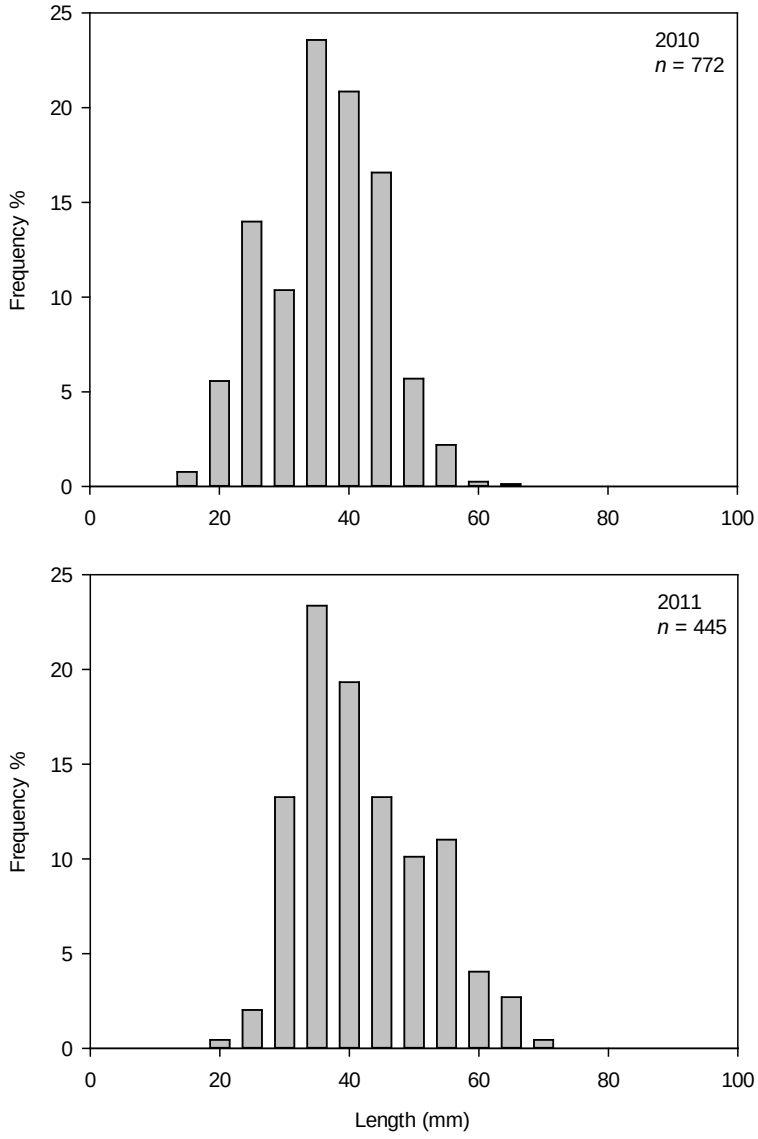

Figure 2 Length frequency distributions of unspecked hardyhead captured from the Katarapko Anabranch system and adjacent Murray River main channel in 2010 and 2011.

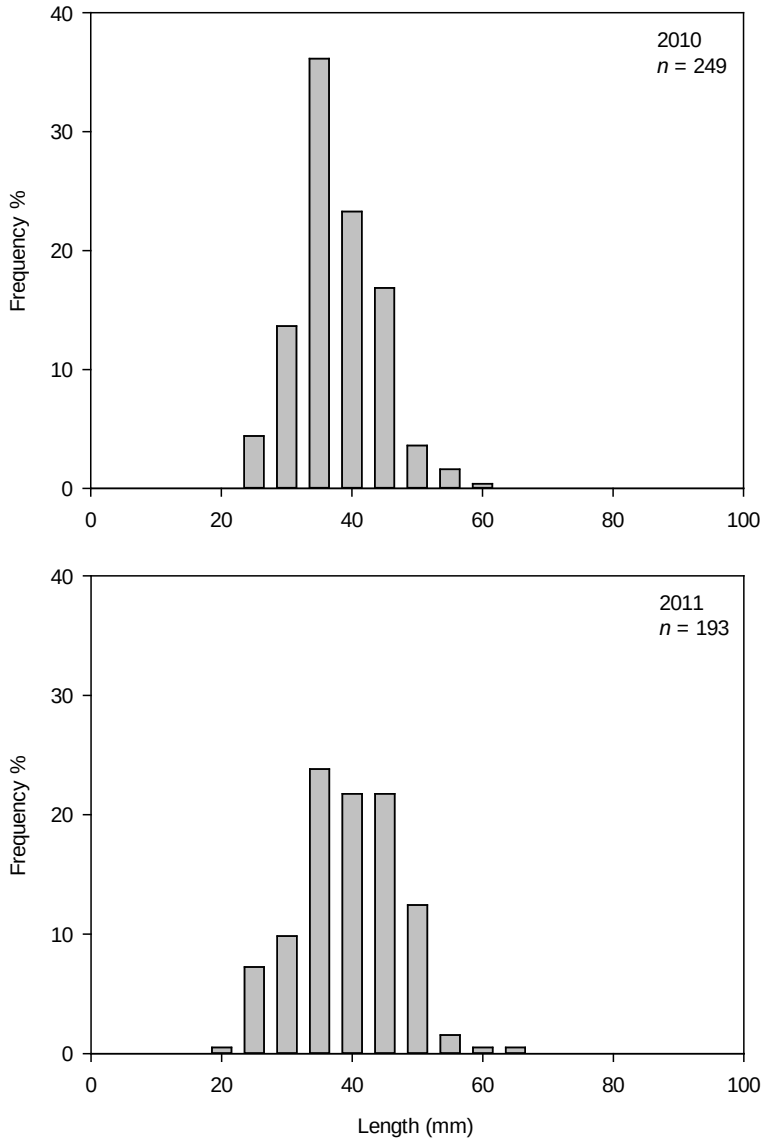

Figure 3 Length frequency distributions of carp gudgeon captured from the Katarapko Anabranch system and adjacent Murray River main channel in 2010 and 2011.

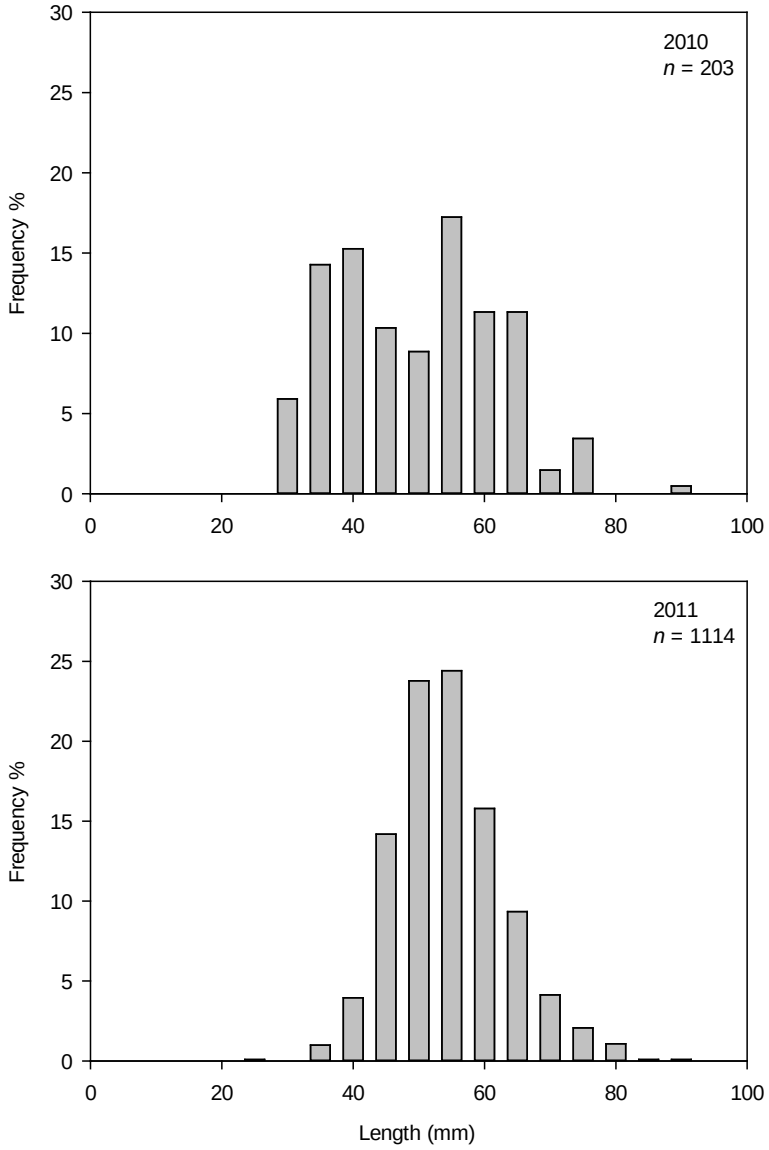

Figure 4 Length frequency distributions of Murray rainbowfish captured from the Katarapko Anabranch system and adjacent Murray River main channel in 2010 and 2011.

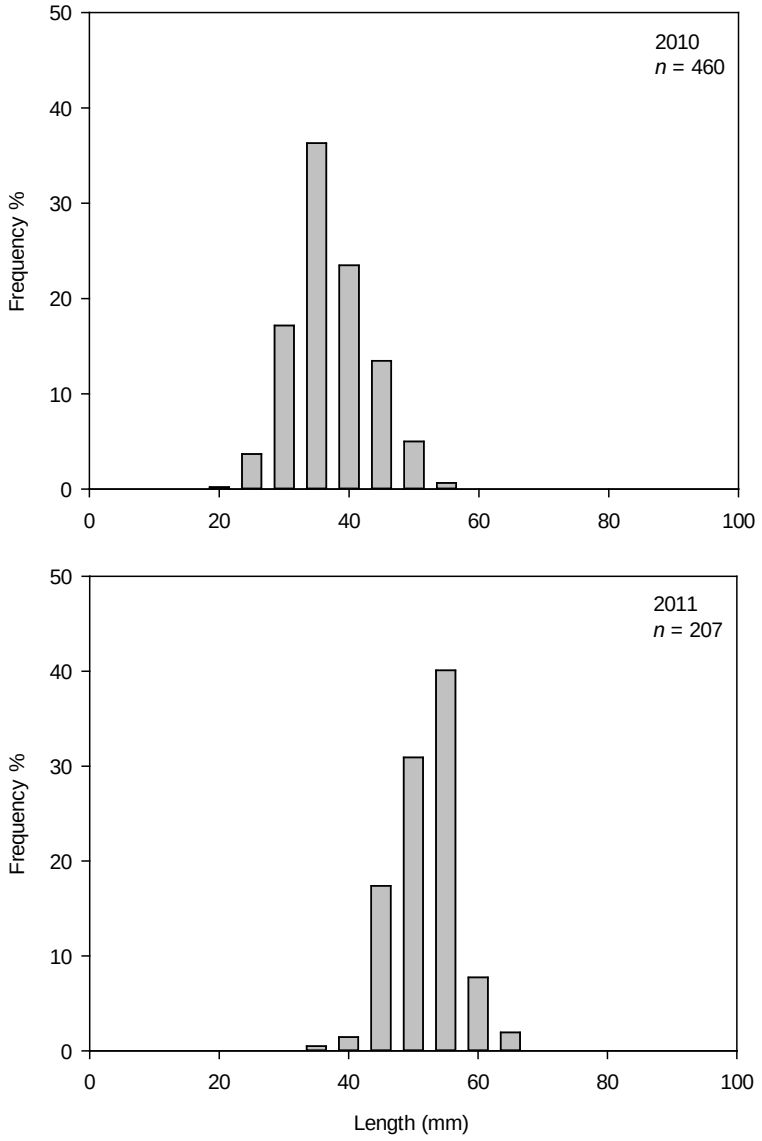

Figure 5 Length frequency distributions of Australian smelt captured from the Katarapko Anabranch system and adjacent Murray River main channel in 2010 and 2011.

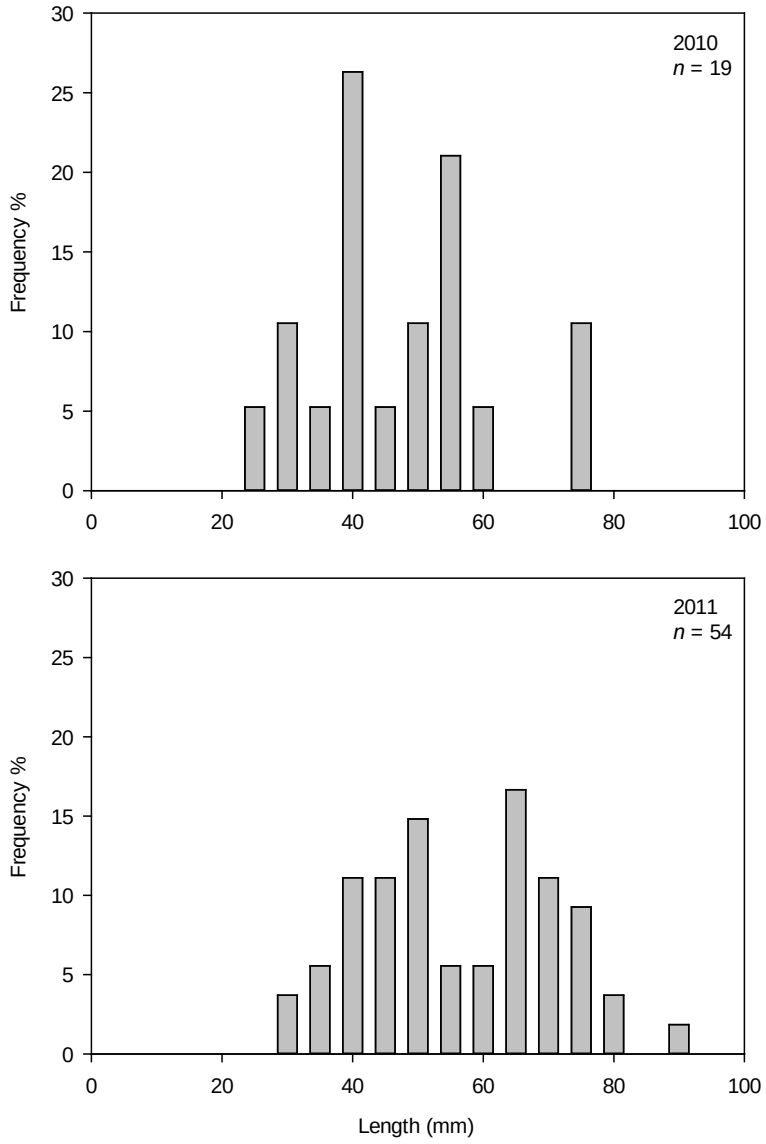

Figure 6 Length frequency distributions of flat-headed gudgeon captured from the Katarapko Anabranch system and adjacent Murray River main channel in 2010 and 2011.

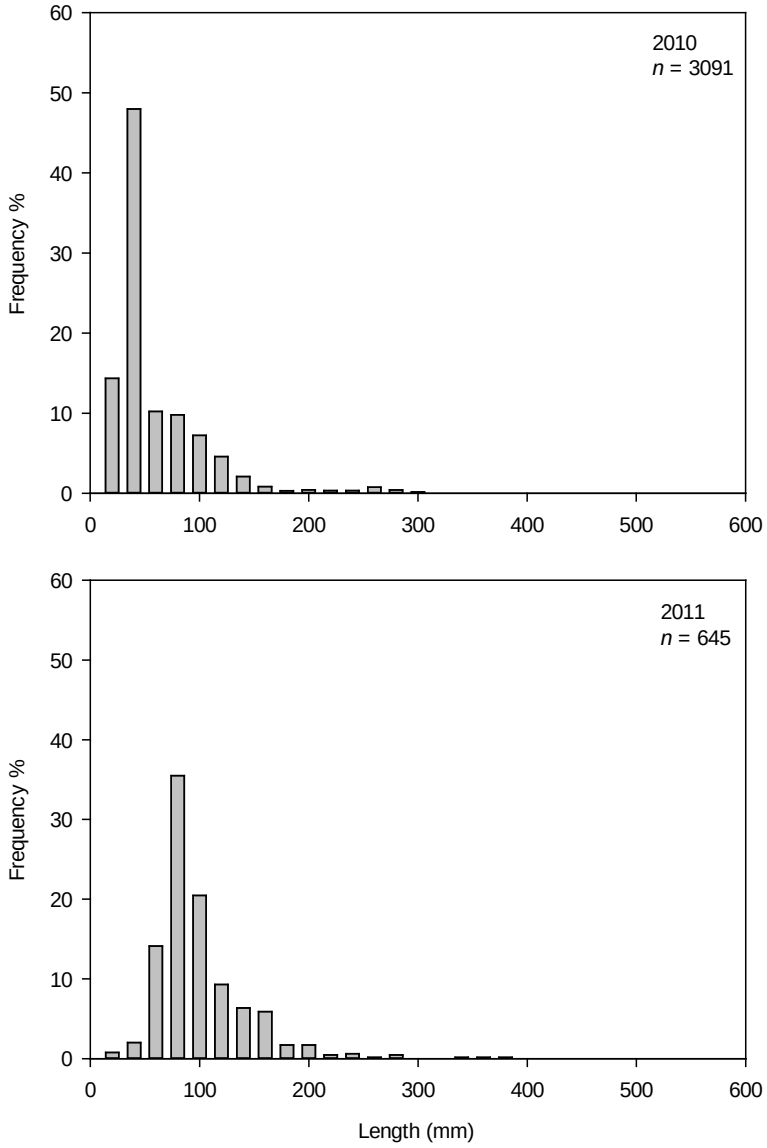

Figure 7 Length frequency distributions of bony herring captured from the Katarapko Anabranch system and adjacent Murray River main channel in 2010 and 2011.

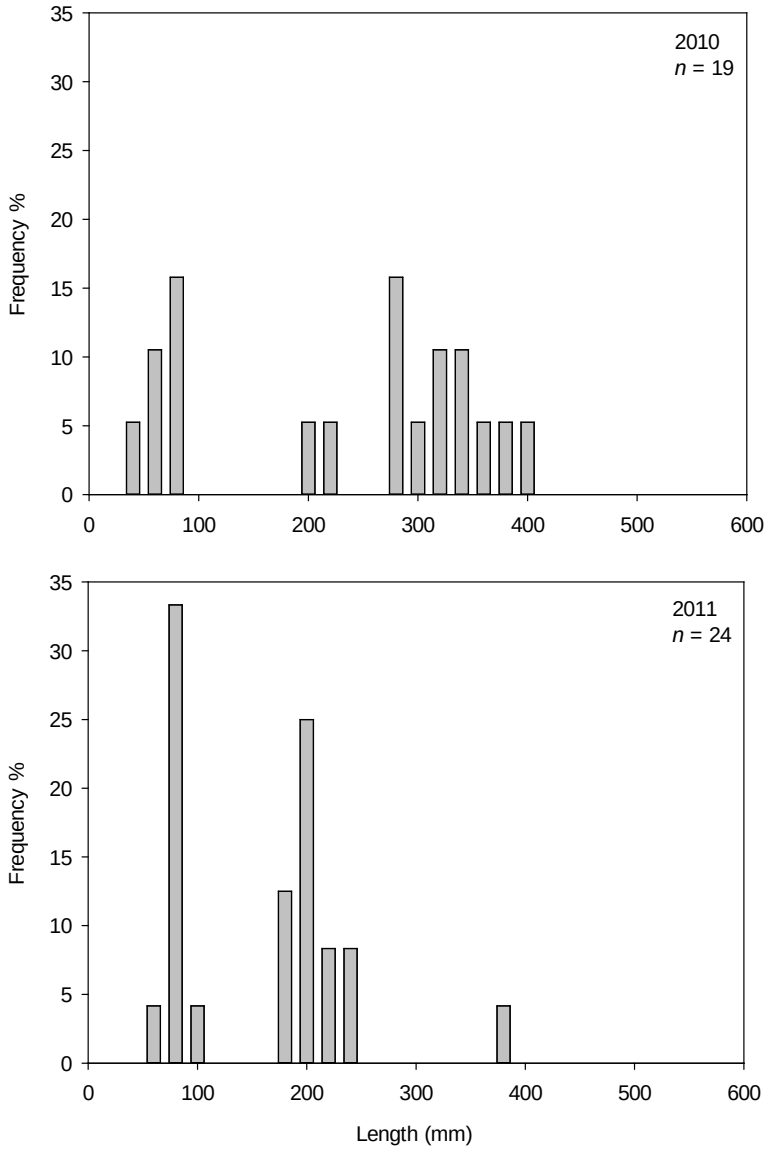

Figure 8 Length frequency distributions of silver perch captured from the Katarapko Anabranch system and adjacent Murray River main channel in 2010 and 2011.

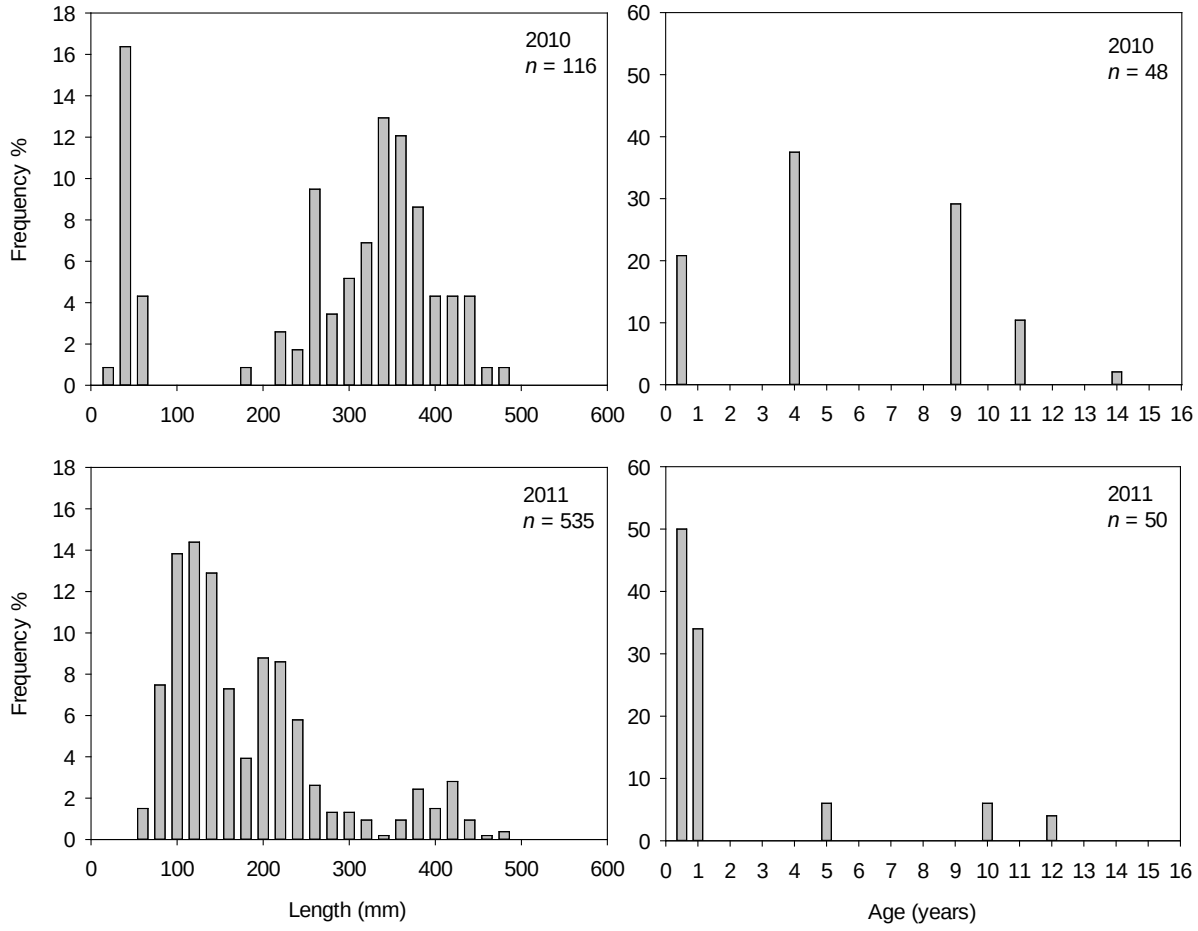

Figure 9 Length and age frequency distributions of golden perch captured from the Katarapko Anabranch system and adjacent Murray River main channel in 2010 and 2011.

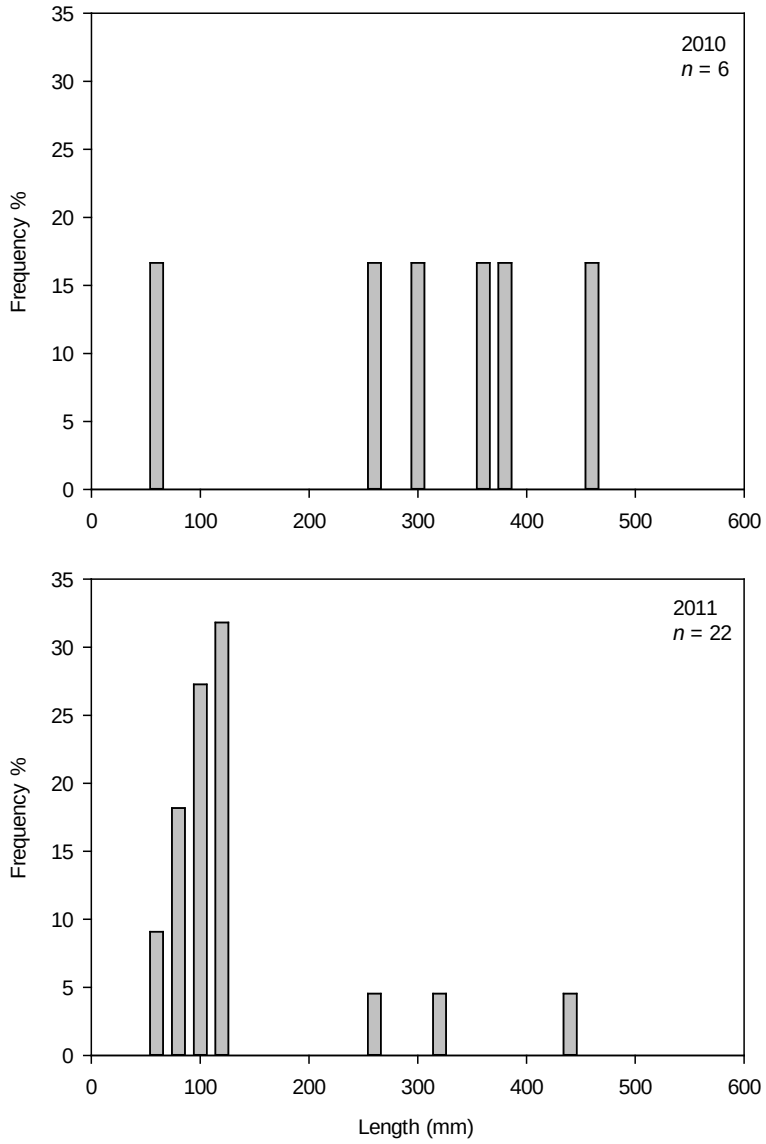

Figure 10 Length frequency distributions of freshwater catfish captured from the Katarapko Anabranch system and adjacent Murray River main channel in 2010 and 2011.

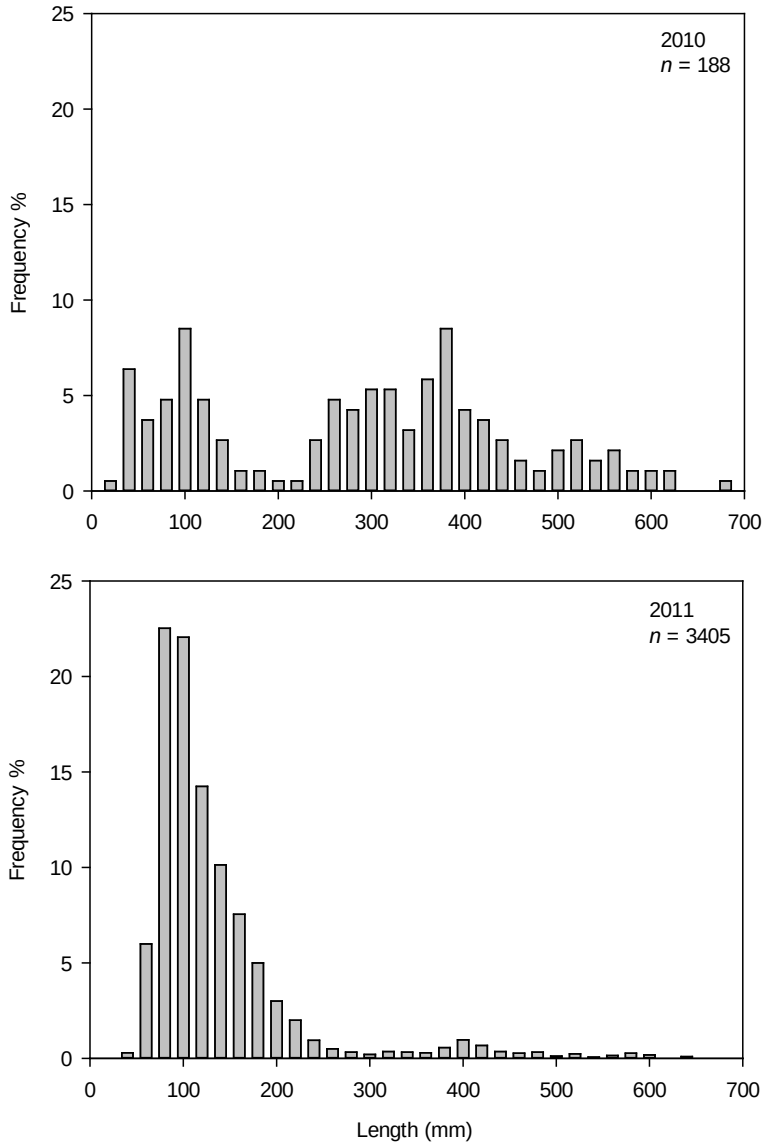

Figure 11 Length frequency distributions of common carp captured from the Katarapko Anabranch system and adjacent Murray River main channel in 2010 and 2011.

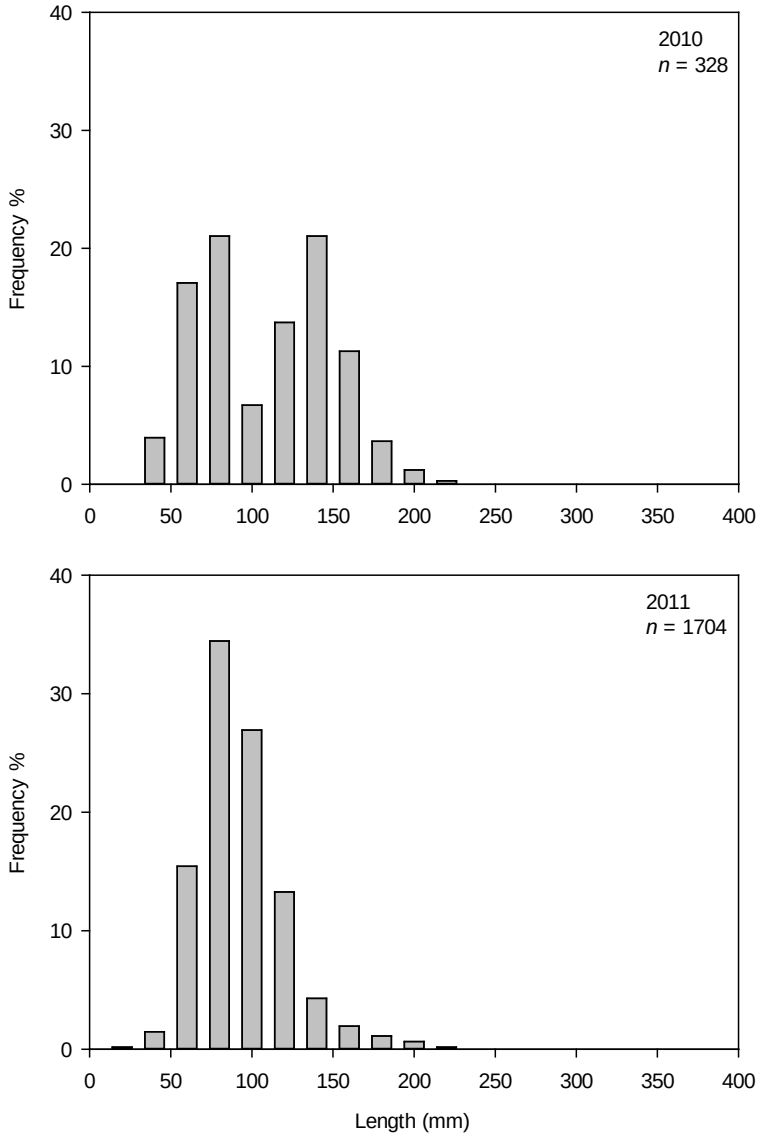

Figure 12 Length frequency distributions of goldfish captured from the Katarapko Anabranch system and adjacent Murray River main channel in 2010 and 2011.

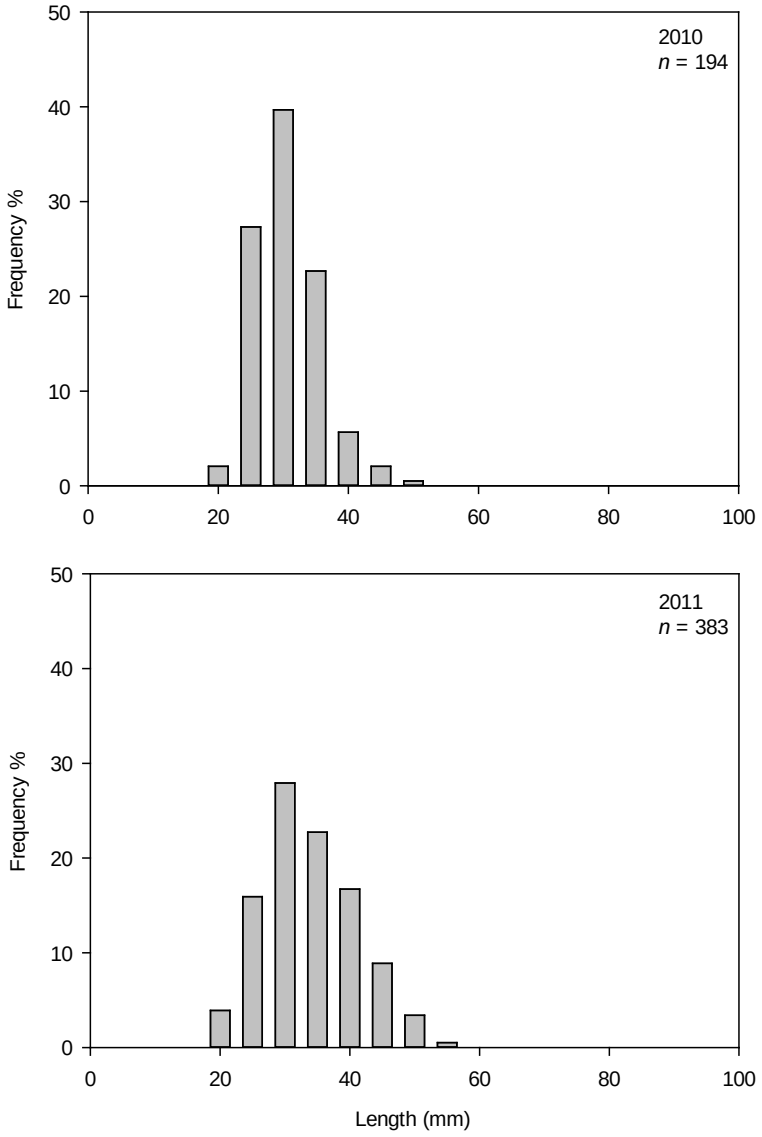

Figure 13 Length frequency distributions of Gambusia captured from the Katarapko Anabranch system and adjacent Murray River main channel in 2010 and 2011.

Habitat availability

Micro-mesohabitat association

Microhabitat (aquatic macrophyte species, species complexes and physical structure) differed between years and among aquatic mesohabitat types (fast-flowing, slow-flowing, backwater and Murray River main channel) and there was a significant interaction between year and mesohabitat type (Table 5). The significant interaction indicates that the change in microhabitats among different mesohabitats was not consistent between years (Figure 14).

Table 5. PERMANOVA pseudo-F-statistic results comparing microhabitat types between years (2010 and 2011) and mesohabitat types (fast-flowing, slow-flowing, backwater and Murray River main channel).

Factor	df	Psuedo-F	P-value
Year	1, 419	64.88	<0.001
Mesohabitat	3, 419	15.75	<0.001
Year × Mesohabitat	3, 419	11.01	<0.001

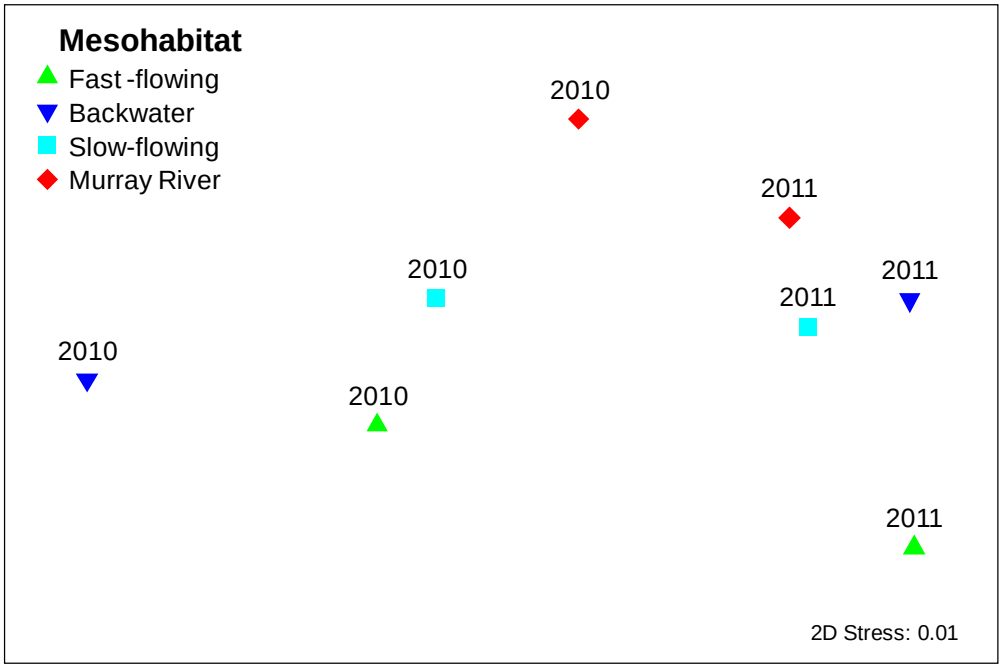

Figure 14. MDS plot showing differences in microhabitats among mesohabitats and between years.

In 2010, a total of 35 microhabitat types were recorded; however, in 2011 the number of microhabitat types recorded had decreased (n = 22) (Table 6). There was almost an entire loss of submergent species, with the exception of *Ludwigia peploides* var. *montevidensis*, hence plant species complexes were also absent. Likewise dominant beds of live emergents such as *Phragmites australis* and *Typha* sp. were largely absent. The 22 microhabitat types recorded in 2011 included the

addition of 8 new microhabitat types (Table 6). These new additions consisted of stands of dead emergents and inundated live (or dead) tree juveniles/saplings (which remained submerged along main channel and creek edges during the surveys). Many microhabitat types were significantly associated with a particular mesohabitat in 2011 (n = 22), whilst in 2010 the number of significant associations declined (n = 11) (Table 6).

Table 6. Microhabitat types and functional groups for 2010 and 2011; with significant indicators (bold type) of associated mesohabitats in 'Katfish Reach'. *represents microhabitat type not recorded.

Microhabitat type	Functional group	2010		2011	
		Mesohabitat	*P*-value	Mesohabitat	*P*-value
Acacia stenophylla (dead)	Structural	*	*	Slow-flowing	1
Acacia stenophylla (juveniles)	Structural	*	*	**Backwater**	**0.0153**
Acacia stenophylla (saplings)	Structural	*	*	Slow-flowing	1
Azolla filiculoides	Floating	**Fast-flowing**	**0.0001**	Fast-flowing	0.5189
Bare soil	N/A	Backwater	0.088	**Fast-flowing**	**0.0032**
Bolboschoenus caldwellii	Emergent	**Backwater**	**0.0001**	*	*
Chara sp.	Alga	**Slow-flowing**	**0.0001**	*	*
Azolla-Elodea complex	Complex	**Murray River**	**0.0001**	*	*
Azolla-Ludwigia complex	Complex	**Fast-flowing**	**0.0002**	*	*
Azolla-Ludwigia-Vallisneria complex	Complex	**Slow-flowing**	**0.0001**	*	*
Azolla -Vallisneria complex	Complex	**Backwater**	**0.0001**	*	*
CWD 1	Structural	Fast-flowing	0.2848	**Fast-flowing**	**0.0002**
CWD 2	Structural	Slow-flowing	0.1228	**Fast-flowing**	**0.0006**
CWD 3	Structural	**Slow-flowing**	**0.0001**	**Slow-flowing**	**0.0027**
Cyperus exaltatus	Emergent	**Slow-flowing**	**0.0021**	*	*
Cyperus gymnocaulos	Emergent	**Backwater**	**0.0001**	Backwater	0.9126
Dead instream emergents	Structural	*	*	**Fast-flowing**	**0.001**
Elodea canadensis	Submergent	Murray River	0.0882	*	*
Enchylaena tomentosa	Emergent (shrub)	*	*	Slow-flowing	1
Eucalyptus camaldulensis (dead)	Structural	*	*	Fast-flowing	0.1712
Eucalyptus camaldulensis (juveniles)	Structural	*	*	**Backwater**	**0.0092**
Eucalyptus camaldulensis (saplings)	Structural	*	*	Murray River	0.5995
Juncus acuta	Emergent	**Murray River**	**0.0186**	*	*
Juncus usitatus	Emergent	Fast-flowing	0.1543	*	*
Lemna sp.	Floating	**Slow-flowing**	**0.0001**	Slow-flowing	0.2284
Lolium sp.	Emergent (grass)	Slow-flowing	1	*	*
Ludwigia peploides var. *montevidensis*	Submergent	**Fast-flowing**	**0.005**	Fast-flowing	0.056
Muehlenbeckia florulenta	Emergent	**Fast-flowing**	**0.0003**	**Murray River**	**0.0047**
Myriophyllum verrucosum	Submergent	Murray River	0.4267	*	*
Nitella sp.	Alga	**Slow-flowing**	**0.0001**	*	*
Open water	N/A	**Murray River**	**0.0001**	**Murray River**	**0.002**
Paspalum distichum	Emergent	**Fast-flowing**	**0.0179**	*	*
Persicaria lapathifolia	Emergent	Fast-flowing	0.6432	*	*
Phragmites australis	Emergent	Fast-flowing	0.0261	Backwater	0.0701
Potamogeton crispus	Submergent	Backwater	0.2463	*	*
Potamogeton tricarinatus	Submergent	**Slow-flowing**	**0.0113**	*	*
Rumex bidens	Emergent	**Fast-flowing**	**0.0073**	**Backwater**	**0.0102**
Sarcocornia quinqueflora	Emergent (shrub)	Slow-flowing	1	*	*
Schoenoplectus validus	Emergent	**Fast-flowing**	**0.006**	*	*
Scour holes	N/A	Slow-flowing	1	*	*
Tree roots	Structural	**Slow-flowing**	**0.0164**	**Fast-flowing**	**0.0095**
Typha sp.	Emergent	Fast-flowing	0.2132	Slow-flowing	0.5057
Vallisneria australis	Submergent	**Fast-flowing**	**0.0001**	*	*

Habitat use

Fish-mesohabitat associations

Fish assemblages differed between years (2010 and 2011) and among aquatic mesohabitat types, and there was a significant interaction between year and mesohabitat type (Table 7). The significant interaction observed indicates that fish assemblages associated with backwater mesohabitats were distinctly different than the other three mesohabitat types in 2010. However, in 2011 fish assemblages in all four mesohabitat types were more similar (Figure 15).

Table 7. PERMANOVA pseudo-F-statistic results comparing fish assemblages between years (2010 and 2011) and among mesohabitat types (fast-flowing, slow-flowing, backwater and Murray River main channel).

Factor	df	Psuedo-F	P-value
Year	1, 419	208.33	<0.001
Mesohabitat	3, 419	8.30	<0.001
Year × Mesohabitat	3, 419	6.97	<0.001

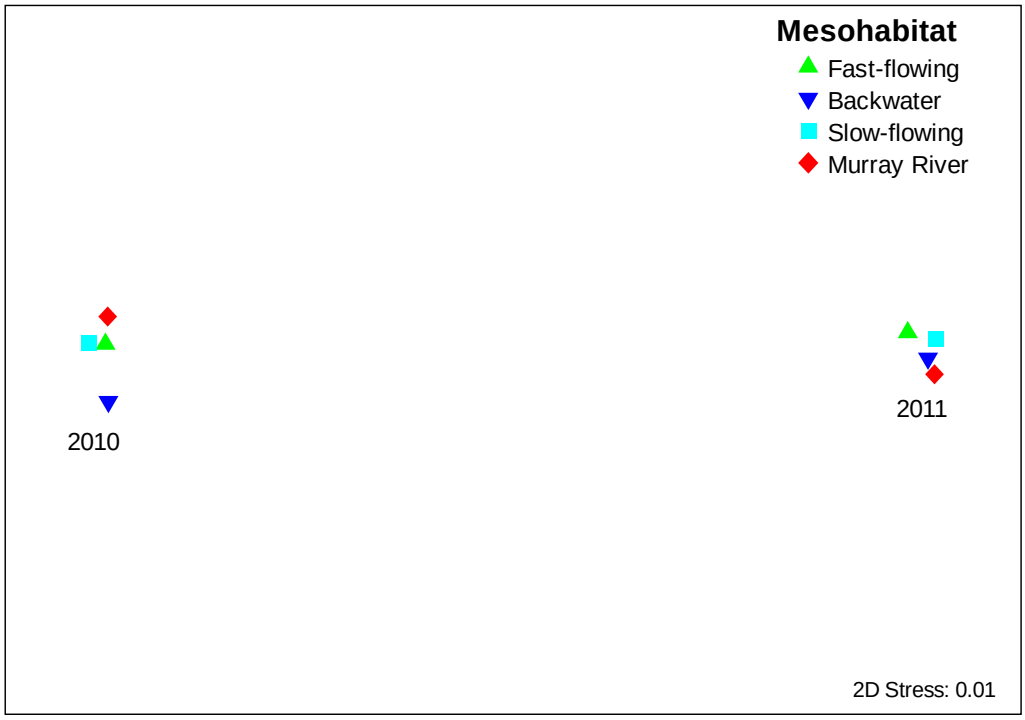

Figure 15. MDS plot showing differences in fish assemblages between mesohabitats and years.

Many individual fish species were identified as being significantly associated with a particular mesohabitat type in both years (Table 6). However, fish-mesohabitat associations were not consistent between years. In 2010, fast-flowing mesohabitats were characterised by significantly

greater abundances of Gambusia, carp gudgeon, Australian smelt, and freshwater catfish, whereas in 2011, bony herring, goldfish and flat-headed gudgeon were significantly associated with fast-flowing habitats. There were no significant indicators of slow-flowing mesohabitats in 2010 and 2011. In 2010, Murray River mesohabitats were characterised by significantly greater abundances of unspecked hardyhead, Murray rainbowfish, common carp, golden perch and silver perch. In 2011, spangled perch were significant indicators of Murray River sites. In 2010 backwater sites were characterised by significantly greater abundances of goldfish; however, in 2011 unspecked hardyhead and Gambusia were most closely associated with backwater sites.

Table 8. Significant indicator species analysis for fish species between years and among mesohabitat types. Bold type represents significant *P*-value ($\alpha = 0.05$). *represents fish species not recorded.

	2010		**2011**	
Common Name	**Mesohabitat type**	***P*- value**	**Mesohabitat type**	***P*-value**
Unspecked hardyhead	**Murray River**	**0.0001**	**Backwater**	**0.0001**
Murray-Darling rainbowfish	**Murray River**	**0.0002**	Murray River	0.1262
Gambusia	**Fast-flowing**	**0.0111**	**Backwater**	**0.0117**
Bony herring	Murray River	0.1708	**Fast-flowing**	**0.0003**
Goldfish	**Backwater**	**0.0001**	**Fast-flowing**	**0.0001**
Common carp	**Murray River**	**0.0003**	Slow-flowing	0.2292
Carp gudgeon	**Fast-flowing**	**0.0038**	Fast-flowing	0.1453
Flat-headed gudgeon	Backwater	0.9098	**Fast-flowing**	**0.0001**
Dwarf flat-headed gudgeon	Slow-flowing	1	Fast-flowing	0.14
Murray cod	Murray River	0.0843	Murray River	0.5774
Golden perch	**Murray River**	**0.0003**	Murray River	0.1015
Silver perch	**Murray River**	**0.0554**	Slow-flowing	0.2419
Australian smelt	**Fast-flowing**	**0.0022**	Murray River	0.1208
Freshwater catfish	**Fast-flowing**	**0.0383**	Murray River	0.8553
Redfin perch	Fast-flowing	0.6418	Slow-flowing	0.5659
Spangled perch	*	*	**Murray River**	**0.0473**

Fish-microhabitat associations

Generally, individual fish species had significant associations (positive or negative) with one or more microhabitat types (i.e. aquatic macrophyte species, species complex, physical structure) (Table 9); however, fish-microhabitat associations were not consistent between years (2010 and 2011). For instance, in 2010 carp gudgeon had a positive association with various microhabitats (*Azolla filiculoides*, *Lemna* sp., *Cyperus gymnocaulus*, *Eucalyptus largiflorens*, *Ludwigia peploides* var.

montevidensis, *Rumex bidens*), but in 2011 they were positively associated with dead instream emergents and *Phragmites australis*. In both years they were negatively associated with open water. In 2010, Murray rainbowfish were positively associated with various microhabitat types (*Acacia stenophylla*, Azolla-Elodea complex, *Chara* sp., CWD 2, *Nitella* sp., open water, *Phragmites australis* and tree roots) and negatively associated with *Bolboschoenus caldwellii*, Azolla-Vallisneria complex, *Cyperus gymnocaulos*, *Juncus usitatus*, *Potomogeton crispus* and *Typha* sp. In 2011, there were no positive associations, but Murray Rainbowfish were negatively associated with open water, *Phragmites australis* and *Rumex bidens*. Flat-headed gudegon were positively associated with *Cyperus exaltatus*, *Cyperus gymnocaulos* and *Potomogeton crispus* and negatively associated with Azolla-Elodea complex, CWD 3, *Nitella* sp. open water and tree roots in 2010. However, in 2011, flat-headed gudgeon were positively associated with bare soil, dead instream emergents and negatively associated with open water. Australian smelt were positively associated with *Chara* sp., *Nitella* sp., *Vallisneria australis* and had a negative association with Azolla-Vallisneria complex and *Typha* sp in 2010, but in 2011 were positively associated with *Phragmites australis* and negatively associated with dead instream emergents. Unspecked hardyhead were positively associated with Azolla-Elodea complex and negatively associated with Azolla-Ludwigia complex and *Typha* sp in 2010, but in 2011 they had a positive association with dead instream emergents and a negative association with CWD 3, *Eucalyptus camaldulensis*, *Phragmites australis* and tree roots. Dwarf flat-headed gudgeon were not sampled in large enough numbers for analysis in both years.

In 2010, bony herring was positively associated with open water and negatively associated with *Azolla filiculoides*, *Lemna sp.* and *Typha sp.*; however, in 2011 there were no significant positive or negative associations. Similarly, freshwater catfish were positively associated with CWD 2, *Eucalyptus largiflorens*, *Phragmites australis* in 2010, yet in 2011 there were no significant positive or negative associations. Golden perch were positively associated with Azolla-Ludwigia-Vallisneria complex, CWD 3, open water, *Phragmites australis* and negatively associated with *Cyperus gymnocaulos*, *Lemna* sp. and *Typha* sp. in 2010. In 2011, they were positively associated with bare soil, CWD 2, CWD 3, tree roots and negatively associated with submerged *Eucalyptus camaldulensis* juveniles and *Muehlenbeckia florulenta*. Murray cod were positively associated with CWD 3 in 2010, but in 2011 the sample size was too small for analysis. Silver perch were positively associated with CWD 3 in 2010 and in 2011 they were again positively associated with CWD 3, as well as overhanging *Acacia stenophylla* trees and tree roots. Spangled perch were not captured in 2010. In 2011 they were positively associated with submerged *Acacia stenophylla* juveniles, overhanging *Phragmites australis* foliage and *Rumex bidens*.

Non-native species also had a number of significant associations with one or more microhabitat types and the nature of the relationships varied between years (Table 9). Common carp had a

positive association with Azolla-Elodea complex in 2010, but in 2011, carp were wide spread and present in every shot or fyke net/box trap set. Gambusia showed a positive association with *Azolla filiculoides*, Azolla-Ludwigia-Vallisneria complex, *Eucalyptus largiflorens* and a negative association with open water in 2010, whereas in 2011, this species had a positive association with *Azolla filiculoides* and dead instream emergents. Goldfish had a positive association with *Bolboschoenus caldwellii*, Azolla-Ludwigia complex, *Cyperus gymnocaulos*, tree roots and *Typha* sp. and a negative association with *Chara* sp. Azolla-Ludwigia-Vallisneria complex, CWD 3, *Nitella* sp. open water in 2010. In 2011, there were no significant indicators. Redfin perch were not sampled in sufficient numbers for analysis in 2010; however, in 2011 they were positively associated with dead instream emergents.

Table 9. Significant indicators for fish-microhabitat associations and non-associations for 2010 and 2011 in 'Katfish Reach' and the Murray River main channel.

Common Name	Scientific Name	2010		2011	
		Positive association	**Negative association**	**Positive association**	**Negative association**
Bony herring	*Nematolosa erebi*	Open water (*P*=0.0009)	*Azolla filiculoides* (*P* = 0.0036) *Lemna* sp.(*P* = 0.0102) *Typha* sp. (*P* = 0.0275)	no significant indicators	no significant indicators
Carp gudgeon	*Hypseleotris* spp.	*Azolla filiculoides* (*P* = 0.0009) *Cyperus gymnocaulos* (*P* = 0.0349) *Eucalyptus largiflorens* (canopy) (P = 0.0445) *Lemna* sp.(*P* = 0.0279) *Ludwigia peploides* var. *montevidensis* (*P* = 0.0271) *Rumex bidens* (*P*= 0.0278)	Open water (*P* = 0.0059)	Dead instream emergents (*P* = 0.0167) *Phragmites australis* (*P*= 0.0151)	Open water (*P*= 0.0051)
Common carp	*Cyprinus carpio*	Azolla-Elodea complex (*P*= 0.0149)	no significant indicators	analysis not possible (present in every shot)	analysis not possible (present in every shot)
Freshwater catfish	*Tandanus tandanus*	CWD 2 (*P* = 0.0405) *Eucalyptus largiflorens* (canopy) (*P* = 0.0016) *Phragmites australis* (*P* = 0.0036)	no significant indicators	no significant indicators	no significant indicators
Flat-headed gudgeon	*Philypnodon grandiceps*	*Cyperus exaltatus* (*P* = 0.0009) *Cyperus gymnocaulos*(*P* = 0.0411) *Potamogeton crispus* (*P* = 0.0438)	Azolla-Elodea complex (*P*= 0.0081) CWD 3 (*P* = 0.0335) *Nitella* sp. (*P* = 0.0489) Open water (*P* = 0.0004) Tree roots (*P* = 0.282)	Bare soil (*P* = 0.154) Dead instream emergents (*P* = 0.0008)	Open water (*P* = 0.0076)

Common Name	Scientific Name	2010		2011	
		Positive association	**Negative association**	**Positive association**	**Negative association**
Eastern gambusia	*Gambusia holbrooki*	*Azolla filiculoides* (*P* = 0.0322) Azolla-Ludwigia-Vallisneria Complex (*P* = 0.0027) *Eucalyptus largiflorens* (canopy) (*P* = 0.0028)	Open Water (*P* = 0.0001)	*Azolla filiculoides* (*P* = 0.0611) Dead instream emergents (*P* = 0.0001)	no significant indicators
Golden perch	*Macquaria ambigua ambigua*	Azolla-Ludwigia-Vallisneria complex (*P*=0.0215) CWD 3 (*P* = 0.0012) Open water (*P* = 0.0201) *Phragmites australis* (*P* = 0.0005)	*Cyperus gymnocaulos* (*P* = 0.0147) *Lemna* sp. (*P* = 0.0194) *Typha* sp. (P = 0.0258)	Bare soil (*P* = 0.0288) CWD 2 (*P* = 0.0199) CWD 3 (*P* = 0.0001) Tree roots (*P* = 0.0017)	*Eucalyptus camaldulensis* (submerged juveniles) (*P* = 0.005) *Muehlenbeckia florulenta* (submerged) (*P* = 0.0262)
Goldfish	*Carassius auratus*	*Bolboschoenus caldwellii* (*P* = 0.0063) Azolla-Ludwigia complex (*P* = 0.0018) *Cyperus gymnocaulos* (*P* = 0.0048) Tree roots (*P* = 0.0081) *Typha* sp. (*P* = 0.0318)	*Chara* sp. (*P* = 0.0009) Azolla-Ludwigia-Vallisneria complex (*P* = 0.0001) CWD 3 (*P* = 0.0015) *Nitella* sp. (*P* = 0.007) Open water (*P* = 0.0075)	no significant indicators	no significant indicators
Murray cod	*Maccullochella peelii*	CWD 3 (*P* = 0.0401)	no significant indicators	analysis not possible (sample number too low)	analysis not possible (sample number too low)

Common Name	Scientific Name	2010		2011	
		Positive association	**Negative association**	**Positive association**	**Negative association**
Murray rainbowfish	*Melanotaenia fluviatilis*	*Acacia stenophylla* (canopy) (P = 0.0003) Azolla-Elodea complex (*P* = 0.0023) *Chara* sp. (*P* = 0.0075) CWD 2 (P = 0.0159) *Nitella* sp. (*P* = 0.0044) Open water (*P* = 0.0001) *Phragmites australis* (*P* = 0.0456) Tree roots (*P* = 0.0279)	*Bolboschoenus caldwellii* (*P* = 0.0002) Azolla-Vallisneria complex (*P* = 0.0009) *Cyperus gymnocaulos* (*P* = 0.0001) *Juncus usitatus (P* = 0.0021) *Potamogeton crispus* (*P* = 0.0456) *Typha* sp. (*P* = 0.0337)	no significant indicator	Open water (*P* = 0.0257) *Phragmites australis* (canopy) (*P* = 0.001) *Rumex bidens* (*P* = 0.0112)
Silver perch	*Bidyanus bidyanus*	CWD 3 (*P* = 0.0235)	no significant indicators	*Acacia stenophylla* (overhanging) (*P* = 0.0492) CWD 3 (*P* = 0.0457) Tree roots (*P* = 0.0065)	no significant indicators
Australian smelt	*Retropinna semoni*	*Chara* sp. (*P* = 0.0405) *Nitella* sp. (*P* = 0.0329) *Vallisneria australis* (*P* = 0.0088)	Azolla-Vallisneria complex (*P* = 0.0049) *Typha* sp. (*P* = 0.0003)	*Phragmites australis* (canopy) (*P* = 0.0081)	Dead instream emergents (*P* = 0.0339)
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	Azolla-Elodea complex (*P* = 0.0098)	Azolla-Ludwigia complex (*P* = 0.0233) *Typha* sp. (*P* = 0.0393)	Dead instream emergents (*P* = 0.0034)	CWD 3 (*P* = 0.0284) *Eucalyptus camaldulensis* (canopy) (*P* = 0.0012) *Phragmites australis* (canopy) (*P* = 0.0019) Tree roots (*P* = 0.0204)

Common Name	Scientific Name	2010		2011	
		Positive association	**Negative association**	**Positive association**	**Negative association**
Spangled perch	*Leiopotherapon unicolor*	not caught	not caught	*Acacia stenophylla* (submerged juveniles) ($P = 0.0487$) *Phragmites australis* (overhanging) $P = 0.0076$) *Rumex bidens* ($P = 0.0181$)	no significant indicators
Redfin perch	*Perca fluviatilis*	analysis not possible (sample number too low)	analysis not possible (sample number too low)	Dead instream emergents ($P = 0.0398$)	no significant indicators
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	analysis not possible (sample number too low)	analysis not possible (sample number too low)	analysis not possible (sample number too low)	analysis not possible (sample number too low)

Discussion

This report describes the fish community structure, instream and riparian habitat characteristics and fish-habitat associations over two years (2010 and 2011) prior to the implementation of management interventions within the Katarapko Anabranch system. An assessment of the response of fish and fish habitats to interventions 1 (inundation of the Eckert Island system) and intervention 2 (drying of parts of the Eckert Island system), can only be undertaken after the interventions are implemented and 'after 'intervention data is collected. For the purpose of describing the 'before' intervention monitoring results presented here, data collected from the electrofishing and fyke net/box trap sites have been combined. However, in order to assess the response of fish and fish habitats following the interventions, data from sites sampled using different fishing methods will be treated separately.

The results from the fish and habitat surveys highlight the varied response of fish (abundance, species composition, richness and recruitment) and habitat (diversity, abundance) and their associations under differing flow conditions. The 'before' intervention monitoring surveys of 2010 and 2011 were undertaken following two very different flow regimes in the lower Murray River: a small within-channel flow (~10,000 ML/d) flow in 2009/2010 and a significant overbank flow (~93,000 ML/d) in 2010/2011. At the time of the 2010 surveys, discharge downstream of Lock No. 4 was ~5,500 ML/d and the water level was ~10.60 m (AHD). High river levels in 2011 resulted in a ~2 month delay in sampling that year. However, despite the delay in survey time in 2011, both discharge (~23,000 ML/d) and water level (~11.89 m) downstream of Lock No. 4 were higher than in 2010 (~17,500 ML/d and 1.3 m higher respectively). As a result, water velocities within slow-flowing, backwater and Murray River main channel mesohabitats were greater in 2011 than in 2010, which likely resulted in increased availability of flowing habitats for fishes within the system.

A total of 43,235 fish were captured over the two years. Total and standardised abundances were greater in 2011 (29712 and 1563.8 respectively) than total and standardised abundances captured in 2010 (13523 and 614.7 respectively). The native species bony herring, unspecked hardyhead and Australian smelt were the most abundant species captured in 2010. In contrast, non-native species common carp and goldfish were the most abundant species captured in 2011. The abundance of common carp, goldfish and golden perch, Murray rainbowfish, carp gudgeon, and Gambusia was greater in 2011 following the overbank flow event, whilst the abundance of bony herring and Australian smelt was greater following the within-channel flow event in 2010.

A total of 16 species were captured over the two years. Fifteen were captured in 2010 and 16 in 2011 the difference resulting from the presence of spangled perch in 2011. Spangled perch are normally distributed in arid northern regions of Australia and the species presence in 2011 highlights the scale of the 2010/2011 overbank flow.

Generally species richness (number of species) was greater in Murray River main channel sites whilst slow-flowing and backwater sites had less species than main channel and fast-flowing sites. Most species were widespread and captured from a wide range of sites and mesohabitats; however, a small number of species were not captured from all mesohabitat types. Murray cod were only captured in the Murray River main channel despite the abundance of suitable habitat (CWD) available in Katarapko Creek. The absence of Murray cod from Katarapko Creek may reflect low velocities created by the Katarapko Stone Weir. Freshwater catfish and silver perch were not captured from backwater mesohabitats.

Recruitment for all species investigated (species captured in sufficient numbers) appeared to have occurred in both years; however, the strength of recruitment for individual species varied. Small-bodied species unspecked hardyhead, carp gudgeon, Murray rainbowfish, Australian smelt and flat-headed gudgeon exhibited broad size distributions that are likely to reflect recruitment in both years. However, the decrease in the total abundance and the proportion of small individuals of Australian smelt captured in 2011 suggests that recruitment was less following the overbank flow in 2010/2011. A similar pattern in recruitment and abundance was observed for bony herring and consistent with observations for the Chowilla Anabranch system (Leigh and Zampatti 2012).

Young-of-year golden perch and silver perch were observed in both years and support the hypothesis that both species spawn and recruit during within-channel and overbank flow (Humphries *et al.* 1999; Mallen-Cooper and Stuart 2003). Recruitment for Gambusia (non-native) and freshwater catfish (native) was similar in both years. Non-native species common carp and goldfish also exhibited recruitment in both years and the increased proportion of juveniles and total abundances of both species captured in 2011 suggests recruitment was greater following the overbank flow in 2010/2011.

Microhabitat availability (i.e. abundance and diversity of aquatic macrophytes species, species complexes and physical structure) varied significantly between years. The number of microhabitat types recorded in 2011 decreased. This is primarily due to an almost entire loss of submergent species, species complexes and beds of emergent species after the overbank flow in 2010/2011. However, alternative microhabitat types were observed during the 2011 surveys, such as dead

instream emergents and inundated tree (juveniles/saplings) which remained submerged along main channel and creek edges during the surveys. The loss of previous habitat types and establishment of new available habitats is likely to contribute to the differences in fish-habitat (micro and meso) associations observed between the two years.

Aquatic mesohabitat types haboured significantly different fish assemblages in both 2010 and 2011. In 2010, fast-flowing mesohabitats were characterised by significantly greater abundances of Gambusia, carp gudgeon, Australian smelt, and freshwater catfish, whereas in 2011, bony herring, goldfish and flat-headed gudgeon were significant indicators. In 2010, Murray River mesohabitats were characterised by significantly greater abundances of unspecked hardyhead, Murray rainbowfish, common carp, golden perch and silver perch, but in 2011 were characterised by spangled perch. In 2010, backwater sites were characterised by significantly greater abundances of goldfish; however, in 2011 unspecked hardyhead and Gambusia were significant indicators. There were no significant indicators of slow-flowing mesohabitats in 2010 and 2011. Changes in microhabitat availability and the increased availability of flowing habitats within the system during the 2011 surveys is likely to have contributed to the differences in fish-mesohabitat associations observed between years.

Most fish species were positively or negatively associated with one or more microhabitat type; however, fish-microhabitat associations differed between 2010 and 2011. Fewer fish-microhabitat associations were observed in 2011 compared to 2010, which may be attributed to a loss of available instream habitats such as submergent species, species complexes and beds of emergent species. In general, those species that were positively associated with open water and physical structure (i.e. CWD and tree roots) in 2010 retained this association in 2011, as the presence and abundance of these habitat types did not differ significantly. The variation we observed in fish-micro- and mesohabitat associations suggests that the fish species captured in this study are highly adaptable to short term habitat disturbance and/or changes in habitat availability. How fish species respond to the accumulative or long term changes in habitat as a result of management interventions (manipulation of discharge and water level) remains unclear and should be closely monitored in order to ensure effective adaptive management of the system.

The variable nature of the responses observed between 2010 and 2011 highlights the importance of collecting 'before' intervention monitoring data under a range of flow scenarios. As such, in order to assess changes over time in fish assemblage structure, habitat use and availability and recruitment success in response to artificial inundation of the Eckert Island system (intervention 1) and artificial drying of parts of the Eckert Island system (intervention 2), the authors propose that 'before' intervention data collected during different flow conditions (i.e. within-channel and

overbank) be treated separately. More specifically we suggest the 'before' data set for each flow condition be used to compare against 'after' intervention data collected during the similar flow conditions (before intervention data collected following within-channel flow compared with after intervention data collected following within-channel flow). Long-term monitoring data is essential to measure ecosystem responses to natural and altered flow conditions in the system. To this end, we recommend that the intervention monitoring programme (pre- and post-intervention) be continued in its current form (i.e. experimental design and number of sites). This information will ensure that a robust understanding of fish and fish habitats is established before and after management interventions are carried out.

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