Intervention Monitoring at the Katarapko Native Fish Demonstration Reach ('Katfish Reach'), South Australia: Progress Report

Kathleen Beyer, Susan Gehrig, Sandra J. Leigh, Jason M. Nicol and Brenton P. Zampatti

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Executive summary

The 'Katfish Reach' initiative was developed in 2007 to provide a holistic approach and to facilitate community involvement in the management of the health of the Katarapko Anabranch system and its associated floodplain (from hereon in referred to as 'Katfish Reach'; Katfish Reach Steering Group, 2008a). The vision of the 'Katfish Reach' initiative is to create 'a healthier and more productive aquatic and floodplain ecosystem that everyone can enjoy'. In order to achieve five ecological objectives, seven management interventions have been proposed for the 'Katfish Reach' system. In order to monitor the effects of the seven management interventions on the fish community within 'Katfish Reach', a number of scientifically robust hypotheses and assessment methodologies were developed based on a 'Paired-Before-After-Control-Impact (BACIP) design.

Two of the seven proposed management interventions (interventions 1 and 2; Katfish Reach Steering Group, 2008b) were selected for monitoring in 2010 and 2011. The aim of the intervention monitoring is to assess the effects of the interventions on the fish community within 'Katfish Reach' by testing six hypotheses relating to fish. This progress report summarises the results from the first year of the 'before' intervention monitoring.

A total of 22 sites were sampled across 'Katfish Reach', including four sites within the main channel of the Murray River. Electrofishing surveys combined with fyke netting and box trapping were undertaken to assess the fish community structure and recruitment success. Habitat assessments were also undertaken in order to determine habitat availability and habitat use.

A total of 13,188 fish representing 15 species (11 native and four non-native) were captured within 'Katfish Reach' during April 2010. The most abundant species were bony herring (*Nematalosa erebi*), unspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*), Australian smelt (*Retropinna semoni*), and goldfish (*Carassius auratus*). Three species of conservation significance were captured in lower abundances, namely, freshwater catfish (*Tandanus tandanus*), silver perch (*Bidyanus bidyanus*) (both listed as protected species under the South Australia

Fisheries Management Act 2007) and Murray cod (*Maccullochella peelii*) (listed as threatened under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999). The abundance and species richness within the system is similar to observations from fish surveys within the Chowilla and Pike anabranch systems and as previously described for 'Katfish Reach'.

The aquatic habitat was dominated by native submergent species and can be considered as being in a similar condition to the Pike and Chowilla anabranch systems (Zampatti *et al.*, 2006a; b; Beyer *et al*., 2009). The floodplain vegetation can also be compared to the Pike and Chowilla systems with areas of salt tolerant vegetation and bare soil (Marsland *et al.*, 2009), and a narrow corridor of riparian understory vegetation along the permanent water courses (Zampatti *et al.*, 2006a; b; Beyer *et al*., 2009).

Recruitment was observed for most species captured in the system. Dwarf-flatheaded gudgeon (*Philipnodon* spp), redfin perch (*Perca fluviatilis*) and Murray cod, however, were captured in low abundances and length frequency analysis could not be used to assess recruitment for these species.

This report presents the data collected in the initial year of the 'before' intervention sampling for the monitoring of interventions 1 and 2. The final year of 'before' intervention sampling will be undertaken in 2011 after which a report analysing the results from both 'before' intervention sampling events will be provided. As interventions are implemented, 'after' intervention monitoring will be undertaken and the response of fish and habitat will be assessed.

1. Introduction

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 associated floodplain (from hereon in referred to as 'Katfish Reach'; Katfish Reach Steering Group, 2008a). The over-arching vision of the 'Katfish Reach' initiative is to create 'a healthier and more productive aquatic and floodplain ecosystem that everyone can enjoy' (Katfish Reach Steering Group, 2008a, b). As part of this initiative, a range of coordinated actions were developed that addressed the major ecological threats to the aquatic and floodplain dependent plants and animals (notably native fish).

The 'Katfish Reach' Implementation Plan (Katfish Reach Steering Group, 2008a) outlined five key ecological objectives to be undertaken within 'Katfish Reach':

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; and
5. Reducing the impacts from pest plant, animal and native species where applicable.

The 'Katfish Reach' Implementation Plan describes the management actions that are needed to achieve these ecological objectives (Katfish Reach Steering Group, 2008a). Seven of these were proposed as management interventions in the 'Katfish Reach' Investment Proposal (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; and
7. Reduce and control carp populations in the Katfish Reach area.

In order to monitor and evaluate the effects of these seven interventions, a number of scientifically robust hypotheses and methodologies were developed based on a 'Paired-Before-After-Control-Impact (BACIP) design (Beyer *et al*., 2009). Two of the proposed management interventions (interventions 1 and 2; Beyer *et al*., 2009) were selected for monitoring in 2010 and 2011. In this progress report 'before-intervention' information relating to fish ecology from 2010 will be presented. The results from both years will be presented in a final report for the current funding cycle in 2011. Once interventions are implemented (planned for 2011) and, if the sampling is continued in its present format, the implications of these two interventions on biological assets (i.e. fish ecology and habitat) of 'Katfish Reach', and will be assessed.

1.1 Aims of the intervention monitoring

The overall aim of the intervention monitoring is to assess the potential impacts of two interventions on the biological assets (i.e. fish ecology and habitat) of 'Katfish Reach'. The monitoring will be used to test six hypotheses (H1-H6; see Appendices 1 and 2 for further details on the links between the interventions and hypotheses and Conceptual Models; see also Beyer *et al*., 2009). The specific aims include:

1. to assess the differences (changes over time) in fish abundance, species composition and diversity in relation to Intervention 1 (H1).
2. the assessment of:
   - changes in habitat diversity and abundance within the Eckert Island system in response to artificial inundation (H2); and
   - changes in fish-habitat associations within the system (H2).
3. to assess the level of recruitment success within the Demonstration Reach for individual fish species and the potential changes in response to the intervention (H3).

4. to determine changes in the fish community structure within the Eckert Island system in response drying parts of the system (H4).

5. to determine:

- changes in habitat diversity and abundance in response to drying some sections of the Eckert Island complex (H5); and
- changes in fish-habitat use within the system (H5).

6. to assess the level of recruitment success within the Demonstration Reach and the potential changes in response to the drying of some sections of the Eckert system (H6).

1.2 Aims of this progress report

Interventions 1 and 2, which were selected to be assessed for the purpose of this intervention monitoring, are to be implemented by 2011 at the earliest (Katfish Reach Steering Group, 2008a, b). This progress report presents the monitoring results from the first year of data collection (April 2010). Hence the data presented in this progress report, provides valuable information on 'before' intervention conditions of fish and habitat within 'Katfish Reach'.

The final report will collate 'before' intervention results from both years (2010 and 2011). Once the planned interventions for 2011 are implemented, 'After' intervention surveys will be undertaken at the same sites. These results will then be analysed to assess the response of fish and habitat to the interventions.

2. Experimental and statistical design of the intervention monitoring

This section describes the overall design of the intervention monitoring (beginning April 2010). The full analysis of the chosen BACIP design can only be completed once all data, including 'before' and 'after' data for 'impact' and 'control' sites has been collected.

For each intervention (1 and 2), three hypotheses were proposed to address four main issues relating to fish ecology in 'Katfish Reach' (labelled H1-H6; Appendices 1 and 2; Beyer *et al.,* 2009):

1. Fish community structure (H1 & H4),
2. Habitat availability (H2 & H5),
3. Fish habitat use (H2 & H5), and
4. Recruitment success (H3 & H6).

2.1 Intervention 1 - Improve spring-summer inundation of Eckert Island at low river flow.

ACTION: Artificial inundation of Eckert Island 3 to 4 months (spring/summer) at a minimum frequency of once every 3 years. A regulator will be installed to the downstream end of Eckert Island and blocking banks will be constructed (existing ones refurbished).

For intervention 1, three hypotheses (H1, H2 and H3) were developed to obtain information relating to fish community structure, habitat availability and recruitment success.

H1: Temporary artificial inundation may alter the structure of the fish community within the Eckert Island system.

The aim of this study is to assess the differences (changes over time) in fish abundance, species composition and diversity in relation to Intervention 1.

H2: Temporary artificial inundation may alter habitat availability and subsequently alter the habitat use by fish within the Eckert Island system.

The aims of this study are to determine changes in habitat diversity and abundance within the Eckert Island system in response to artificial inundation; and changes in fish-habitat associations within the system.

H3: Temporary artificial inundation may alter recruitment success in some fish species within the Eckert Island system.

This study aims to assess the level of recruitment success within the Demonstration Reach for individual fish species, and the potential changes in response to the intervention.

Using the 'BACIP' design (Boys *et al*., 2008), reaches potentially affected by the management intervention will eventually serve as the 'Impact' sites, while unaltered reaches will be the 'Control' sites. Eckert Island complex was divided into four sections based on current meso-habitat types (Figure 1).

'Impact' site(s):

1. Eckert Creek (Bank J to Wide Water) - fast flowing habitat;
2. Eckert Wide Water - backwater habitat;
3. Lower Splash - backwater habitat;
4. Lower Eckert (end of Wide Water to lower Splash) - slow flowing habitat.

'Control' site(s):

5. Katarapko Creek.

To assess the fish community structure, sites were sampled once in April in 2010, and will be sampled again in April 2011. These monitoring dates are designed to ensure that information pertaining to the 'before' intervention fish community structure of 'Katfish Reach' are collected twice before the intervention actions begin (scheduled 2011).

2.2 Intervention 2 - Temporarily partially dry and vary pool level of Eckert Creek anabranch system.

ACTION: Temporarily dry some sections (North Arm, South Arm, The Splash) of the Eckerts Island complex for 4 to 5 months (spring/summer) in 3 out of 5 years using a series of regulators.

For intervention 1, three hypotheses (H4, H5 and H6) were developed to obtain information relating to fish community structure, habitat availability, fish habitat use and recruitment success.

H4: Temporarily drying various reaches of the Eckert Island system may alter the fish community structure.

The aim of this study is to determine changes in the fish community structure within the Eckert Island system in response drying selected regions of the system.

H5: Temporarily drying various reaches of the Eckert Island system may alter habitat availability and subsequently alter the habitat use by fish.

The aims of this study are to determine changes in habitat diversity and abundance in response to drying some sections of the Eckert Island complex and changes in fish-habitat use within the system.

H6: Temporarily drying various reaches of the Eckert Island system may alter recruitment success.

This study aims to assess the level of recruitment success within the Demonstration Reach and the potential changes in response to the drying of some sections of the Eckert system.

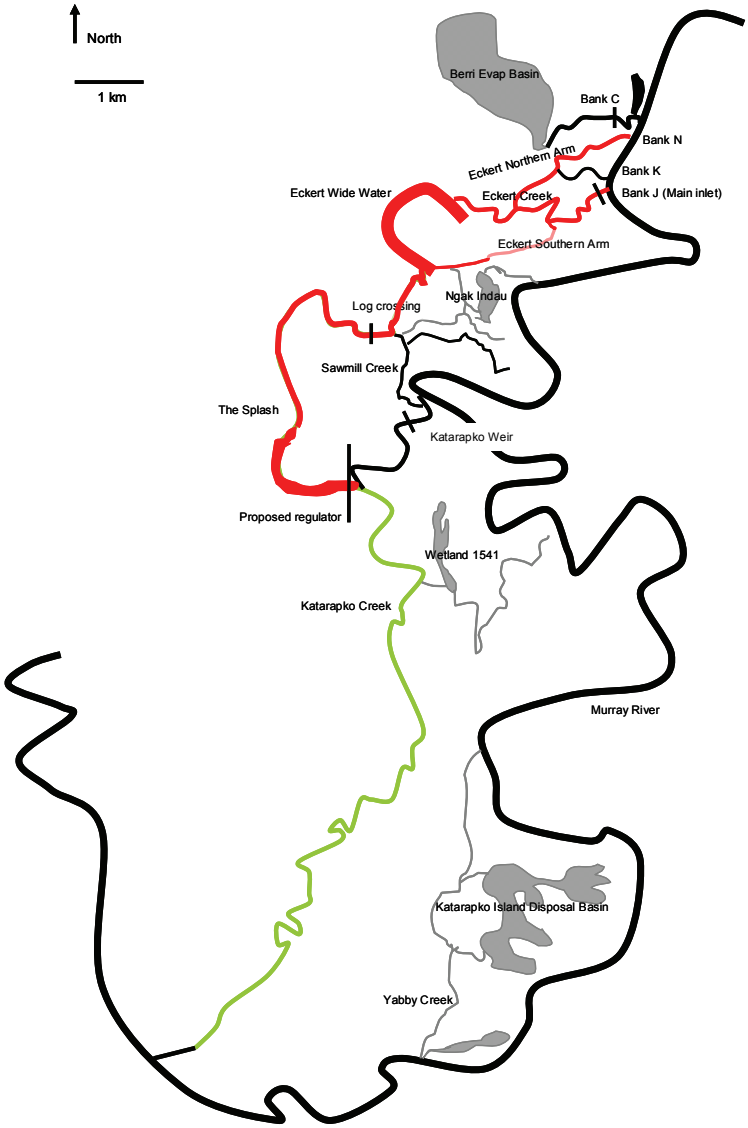

Figure 1: Map showing the locations of control (green) and impact (red) locations within 'Katfish Reach' to be monitored to address the hypotheses developed for Intervention 1.

Using the 'BACIP' design (Boys *et al*., 2008), site selection for Intervention 2 will be similar to those sites selected for Intervention 1 (H1 to H3), where the Eckert Island complex has been divided into four sections (based on current meso-habitat types) (Figure 2) Reaches potentially affected by the management intervention will be used as 'Impact' sites, while unaltered reaches will be used as 'Control' sites:

'Impact' sites:

1. The Splash (upper section) – fast flowing habitat
2. The Splash (lower section) – backwater habitat
3. Northern Arms (Eckert Creek) – slow flowing habitat

4. Southern Arms (Eckert Creek) – slow flowing habitat

'Control' sites:

5. Eckert Creek (Bank J to Wide Water) - fast flowing habitat;
6. Eckert Wide Water - backwater habitat;
7. Lower Eckert Creek (end of Wide Water to log crossing) - slow flowing habitat.

To identify differences in the fish community structure over time in response to Intervention 2, sampling was carried out in April 2010 and will be conducted again in April 2011. Given the proposed funding cycle and the timing of the interventions, the proposed monitoring will result in information on the fish community being collected twice before the implementation of the intervention plan. Using the 'BACIP' design (Boys *et al.,* 2008), several 'Impact' and 'Control' sites were selected (Figure 2).

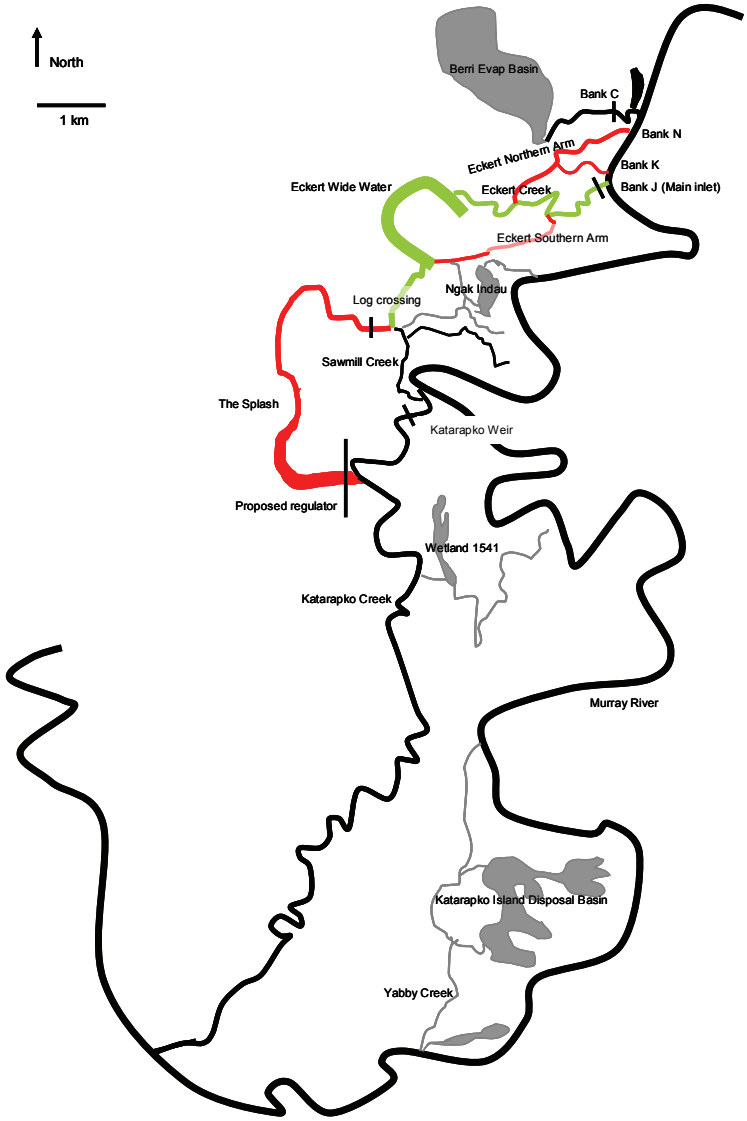

Figure 2: Map showing the location of control (green) and impact (red) locations within 'Katfish Reach' to be monitored to address hypotheses developed for Intervention 2.

3. Methods

3.1 Study site and sampling locations

'Katfish Reach' bypasses Lock and Weir No. 4, generating a head differential of ~ 3.5 m between the inlet of Eckert Creek and the confluence of Katarapko Creek with the Murray River. The head differential creates hydraulically diverse habitats that are now uncommon in the lower Murray River (Zampatti *et al.* 2008).

Twenty-two sites were surveyed in 'Katfish Reach' and adjacent Murray River during April 2010 (Figure 3). In 2007, twelve of these sites (sites 1–12) were surveyed (Leigh *et al.* 2007) and in 2009, fourteen sites (sites 1–12, plus an additional two sites) were surveyed (Leigh *et al.* 2009). Sampling sites were not only representative of the range of aquatic meso-habitats available in 'Katfish Reach', but also appropriate for their role as potential 'Impact' and 'Control' sites (see Section 2). The range of aquatic habitats represented fast- and slow-flowing habitats, backwater environments and the Murray River main channel (Table 1).

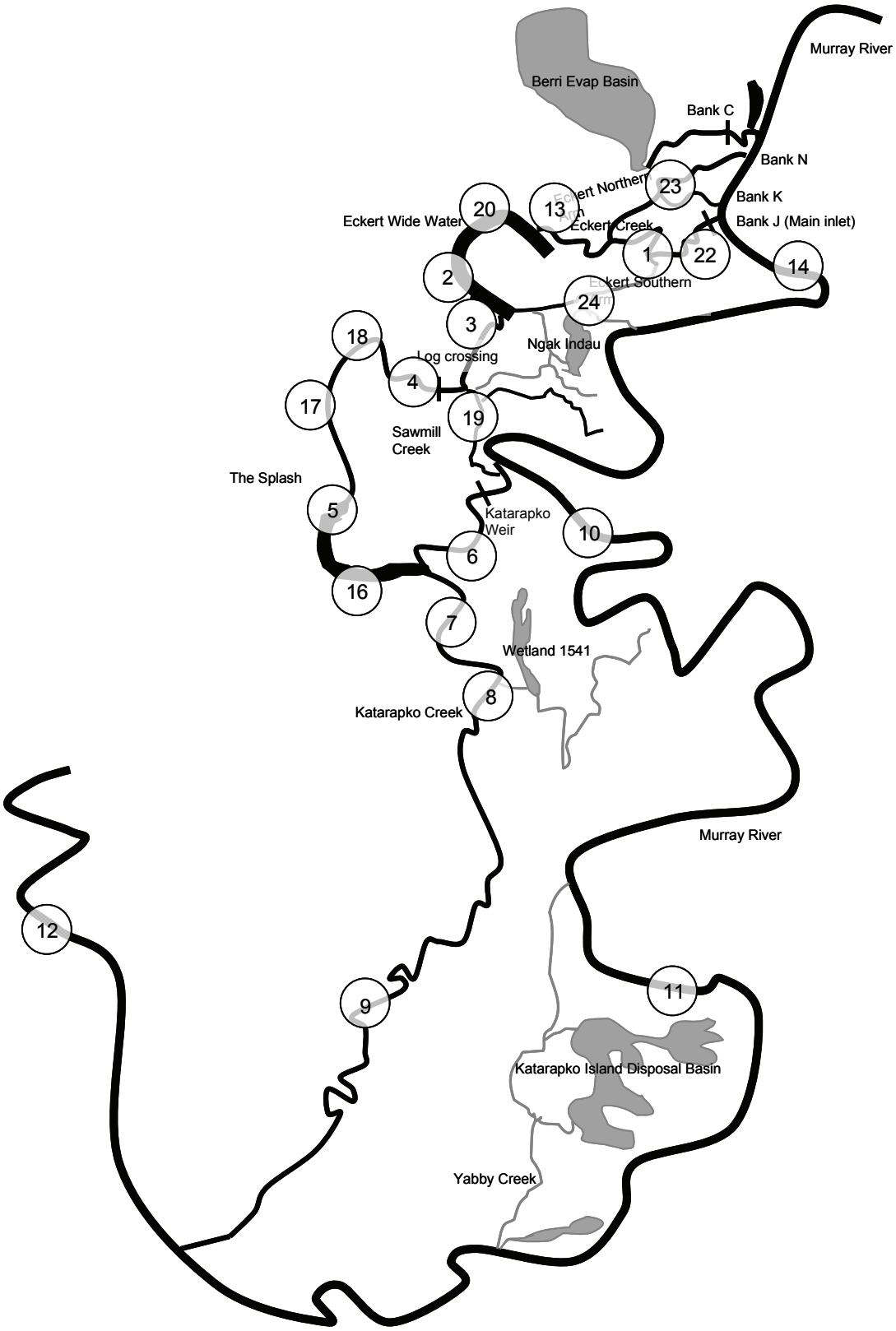

Figure 3: Map of 'Katfish Reach' displaying the locations of the 22 sampling sites chosen for the intervention monitoring starting in April 2010. Sites 15 and 21, which were previously selected, were merged with remaining sites to reduce bias and promote independency of sampling sites.

Table 1: Codes, names and flow types [1) Fast-flowing, 2) Slow-flowing, 3) Backwater, and 4) River Murray main channel] for 22 sampling sites in 'Katfish Reach' assessed during April 2010. Sites 15 and 21, which were previously selected, were merged with remaining sites to reduce bias and promote independency of sampling sites.

Code	Site Name	Fishing method	Flow type
1	Eckert Creek Downstream Weir (~1km)	Eboat	Fast-flowing
2	Eckert Wide Water Downstream	Eboat	Backwater
3	Eckert Creek Upstream Log Crossing	Eboat	Slow-flowing
4	Eckert Creek Downstream Log Crossing	Eboat	Fast-flowing
5	The Splash Upstream	Eboat	Backwater
6	Katarapko Downstream Weir	Eboat	Slow-flowing
7	Katarapko Creek Upstream (Katarapko Island)	Eboat	Slow-flowing
8	Katarapko Creek Mid Section (campsite 16)	Eboat	Slow-flowing
9	Katarapko Creek Downstream (campsite 30)	Eboat	Slow-flowing
10	Murray 3.5 km downstream of Lock 4	Eboat	River Murray main channel
11	Murray 10 km downstream of Lock 4	Eboat	River Murray main channel
12	Murray downstream of Katarapko Junction	Eboat	River Murray main channel
13	Eckert Creek Below Ford	Eboat	Slow-flowing
14	Murray upstream of Lock 4	Eboat	River Murray main channel
16	The Splash Downstream	Eboat	Backwater
17	Eckert Creek Downstream	Fyke/box	Fast-flowing
18	Eckert Creek Upstream	Eboat	Fast-flowing
19	Sawmill Creek	Fyke/box	Slow-flowing
20	Eckert Wide Water Upstream	Eboat	Backwater
22	Eckert Creek downstream Eckert Weir	Eboat	Fast-flowing
23	Eckert Northern Arm	Fyke/box	Slow-flowing
24	Eckert Southern Arm	Fyke/box	Slow-flowing

3.2 Data collection

To monitor and evaluate the implementation of two interventions and test associated hypotheses, the following were used for data collection: 1. electrofishing surveys (fish community structure and recruitment success), 2. fyke netting and box trapping (fish community structure and recruitment success), and 3. habitat assessment (habitat availability and habitat use).

Electro fishing surveys (fish community structure and recruitment success)

Boat electrofishing surveys were used to assess the fish community and recruitment success at selected sampling sites (see Section 2; Table 1). Surveys were conducted using a boat mounted 5kW Smith-Root electro fishing system. At each site, 12 (six on each bank) x 90 second (power on time) electro fishing shots were sampled during daylight. 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; determined by the morphology of the respective fish species). Any positively identified fish unable to be dip netted were recorded as "observed".

To detect recruitment success for individual fish species length distributions were generated. Alternatively, for species where the relationship between length and age is highly variable (e.g. golden perch; Anderson et al. 1992, Mallen-Cooper and Stuart 2003) age was determined using otolith ageing techniques.

Fyke netting and box trapping (fish community structure and recruitment success)

Where efficient electro fishing from a boat was not possible, fyke netting and box trapping were used to assess fish community structure and recruitment success. At each netting/trapping site, three single-winged fyke nets (wing length 6 m, stretched mesh size 8 mm) and two unbaited box traps (24 x 24 x 40 cm) were set overnight. Where possible, fyke nets positioned perpendicular to the bank and preferably in areas with macrophyte growth. Box traps were set randomly without being selective towards areas containing macrophytes.

Habitat assessment (habitat availability and habitat use)

Simultaneously to the electro fishing surveys, quantitative habitat assessments were carried out for each of the 90-second electro fishing shots (Zampatti *et al.* 2006). The percentage cover of each plant species, large woody debris (loading and complexity) and open water in the area covered were estimated within the shot area. Submerged vegetation was sampled using a van Veen grab to enable identification to species where possible.

Age determination for golden perch

The relationship between length and age for golden perch (*Macquaria ambigua*) is highly variable (Anderson *et al.* 1992; Mallen-Cooper and Stuart 2003) therefore age was assessed using thin sectioned otoliths. Specifically, sub samples of 48 golden perch (38 adults; 10 juveniles) were euthanized and their otoliths removed to provide estimates of population structure.

For individual adult golden perch, measurements of length (TL; 1 mm) were made and the otoliths were removed. 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 from the primordium to the otolith edge. Otoliths were accepted if two or more readers agreed on the number of increments. If all three readers differed in the estimate of age for an individual otolith then the otoliths was rejected.

Juvenile golden perch were measured for their length (TL; 1 mm) and otoliths were removed under a dissecting microscope (x 40 magnification). Transverse sections of sagittae were prepared and examined using a compound microscope (x 600 magnification) fitted with image analysis software. For the purpose of this report the aim of the estimate of age was to establish if these fish were young-of-year (YOY) recruits. Each otolith was examined on a single occasion by an experienced reader where three counts of the increments were performed. If these readings differed by

more than 5% the respective otolith was rejected, but if not the mean was accepted as the best estimate of the count.

3.3 Data analysis

The data collected from the electrofishing and fyke net/box trap sites are combined for the purpose of this report. However in future analyses, sites sampled using different fishing methods will be treated separately.

Length frequencies

Where a sufficient number of individuals were captured; length frequencies were derived to assist in describing fish population and life history aspects. The length modes from this analysis may be used to describe age groups, and are generally most pronounced in fish with a short spawning season, and fast and uniform growth (Bagenal and Tesch, 1968).

Age structure of golden perch

To determine the age structure of golden perch age frequency plots were generated for each survey year by combining the age estimates obtained from juveniles and adults. Fish < 6 months old (YOY) were assigned an age classification of 0.5 years in order to be integrated into the age frequency graphs.

Physical habitat and meso-habitat types

Physical habitat composition was compared between meso-habitats (fast anabranch, slow anabranch, backwater and main river channel) using indicator species analysis. Indicator species analysis (Dufrene and Legendre 1997) was carried out using the package PCOrd version 5.12 (McCune and Mefford 2006).

Fish assemblage and aquatic meso-habitat types

Differences in fish assemblages (using catch per unit effort) between meso-habitats were determined using indicator species analysis (Dufrene and Legendre 1997).

Fish species and physical habitat

Fish-habitat associations were determined using indicator species analysis (Dufrene and Legendre 1997) to determine whether a plant species (or CWD category) had a significantly higher percentage cover when a fish species was either present or absent.

4. Results

4.1 Fish community structure

Total catch

A total of 13,188 fish representing 15 species (11 native and four exotic species) were captured within 'Katfish Reach' during April 2010 (Table 1). An average (± S.E.) number of 677 ± 83 fish were captured per electrofishing sampling site (*n*=18), and 248 ± 43 fish were captured per fyke/box sampling site (*n*=4). The most abundant species were bony herring (*Nematalosa erebi*) (*n*=8,941), unspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*) (*n*=1,517), Australian smelt (*Retropinna semoni*) (*n*=809), and goldfish (*Carassius auratus*) (*n*=471). Three species of federal and state conservation significance were captured in relatively low numbers, namely, freshwater catfish (*Tandanus tandanus*) (*n*=10) and silver perch (*Bidyanus bidyanus*) (*n*=19) (listed as protected species under the South Australia Fisheries Management Act 2007) and Murray cod (*Maccullochella peelii peelii*) (*n*=3) (listed as threatened under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999) (Table 1).

Species richness

A total of 15 fish species were caught, but species richness was highly variable between sampling sites (range 6 to 12 fish species) (Table 1). The greatest number of species (n=12) was observed in a Murray River main channel site (site 10).

Distribution of fish

The most abundant fish species were widely distributed across the system. For instance, goldfish were collected at every site, un-specked hardyhead and bony herring were found at 21 sites, and Australian smelt at 20 sites (Table 1). Silver perch (*n*=19) occurred at ten of the 22 sampling sites, with the majority of numbers also recorded from site 10 (River Murray channel; *n*=7). Freshwater catfish (*n*=10) were collected from five out of the 22 sampling sites across of a range of meso-habitat types reflecting fast-flowing habitats (site 1: *n*=4 and site 22: *n*=2), slow-flowing habitats (site 19; *n*=1) and the main river channel (site 14: *n*=2). Individual specimens of Murray cod were also recorded across a range of meso-habitat categories such as slow-flowing (site 3), and the main river channel (sites 10 and 11).

Table 2. Table showing species richness and total abundance of fish captured from 'Katfish Reach' in April 2010. Due to their physical characteristics sites 17, 19, 23 and 24 were sampled using fyke nets and box traps, while all remaining sites were sampled using an electrofishing boat.

	Site Number																						
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**16**	**17**	**18**	**19**	**20**	**22**	**23**	**24**	**Total**
Silver perch	0	0	0	1	0	1	1	1	2	7	3	0	0	0	0	1	0	0	0	0	1	1	**19**
Goldfish	17	47	35	33	41	1	3	13	16	38	1	30	21	17	46	1	25	2	54	20	3	7	**471**
Unspecked hardyhead	277	9	11	67	49	30	59	21	33	196	45	270	43	87	71	54	6	70	7	110	0	2	**1517**
Carp	5	7	9	18	16	11	7	13	12	18	21	49	9	12	14	1	23	9	19	15	0	7	**295**
Gambusia	5	0	0	4	1	9	8	0	0	5	0	1	0	0	6	5	1	54	0	13	111	23	**246**
Carp gudgeon spp	9	0	0	6	3	10	0	2	2	11	3	2	5	0	3	7	0	96	0	20	29	159	**367**
Golden perch	2	1	0	8	7	34	7	13	8	29	9	6	0	3	0	7	2	1	0	1	0	11	**149**
Murray cod	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	**3**
Murray rainbowfish	1	80	3	5	1	6	7	66	55	12	11	18	3	39	0	0	1	0	1	10	1	0	**320**
Bony herring	703	0	819	401	498	481	359	824	1205	548	793	448	98	349	246	89	236	96	97	628	14	9	**8941**
Redfin perch	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Flathead gudgeon	0	0	1	2	0	0	0	0	0	0	0	0	0	0	2	3	0	4	0	0	1	4	**17**
Dwarf-flatheaded gudgeon	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	**3**
Australian smelt	125	0	4	63	48	16	21	15	17	99	103	19	10	29	25	68	18	36	16	73	4	0	**809**
Freshwater catfish	4	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	1	0	2	0	0	**10**
Number of species	11	8	8	11	9	10	9	9	9	12	10	9	7	9	8	10	8	10	6	10	8	10	
Total no of fish/site	**1149**	**146**	**883**	**608**	**664**	**599**	**472**	**968**	**1350**	**965**	**990**	**843**	**189**	**540**	**413**	**236**	**312**	**369**	**194**	**892**	**164**	**224**	*13188*

4.2 Habitat availability

Habitat assessments of vegetation, woody debris and open water coverage were made at each sampling site. Plant species were categorised into 'functional' groups depending on the role they provided within each site (i.e. in-stream, fringing and/or riparian zone habitats) (Table 3). Site names codes, flow types and locations are provided in Table 1; Figure 1).

Table 3. Functional grouping of the riparian and aquatic vegetation within 'Katfish Reach' (April 2010).

Location	Functional Group	Species Name (*denotes exotic species)
Instream	Submergents	*Elodea canadensis*, Myriophyllum verrucosum, Potamogeton crispus, Potamogeton tricarinatus, Vallisneria australis.*
Instream	Floating	*Azolla filiculoides, Lemna* sp. *Ludwigia peploides* ssp. *montevidensis,*
Instream	Submergent-Floating Association	Vallisneria-Azolla Complex, Vallisneria-Ludwigia-Azolla Complex, Elodea –Azolla Complex
Instream	Emergent	*Bolboschoenus caldwellii, Muehlenbeckia florulenta, Persicaria lapathifolium, Phragmites australis, Rumex bidens, Schoenoplectus validus, Typha* sp.
Instream	Alga	*Chara* sp., *Nitella* sp.
Fringing	Emergents	*Cyperus exaltatus, Cyperus gymnocaulos, Eleocharis acuta, Juncus acutus*, Juncus usitatus, Lolium* sp.*, *Paspalum distichum*, Phragmites australis, Typha* sp.,
Riparian Zone	Overstorey (overhanging)	*Acacia stenophylla, Callistemon brachyandrus* , *Eucalyptus camaldulensis* var. *camaldulensis, Eucalyptus largiflorens, Muehlenbeckia florulenta, Sarcocornia quinqueflora*

Habitat descriptions

Site 1 (Eckert Creek Downstream Weir)

Creek edges were dominated by stands of *Phragmites australis,* with smaller stands of *Typha* sp. also present along the southern edge. Discreet patches of *Paspalum distichum, Juncus usitatus* and *Cyperus gymnocaulos* were also recorded, particularly along the northern edge. In-stream habitat was dominated by coarse woody debris (i.e. fallen trees and branches, tree roots and twigs), patches of the *Vallisneria australis* and open water. Small patches of other species such as *Ludwigia peploides, Persicaria lapathifolium, Potamogeton crispus*, *Potamogeton tricarinatus, Chara* sp. and *Nitella*

sp. and *Azolla filiculoides* were also present. *Eucalyptus camaldulensis* var. *camaldulensis* trees were the dominant overstorey along the banks of the creek; however *Eucalyptus largiflorens* was also present. In general, these trees did not tend to overhang either side of the site.

Site 2 (Eckert Wide Water Downstream)

Creek edges were dominated by dense, wide stands of *Typha* sp., occasionally interspersed occasionally with *Phragmites australis, Cyperus gymnocaulos, Cyperus exaltatus* and *Paspalum distichum.* In-stream habitat was characterised by open water and high densities of the Vallisneria-Azolla Complex in areas where *Typha* sp. cover was low. Discreet patches of the submergent *Ludwigia peploides* ssp. *montevidensis* were also observed in this site, although in very low abundances, as was the abundance of coarse woody debris. The riparian zone consisted of a sparse overstorey of *Eucalyptus camaldulensis* var. *camaldulensis* and *Acacia stenophylla*, that provided little overhang. The lack of riparian, emergent and submergent plant diversity in this area, and greater abundance of *Typha* sp. is most likely related to the hydrology of this site, as similar habitat characteristics are also found in other shallow, low flowing wetlands.

Site 3 (Eckert Creek Upstream Log Crossing)

Stands of *Typha* sp. were the dominant emergents, with abundance varying from dense to sparse. Other emergents included *Cyperus gymnocaulos and Cyperus exaltatus* in relatively low abundances. The in-stream habitat was predominantly open water and submerged beds of Vallisneria-Azolla Complex, although large fallen logs were also abundant in some areas. Discreet patches of *Ludwigia peploides* and *Potamogeton crispus* were also present. Riparian edges were dominated by *Eucalyptus camaldulensis* var. *camaldulensis* and *Acacia stenophylla* trees, although overhanging overstorey was minimal in this site.

Site 4 (Eckert Creek Downstream Log Crossing)

The edge habitat was highly diverse, with predominant stands of *Phragmites australis* and *Typha* sp. interspersed with a diverse range of other species such as *Juncus usitatus*, *Cyperus gymnocaulos, Schoenoplectus validus, Bolboschoenus caldwellii, Paspalum*

distichum and *Muehlenbeckia florulenta.* In-stream habitat consisted of occasional stands of *Vallisneria australis* and *Ludwigia peploides* ssp. *montevidensis*, generally in low abundance (although more dense beds were observed in some areas). Coarse woody debris and tree roots were also present, but to a limited extent. *Eucalyptus camaldulensis* var. *camaldulensis*, *Eucalyptus largiflorens* and *Acacia stenophylla* trees were present along the banks, but did not provide much overhang.

Site 5 (The Splash Upstream)

The edges of the creek were characterised by stands of *Bolboschoenus caldwellii* interspersed with one or more of stands of *Cyperus gymnocaulos, Typha* sp., *Paspalum distichum* and *Juncus usitatus.* In-stream habitat was dominated by open water and sparse to dense beds of Vallisneria-Azolla Complex, along with occasional patches of large woody debris and/or *Ludwigia peploides* ssp. *montevidensis*. Discreet patches of *Chara* sp. and *Nitella* sp. were also present. *Eucalyptus camaldulensis* var. *camaldulensis* trees were found along the banks of the creek, but did not provide any overhang.

Site 6 (Katarapko Downstream Weir)

Emergent vegetation differed between both sides of the creek; with *Bolboschoenus caldwellii* predominantly found on the western side, compared to stands of *Typha* sp. and *Phragmites australis* on the eastern side. Other species, such as *Cyperus exaltatus, Cyperus gymnocaulos* and *Rumex bidens* were also present in low abundances. The in-steam habitat was predominantly open water and large patches of the submergents Vallisneria-Ludwigia-Azolla Complex, although patches of *Potamogeton tricarinatus* and *Chara* sp. and *Nitella* sp., were also observed in low numbers throughout the site. Occasional patches of large coarse woody debris and tree roots were also present. Similarly, *Eucalyptus camaldulensis var. camaldulensis* and *Acacia stenophylla* trees were observed along the western bank, whereas the eastern bank was characterised by a diverse overstorey of *Acacia stenophylla, Eucalyptus largiflorens* and *Eucalyptus camaldulensis var. camaldulensis*.

Site 7 (Katarapko Creek Upstream)

The banks were fringed with patches of *Phragmites australis*, *Cyperus exaltatus, Cyperus gymnocaulos, Juncus usitatus* and *Paspalum distichum.* In-stream habitat was characterised by open water, large fallen trees and intermittent, dense beds of Vallisneria - Ludwigia – Azolla Complex. There were the occasional, rare patches of *Potamogeton tricarinatus, Chara* sp. and *Nitella* sp. The riparian zone was dominated by *Eucalyptus camaldulensis* var. *camaldulensis* and *Acacia stenophylla* trees, which provided some overhang.

Site 8 (Katarapko Creek Mid Section)

The western side of the creek was principally composed of dense stands of *Phragmites australis*, interspersed with *Cyperus exaltatus* whereas the eastern side was more sparsely vegetated with *Phragmites australis* and occasional patches of *Cyperus exaltatus* and *Juncus usitatus.* In-stream habitat was characterised by numerous large fallen logs, open water habitat and a diverse array of submergents; predominantly *Vallisneria australis* and *Ludwigia peploides* ssp. *montevidensis* and to a lesser extent *Potamogeton tricarinatus* and *Azolla filiculoides.* The riparian zone was characterised by overhanging *Eucalyptus camaldulensis* var. *camaldulensis* and *Acacia stenophylla* trees.

Site 9 (Katarapko Creek Downstream)

There was minimal emergent vegetation, as the plants were generally confined to the banks, but included discreet patches of *Typha* sp., *Lolium* sp. and *Cyperus exaltatus*. In-stream habitat was predominantly provided by large fallen logs and open water and hence aquatic vegetation was minimal. Specifically, patches of Elodea-Azolla Complex was highly abundant throughout the creek, with small patches of *Vallisneria australis, Ludwigia peploides* ssp. *montevidensis, Potamogeton tricarinatus*, *Chara* sp. and *Nitella* sp. The riparian zone was dominated by *Eucalyptus camaldulensis* var. *camaldulensis* and *Acacia stenophylla* trees, but provided minimal overhang.

Site 10 (Murray 3.5km downstream of Lock 4)

The dominant emergent vegetation was *Phragmites australis* interspersed with discreet patches of *Typha* sp., *Bolboschoenus caldwellii, Juncus acutus, Juncus usitatus,*

Cyperus gymnocaulos and *Paspalum distichum*. In-stream habitat was predominantly *Vallisneria australis* with patches of *Ludwigia peploides* ssp. *montevidensis, Eleocharis acuta* and *Azolla filiculoides*. Coarse woody debris such as fallen logs and branches were also moderately abundant throughout the site. In the riparian zone *Eucalyptus camaldulensis* var. *camaldulensis, Acacia stenophylla* and *Eucalyptus largiflorens* were present, providing minimal overhang.

Site 11 (Murray 10km downstream of Lock 4)

Emergent vegetation was not highly abundant, but was composed of patches of *Phragmites australis* interspersed with *Juncus acutus, Cyperus gymnocaulos, Typha* sp. and *Bolboschoenus caldwellii*. The submergent vegetation was highly variable, but there were intermittent patches of Elodea –Azolla Complex along with discreet patches of *Vallisneria australis, Potamogeton tricarinatus* and *Potamogeton crispus*, *Chara* sp. and *Nitella* sp. Fallen branches and tree roots also provided sporadic in-stream habitat throughout the site. Both banks were dominated by *Acacia stenophylla* and *Eucalyptus camaldulensis* var. *camaldulensis* trees.

Site 12 (Murray downstream of Katarapko junction)

Phragmites australis was sparsely distributed along the southern side, interspersed with patches of *Typha* sp. and *Paspalum distichum*. In-stream habitat was mostly open water and dense beds of Elodea-Azolla Complex with discreet patches of *Vallisneria australis, Myriophyllum verrucosum* and *Ludwigia peploides* ssp. *montevidensis*. A small amount of coarse woody debris was also found. The dominant overstorey along the banks was *Eucalyptus camaldulensis* var. *camaldulensis* and *Acacia stenophylla* trees with some degree of canopy overhang.

Site 13 (Eckert Creek Below Ford)

There were intermittent, dense stands of *Typha* sp., interspersed with other emergents such as *Paspalum distichum*, *Juncus usitatus, Phragmites australis, Cyperus gymnocaulos* and *Rumex bidens.* In-stream habitat was mostly open water, with aquatic vegetation, such as *Vallisneria australis* and *Potamogeton crispus*, *Azolla filiculoides*, L*emna* sp., *Chara* sp. and *Nitella* sp. A moderate amount of coarse woody debris was also present. In the riparian zone, the fringing vegetation was composed of shrubs such

as *Muehlenbeckia florulenta* and *Sarcocornia quinqueflora,* amongst dead *Eucalyptus camaldulensis* var. *camaldulensis* and *Acacia stenophylla* trees.

Site 14 (Murray upstream of Lock 4)

Emergent vegetation was minimal, although there were occasional patches of *Phragmites australis, Paspalum distichum* and *Typha* sp. In-stream habitat was mostly open water, with scarce patches of as aquatic vegetation such as *Vallisneria australis*, Elodea-Azolla Complex and *Ludwigia peploides* ssp. *montevidensis*. There was a minimal amount of coarse woody debris present and due to the steep, sloping (90 degree) banks on the eastern side. Overstorey was predominantly composed of *Eucalyptus camaldulensis* var. *camaldulensis,* interspersed with *Eucalyptus largiflorens*, *Acacia stenophylla (*and one *Callistemon brachyandrus*) providing a fair degree of overhang.

Site 16 (The Splash Downstream)

The emergent vegetation was predominantly composed of *Bolboschoenus caldwellii*, interspersed with discreet patches of *Typha* sp., *Cyperus exaltatus, Cyperus gymnocaulos* and *Juncus usitatus*. In-stream habitat was predominantly open water and dense patches of the Vallisneria–Azolla Complex, interspersed with *Ludwigia peploides* and *Potomageton crispus*, and low abundances of coarse woody debris. Overstorey vegetation was a mix of *E. camaldulensis* and *Acacia stenophylla* trees, providing very little canopy overhang.

Site 17 (Eckert Creek Downstream [Fyke net/box trap site])

Creek edges were dominated by stands of *Typha* sp. interspersed with a diverse range of emergents, such as *Bolboschoenus caldwellii, Cyperus exaltatus, Cyperus gymnocaulos* and *Juncus usitatus.* In-stream habitat was characterised by dense patches of *Ludwigia peploides* ssp. *montevidensis* and/or Vallisneria-Azolla Complex and open water. *Eucalyptus camaldulensis* var. *camaldulensis* provided moderate levels of canopy overhang.

Site 18 (Eckert Creek Upstream)

The edges of the creek were characterised by stands of *Phragmites australis* and *Typha* sp., interspersed with small to dense patches of *Cyperus gymnocaulos, Paspalum distichum, Juncus usitatus, Schoenoplectus validus* and *Bolboschoenus caldwellii.* The in-stream habitat was dominated by open water and occasional dense beds of Ludwigia-Azolla Complex or Vallisneria-Azolla Complex, and a moderate abundance of large woody debris. Within the riparian zone, *Eucalyptus camaldulensis* var. *camaldulensis* and *Acacia stenophylla* trees and shrubs of *Muehlenbeckia florulenta* provided minimal canopy overhang.

Site 19 (Sawmill Creek [Fyke net/box trap site])

The edges of the creek were dominated by stands of *Typha* sp. interspersed with *Cyperus exaltatus* and *Cyperus gymnocaulos.* In-stream habitat was dominated by dense beds of Vallisneria-Azolla Complex and open water and the occasional patch of *Potamogeton crispus*. *Eucalyptus camaldulensis* var. *camaldulensis* and *Acacia stenophylla* were present in the riparian zone, but provided no canopy overhang.

Site 20 (Eckert Wide Water Upstream)

The edges of the creek were characterised by stands of *Typha* sp., with small to moderate patches of *Phragmites australis, Paspalum distichum, Bolboschoenus caldwellii* and *Cyperus gymnocaulos.* In-stream habitat was dominated by open water and occasional dense beds of *Vallisneria australis* interspersed with occasional patches of *Potamogeton crispus* and the floating *Azolla filiculoides*.

Site 22 (Eckert Creek downstream Eckert Weir)

The edges of the creek were characterised by dense stands of *Typha* sp., with small to moderate patches of *Phragmites australis, Paspalum distichum, Bolboschoenus caldwellii, Rumex bidens* and *Cyperus gymnocaulos.* The in-stream habitat was dominated by open water, abundant coarse woody debris (fallen logs and snags), and occasional dense beds of *Vallisneria australis*, *Ludwigia peploides* ssp. *montevidensis, Azolla filiculoides*; interspersed with occasional patches of *Potamogeton crispus.* Within the riparian zone, *Eucalyptus camaldulensis* var. *camaldulensis* and *Acacia stenophylla* trees provided some level of canopy overhang.

Site 23 (Eckert Northern Arm [fyke net/box trap site])

The edges of the creek were characterised by dense stands of either *Typha* sp. or *Phragmites australis* interspersed with occasional stands of *Paspalum distichum* or *Cyperus gymnocaulos.* The in-stream habitat was dominated by open water and dense floating patches of *Azolla filiculoides* and/or *Lemna* sp. interspersed with occasional beds of *Vallisneria australis* and *Ludwigia peploides* ssp. *montevidensis* and some coarse woody debris (e.g. fallen logs). Within the riparian zone, *Eucalyptus camaldulensis* var. *camaldulensis*, *Eucalyptus. largiflorens* and *Acacia stenophylla* trees were present, but did not provide any canopy overhang.

Site 24 (Eckert Southern Arm [fyke net/box trap site])

The in-stream habitat was dominated by dense floating patches of *Azolla filiculoides*, dense stands of either emergents such as *Typha* sp. or *Phragmites australis* and the occasional patch of *Paspalum distichum.* Within the riparian zone, *Eucalyptus camaldulensis* var. *camaldulensis* and *Eucalyptus largiflorens* trees were present, but provided no canopy overhang.

Physical habitat vs meso-habitat type

Indicator species analysis was used to assess the physical habitat composition and species percent cover between sites the four meso-habitat types (fast-flowing, slow-flowing, backwater and River Murray main channel). The River Murray channel sampling sites were best described by overhanging canopy ($P \leq 0.01$), Azolla-Elodea complex ($P \leq 0.0001$), emergent *Juncus acutus* ($P \leq 0.05$) and, not unexpectedly, open water ($P \leq 0.0001$) (Table 4). Backwaters were significantly associated with submergent *Bolboschoenus caldwellii* ($P \leq 0.0001$), Azolla-Vallisneria complex ($P \leq 0.0001$), and emergent *Cyperus gymnocaulos* ($P \leq 0.0001$). Fast anabranches could best be described by floating *Acacia stenophylla* ($P \leq 0.0001$), Azolla-Ludwigia complex ($P \leq 0.0001$), overhanging *Eucalyptus camaldulensis* var. *camaldulensis* ($P \leq 0.01$), submergent *Ludwigia peploides* ssp. *montevidensis* ($P \leq 0.01$), the shrub *Muehlenbeckia florulenta* ($P \leq 0.0001$), the grasses *Phragmites australis* and *Paspalum distichum* (both $P \leq 0.05$), emergent *Rumex bidens* ($P \leq 0.01$), emergent *Schoenoplectus validus* ($P \leq 0.01$) and submergent *Vallisneria australis* ($P \leq 0.0001$). Slow anabranches were significantly

associated with overhanging *Acacia stenophylla* ($P \leq 0.0001$), the algae *Chara* sp and *Nitella* sp (both $P \leq 0.0001$), Azolla-Ludwigia-Vallisneria complex ($P \leq 0.0001$), coarse woody debris 3 ($P \leq 0.0001$), emergent *Cyperus exaltatus* ($P \leq 0.01$), floating *Lemna* sp ($P \leq 0.0001$), submergent *Potamogeton tricarinatus* ($P \leq 0.05$) and tree roots ($P \leq 0.05$).

Table 4. *P*-values resulting from the indicator species analysis assessing the physical habitat between the four meso-habitats in 'Katfish Reach' in April 2010.

Physical habitat	Functional group	Meso-habitat type	*P*-value
Acacia stenophylla	Riparian Zone	slow-flowing	**<0.001**
Azolla filiculoides	Floating	fast-flowing	**<0.001**
bare soil	N/A	backwater	0.09
Bolboschoenus caldwellii	Emergent	backwater	**<0.001**
overstorey canopy overhanging	Overhanging	River Murray channel	**0.002**
Chara sp.	Alga	slow-flowing	**<0.001**
Azolla-Elodea Complex	Complex	River Murray channel	**<0.001**
Azolla-Ludwigia Complex	Complex	fast-flowing	**<0.001**
Azolla-Ludwigia-Vallisneria Complex	Complex	slow-flowing	**<0.001**
Azolla-Vallisneria Complex	Complex	backwater	**<0.001**
Coarse woody debris 1	N/A	fast-flowing	0.28
Coarse woody debris 2	N/A	slow-flowing	0.13
Coarse woody debris 3	N/A	slow-flowing	**<0.001**
Cyperus exaltatus	Emergent	slow-flowing	**0.002**
Cyperus gymnocaulos	Emergent	backwater	**<0.001**
Elodea canadensis	Submergent	River Murray channel	0.09
Eucalyptus camaldulensis var. *camaldulensis*	Riparian Zone	fast-flowing	**0.002**
Eucalyptus largiflorens	Riparian Zone	fast-flowing	0.06
Juncus acutus	Emergent	River Murray channel	**0.0185**
Juncus usitatus	Emergent	fast-flowing	0.15
Lemna sp.	Floating	slow-flowing	**<0.001**
Lolium sp.	Emergent	slow-flowing	1.00
Ludwigia peploides ssp. *montevidensis*	Floating	fast-flowing	**0.0063**
Muehlenbeckia florulenta	Emergent	fast-flowing	**<0.001**
Muehlenbeckia florulenta	Riparian Zone	slow-flowing	0.17
Myriophyllum verrucosum	Submergent	River Murray channel	0.43
Nitella spp	Alga	slow-flowing	**<0.001**
Open water	N/A	River Murray channel	**<0.001**
Paspalum distichum	Emergent	fast-flowing	**0.016**
Persicaria lapathifolium	Emergent	fast-flowing	0.65
Phragmites australis	Emergent	fast-flowing	**0.0222**
Populus sp.	Riparian Zone	slow-flowing	1.00
Potamogeton crispus	Submergent	backwater	0.25
Potamogeton tricarinatus	Submergent	slow-flowing	**0.0125**
Rumex bidens	Emergent	fast-flowing	**0.0075**
Sarcocornia quinqueflora	Emergent	slow-flowing	1.00
Sarcocornia quinqueflora	Riparian zone	slow-flowing	0.07
Schoenoplectus validus	Emergent	fast-flowing	**0.0074**
Scour holes	N/A	slow-flowing	1.00
Tree roots	N/A	slow-flowing	**0.0179**
Typha sp.	Emergent	fast-flowing	0.22
Vallisneria australis	Submergent	fast-flowing	**<0.001**

4.3 Fish habitat use

Fish assemblage and aquatic meso-habitat types

Indicator species analysis showed a number of significant indicators for each of the four different meso-habitat types (Table 5). Unspecked hardyhead, Murray-Darling rainbowfish, common carp and golden perch were significantly associated with the Main River Channel. Goldfish was a significant indicator of backwaters, and bony herring of slow anabranches. Australian smelt, Eastern gambusia, carp gudgeon freshwater catfish were significantly more abundant in fast anabranches (Table 5).

Table 5. *P*-values resulting from the indicator species analysis assessing the fish community structure (CPUE) between the four meso-habitats in 'Katfish Reach' in April 2010.

Common name	Scientific name	Meso-habitat	*P*-value
Silver perch	*Bidyanus bidyanus*	River Murray Channel	0.14
Goldfish	*Carassius auratus*	Backwater	**0.0001**
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	River Murray Channel	**0.0002**
Common carp	*Cyprinus carpio*	River Murray Channel	**0.0044**
Eastern gambusia	*Gambusia holbrooki*	Fast-flowing	**0.0093**
Carp gudgeon	*Hypseleotris* spp.	Fast-flowing	**0.0024**
Golden perch	*Macquaria ambigua ambigua*	River Murray Channel	**0.0101**
Murray cod	*Maccullochella peelii peelii*	River Murray Channel	0.70
Murray-Darling rainbowfish	*Melanotaenia fluviatilis*	River Murray Channel	**0.0009**
Bony herring	*Nematolosa erebi*	Slow-flowing	**0.0445**
Redfin perch	*Perca fluviatilis*	Fast-flowing	0.68
Flatheaded gudgeon	*Philypnodon grandiceps*	Backwater	0.28
Dwarf-flatheaded gudgeon	*Phylipnodon* spp.	River Murray Channel	0.66
Australian smelt	*Retropinna semoni*	Fast-flowing	**0.004**
Freshwater catfish	*Tandanus tandanus*	Fast-flowing	**0.0443**

Fish species vs micro-habitat use

Indicator species analysis revealed that statistical significant associations of native and non-native fish species were highly variable for a variety of physical habitat types. For instance, Murray cod were significantly associated with one habitat type (tree roots; $P \leq 0.0001$) compared to 16 significant indicators observed for Murray-Darling rainbowfish (from $P \leq 0.05$ to $P \leq 0.0001$; Table 6). Significant habitat associations in non-native fish species ranged between two (common carp) and six (goldfish, Eastern gambusia) (Table 6). Single associations were observed for overhanging overstorey

canopy (eastern gambusia; $P \leq 0.05$), Azolla-Ludwigia complex (unspecked hardyhead; $P \leq 0.05$), coarse woody debris (CWD1) (carp gudgeon; $P \leq 0.01$), overhanging *Eucalyptus camaldulensis* var. *camaldulensis* (Murray-Darling rainbowfish; $P \leq 0.05$), emergent *Juncus usitatus* (Murray-Darling rainbowfish; $P \leq 0.01$), the shrub *Muehlenbeckia florulenta* (unspecked hardyhead; $P \leq 0.05$), submergent *Potamogeton crispus* (flatheaded gudgeon; $P \leq 0.01$), overhanging *Sarcocornia quinqueflora* (carp gudgeon; $P \leq 0.05$) and submergent *Vallisneria australis* (Australian smelt; $P \leq 0.05$) (Table 6). The greatest number of indicators were observed for open water (from $P \leq 0.05$ to $P \leq 0.0001$; silver perch, eastern gambusia, golden perch, Murray-Darling rainbowfish, bony herring and Australian smelt) and emergent *Typha* sp (from $P \leq 0.05$ to $P \leq 0.0001$; silver perch, unspecked hardyhead, golden perch, Murray-Darling rainbowfish, bony herring and Australian smelt) (Table 6).

Table 6. Fish habitat preferences in 'Katfish Reach' and the adjacent River Murray main channel.

Fish Species	Associated Habitat
Silver perch	Coarse Woody Debris 3 (P=0.008), Open Water (P=0.038), *Phragmites australis* (P=0.034), Tree Roots (P= 0.002), *Typha* sp. (P=0.040)
Goldfish	*Bolboschoenus caldwellii* (P=0.003), *Chara* sp. (P=0.004), Azolla-Ludwigia complex (P<0.001), Azolla-Vallisneria complex (P<0.001), *Cyperus gymnocaulos* (P=0.006), *Nitella* sp. (P=0.002)
Unspecked hardyhead	Azolla-Ludwigia complex (P=0.030), *Muehlenbeckia florulenta* (in stream) (P=0.016), *Typha* sp. (P=0.019)
Common carp	Azolla-Elodea complex (P=0.010), Tree Roots (P=0.035)
Eastern gambusia	Overhanging Canopy (P=0.019), Azolla-Ludwigia complex (P<0.001), Overhanging *Eucalyptus largiflorens* (P=0.006), Open Water (P=0.002), *Paspalum distichum* (P=0.041), *Rumex bidens* (P=0.048)

Fish Species	Associated Habitat
Carp gudgeon	*Azolla filiculoides* (*P*=0.009), Coarse Woody Debris 1 (*P*=0.010), *Lemna* sp. (*P*=0.034), *Paspalum distichum* (*P*=0.013), *Rumex bidens* (*P*=0.018), *Sarcocornia quinqueflora* (*P*=0.046)
Golden perch	Overhanging *Acacia stenophylla* (*P*=0.014), Azolla-Ludwigia complex (*P*=0.008), Coarse Woody Debris 2 (*P*=0.049), Coarse Woody Debris 3 (*P*<0.001), *Lemna* sp. (*P*=0.035), Open Water (*P*<0.001), *Phragmites australis*, (*P*<0.001), *Typha* sp. (*P*=0.003)
Murray cod	Tree Roots (*P*<0.001)
Murray-Darling rainbowfish	Overhanging *Acacia stenophylla* (*P*<0.001), *Bolboschoenus caldwellii* (*P*=0.001), *Chara* sp. (*P*=0.004), Azolla -Elodea complex (*P*=0.002), Azolla-Vallisneria complex (*P*=0.006), Coarse Woody Debris 2 (*P*=0.003), *Cyperus gymnocaulos* (*P*<0.001), Overhanging *Eucalyptus camaldulensis* (*P*=0.037), *Juncus usitatus* (*P*=0.006), *Nitella* sp. (*P*=0.002), Open Water (*P*<0.001), *Phragmites australis* (*P*=0.010), Tree Roots (*P*=0.009), *Typha* sp. (*P*=0.003)
Bony herring	*Azolla filiculoides* (*P*<0.001), Open Water (*P*<0.001), *Typha* sp. (*P*=0.005)
Flathead gudgeon	Azolla-Vallisneria complex (*P*=0.015), *Potamogeton crispus* (*P*=0.005)
Australian smelt	*Chara* sp. (*P*= 0.019), Azolla-Vallisneria complex (*P*=0.003), *Nitella* sp. (*P*=0.016), Open Water (*P*=0.011), *Typha* sp. (*P*<0.001), *Vallisneria australis* (*P*=0.021)
Freshwater catfish	Overhanging *Eucalyptus camaldulensis* (*P*<0.001), *Phragmites australis* (*P*<0.001)

4.4 Recruitment success

Generally uni-modal distributions were observed for small-bodied species (≤100mm length) captured in the system (Figure 4 and Figure 5). The length distributions generated for medium and large-bodied fish species (≥100mm length) were generally multi-modal (Figure 6 and Figure 7). Goldfish and bony herring displayed strong cohorts of fish between 50 to 100mm, and 30 to 70mm respectively (Figure 6). Similarly, common carp, golden perch and silver perch displayed a distinct mode of smaller individuals (<150mm) and less distinct modes of larger individuals (>200mm) (Figure 7). Golden perch otolith analysis revealed the presence of five age-classes (young-of-year, 4, 9, 11 and 14 years) (Figure 8). Young-of-year (YOY) individuals are represented in the length frequency data by individuals <100mm (Figure 7).

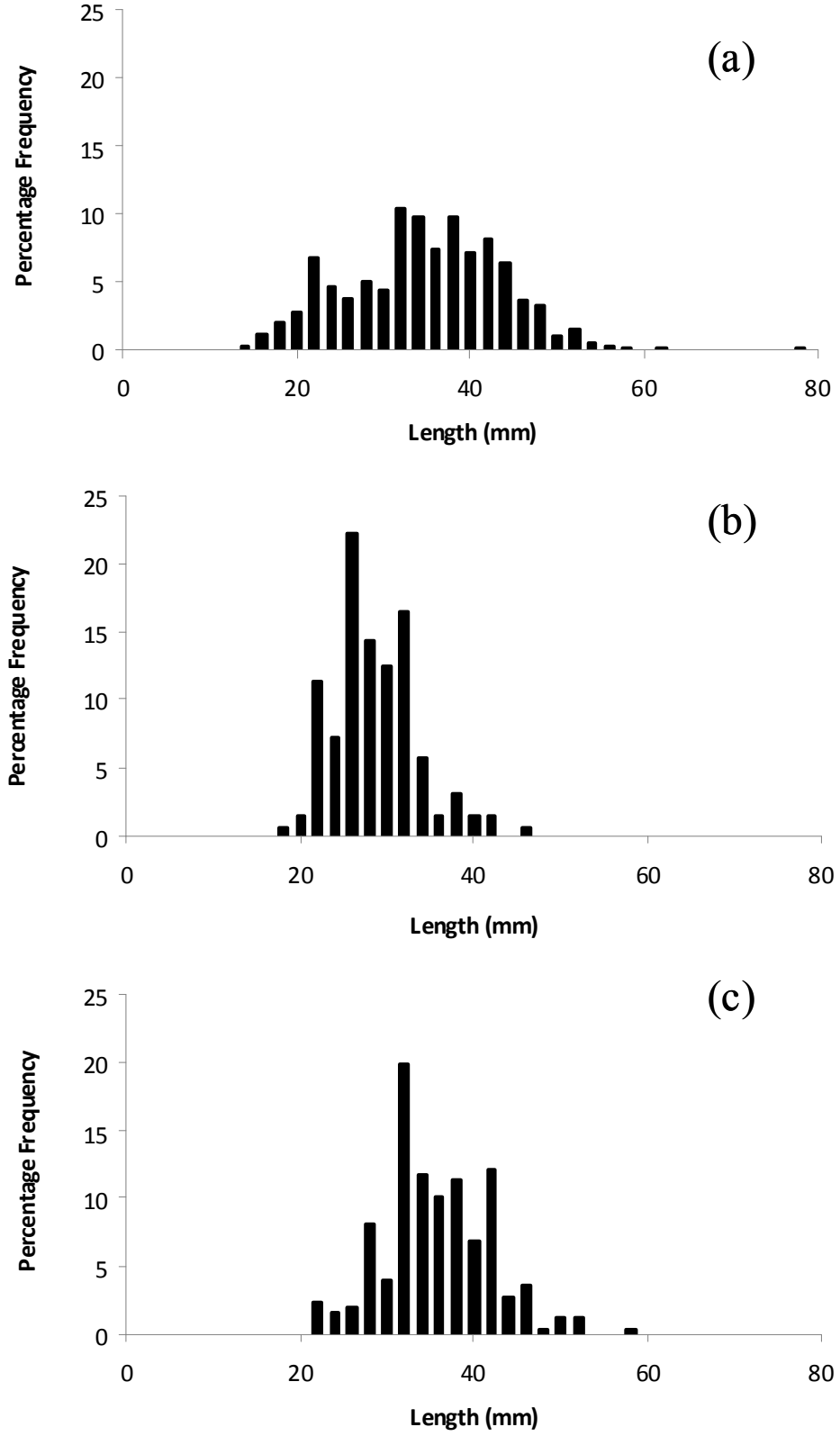

Figure 4. Percentage length frequencies of a) unspecked hardyhead (*n*=1,517), b) Eastern gambusia (*n*=246) and c) carp gudgeon (*n*=367) captured within 'Katfish Reach' and the adjacent River Murray main channel in April 2010.

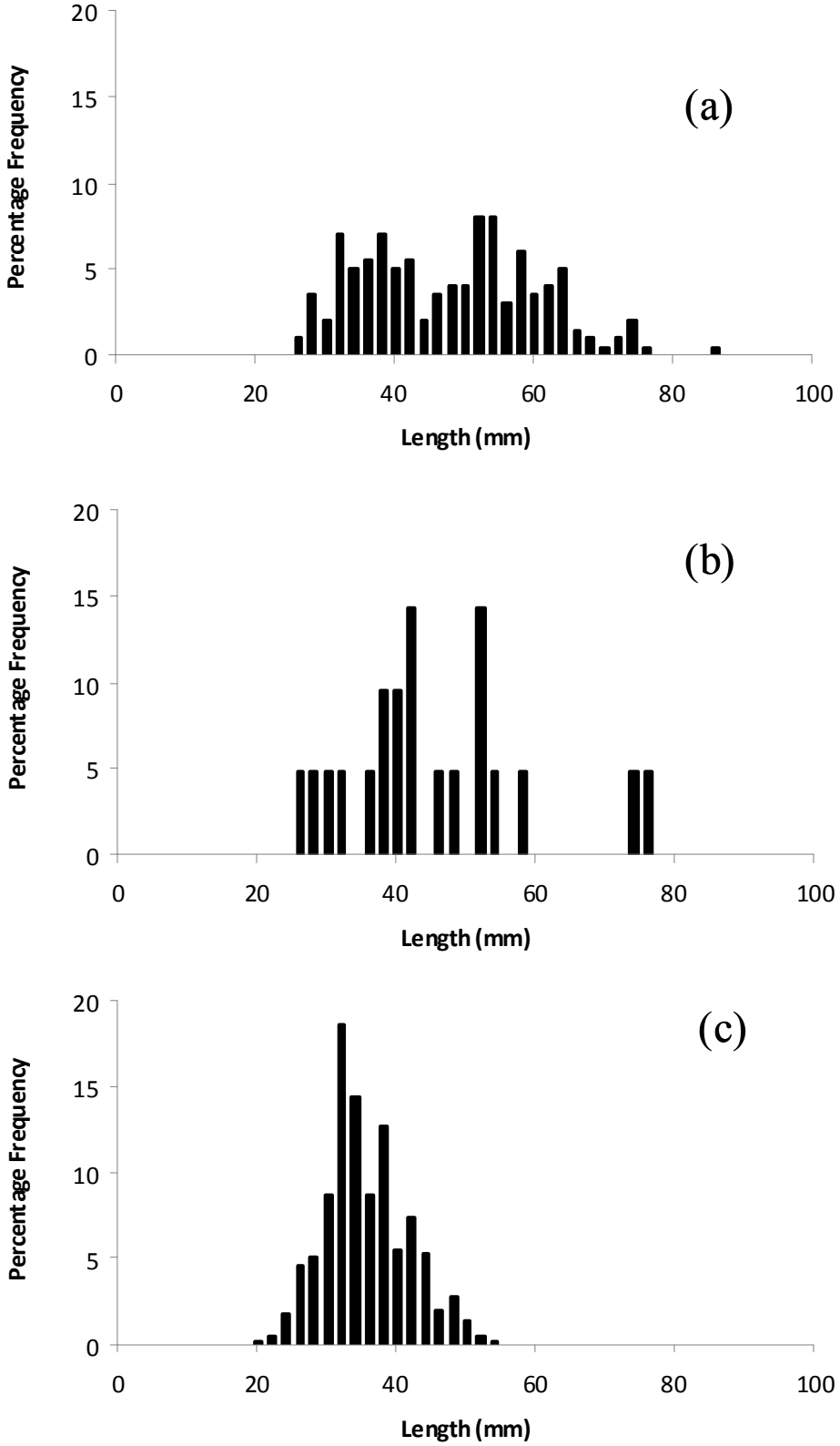

Figure 5. Percentage length frequencies of a) MD rainbowfish (n=320), b) flathead gudgeon (*n*=17) and c) Australian smelt (*n*=809) captured within 'Katfish Reach' and the adjacent River Murray main channel in April 2010.

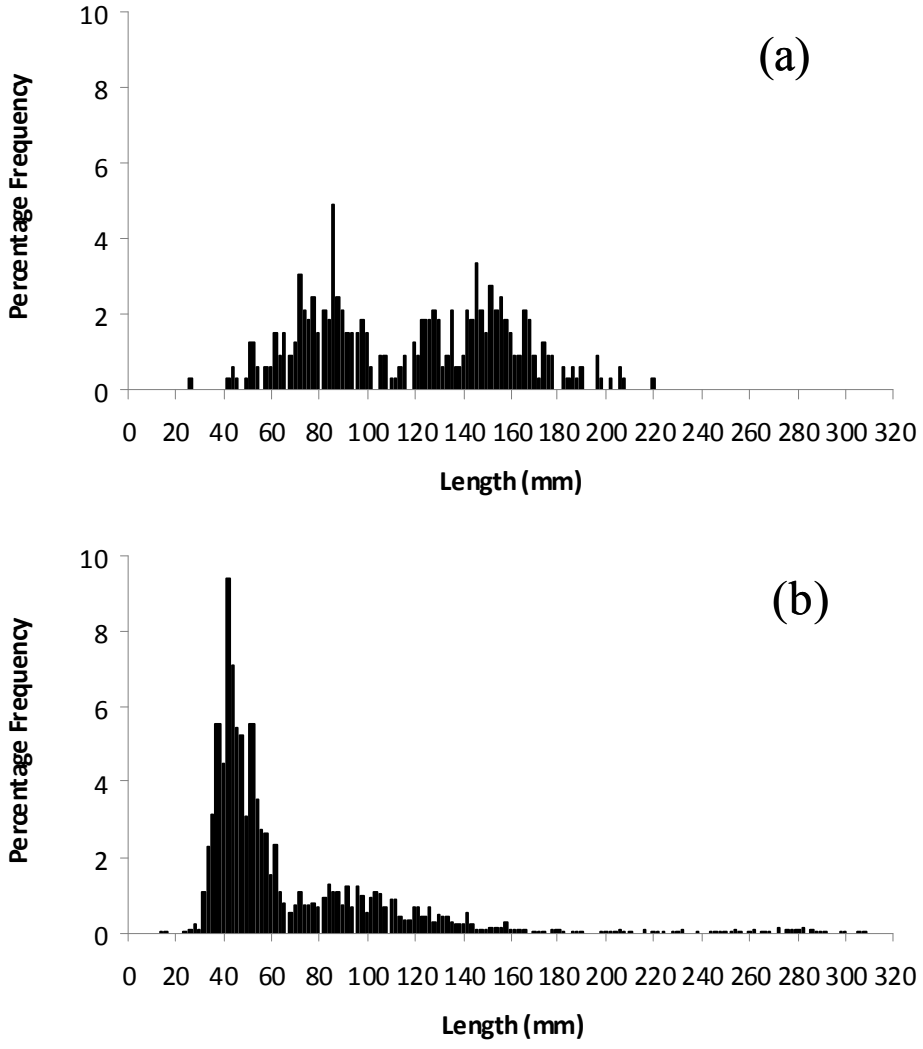

Figure 6. Percentage length frequencies for length of a) goldfish (*n*=471) and b) bony herring (*n*=8,941) captured within 'Katfish Reach' and the adjacent River Murray main channel in April 2010.

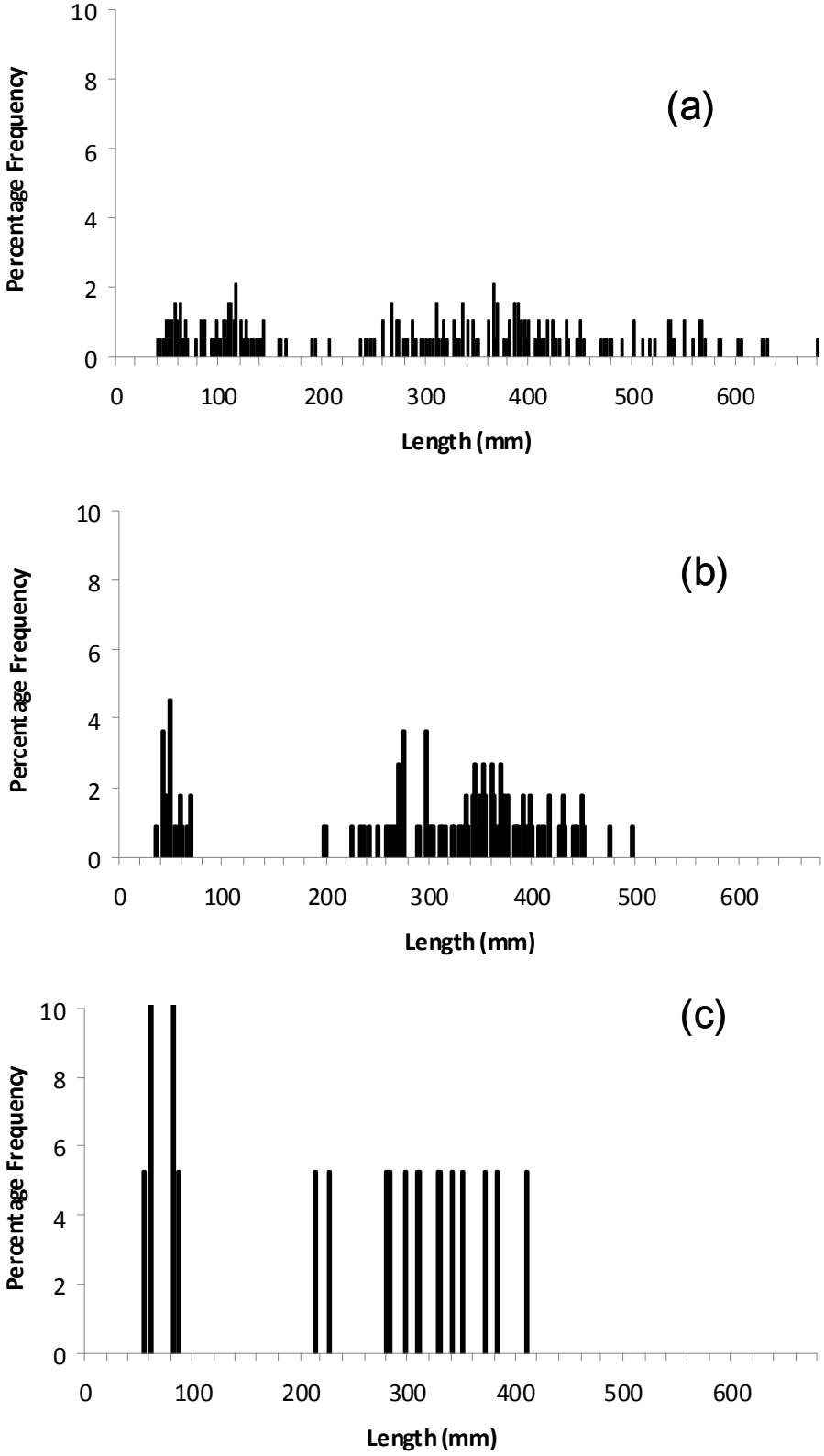

Figure 7. Percentage length frequencies of a) common carp (*n*=295), b) golden perch (*n*=149) and silver perch (*n*=19) captured within 'Katfish Reach' and the adjacent River Murray main channel in April 2010.

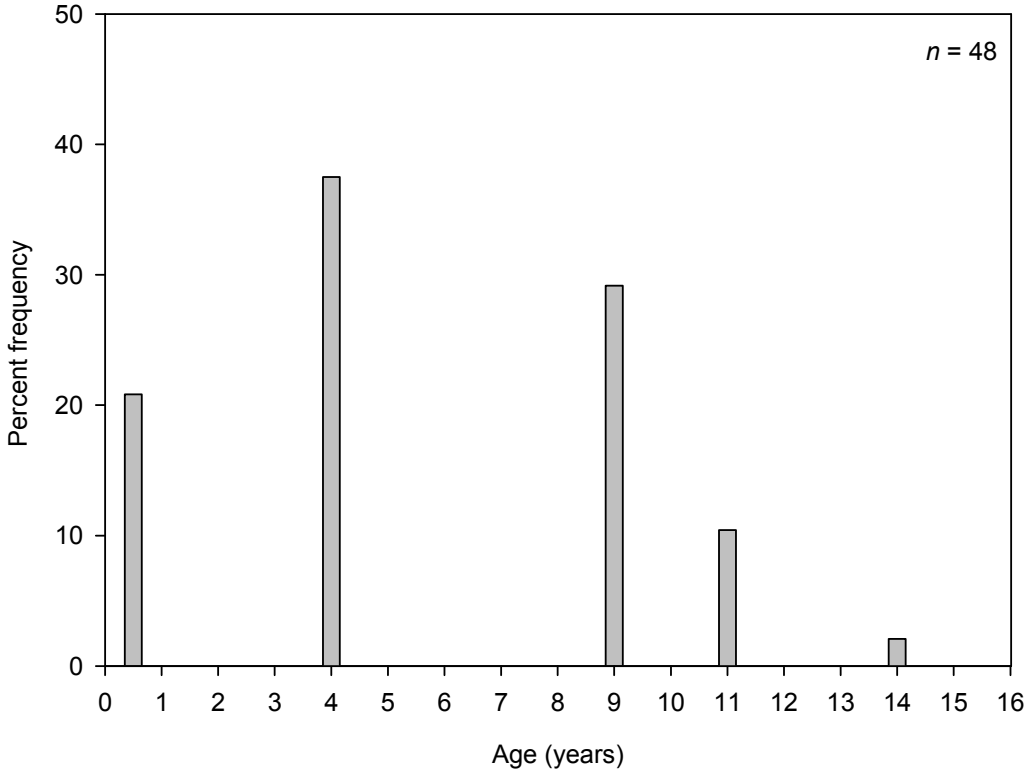

Figure 8: Percentage age frequencies of 48 golden perch captured in 'Katfish Reach' in April 2010.

5. Discussion

The results presented in this progress report provide 'before' intervention information relating to fish community structure, habitat availability, fish-habitat use and recruitment success within 'Katfish Reach'. The sampling carried out in 2010 will be replicated in April 2011 and the results from both years will be analysed as a combined data set forming the 'before' intervention data. A final report will be provided for the current funding cycle ending in 2011. 'After' intervention surveys will be undertaken following the implementation of the intervention (timing still to be determined based on timing of works and funding) to assess the effects of interventions 1 and 2 on fish and fish habitats within 'Katfish Reach'.

Fish community structure

A total of 13,188 fishes were captured at 22 sampling sites within the 'Katfish Reach' system in April 2010 (Table 2). A mean (± S.E.) number of 677 ± 83 fish were captured per sampling site (*n*=18; electrofishing sites only), which is greater than previously observed at 'Katfish Reach' using boat electrofishing (255 ± 34 individual fish per site; Leigh *et al*., 2009). However, when comparing the 14 sampling sites assessed during both, the 2009 and 2010 surveys, with the total and fish per site numbers are different. A total of 3,580 (2009, Leigh *et al.*, 2009) and 10,366 (740 ± 92 individual fish per site) (2010) individual fish were captured during the respective surveys.

The numbers of fish captured at 'Katfish Reach' in April 2010 are comparable to observations from similar surveys in the Chowilla Anabranch system. Fish surveys at 16 sampling sites across the Chowilla Anabranch system, using the same method used during the present study over 4 years (2005-2008), recorded an average of 9,735 ± 575 individual fish per year (Zampatti *et al.*, 2008). This presents a relatively similar abundance of fish per site (Chowilla 2006-2008: 692 ± 96 individual fish per site; Zampatti *et al.*, 2008). In the past, however, the total number of fish as well as the mean number of fish per sampling site in 'Katfish Reach' (255 ± 34 individual fish per site; Leigh *et al*., 2009) has been more similar to results from the Pike Anabranch system (258 ± 40 individual fish per site; Beyer *et al.*, 2010).

Total species richness and variation in species richness between sites/meso-habitats (Table 2) is similar to that previously recorded in 'Katfish Reach' and the Chowilla system (Zampatti *et al.*, 2008; Leigh *et al*., 2009). The greatest species richness (10 to 12 species) was observed in the River Murray main channel sites and sites in fast-flowing meso-habitats. Nevertheless, 10 species were also recorded at two sites in slow-flowing meso-habitats. Differences in species diversity between sampling sites and meso-habitat types are likely related to differences in the availability, diversity and complexity of fish habitat (Gorman and Karr, 1978; Merigoux *et al*., 1998; Young, 2001).

Variation in species richness between sites is further corroborated in the results of the indicator species analysis, which revealed a number of significantly higher abundances of different fish species in different meso-habitats (Table 5).

Recruitment success

Absence or very low numbers of individuals <20mm TL and the general limited distinctness in length modes was observed in most short-lived small-bodied fish species, including unspecked hardyhead, Eastern gambusia, carp gudgeon, Murray-Darling rainbowfish, flatheaded gudgeon and Australian smelt (Figure 4 and Figure 5). Boat electrofishing, however, does result in some bias towards larger individuals, and may have contributed to the observed reduced distinctness of length modes in some fish species. Nevertheless, a relatively wide size range was observed for those species with small maximum body sizes (≤100mm TL; Lintermans, 2007) and the presence of fish < 40mm, suggests recent recruitment from spawning in the preceding spring/summer.

Relatively strong cohorts of smaller individuals of the medium-bodied fish species non-native goldfish (50-100mm FL; ≤1 year old; Lintermans, 2007) and native bony herring (25-80mm FL; ≤1 year old [Puckridge & Walker, 1990]) confirm the recent recruitment for these species. Bony herring are well suited to recruit in environments that provide variable flow conditions (Humphries *et al*., 1999), and this is particularly important in floodplain habitats such as 'Katfish Reach'. Common carp revealed relatively distinct modes of small (150mm FL; mostly ≤1 year old [Brown *et al*., 2005]) and large (250-450mm FL; ≈5-8 years old [Brown *et al*., 2005]) individuals thus indicating successful recruitment.

A broad size range of golden perch were collected with small individuals (<100mm TL) appearing as a distinct mode. Age determination (using otoliths) revealed the presence of fish from five different age groups, i.e. <1, 4, 9, 11 and 14 year olds. These data show a progression of age classes from those golden perch sampled in April 2009 albeit with the addition of a new cohort of YOY (<1 year old) fish (Leigh *et al.*, 2009). Similar age structure has been observed for golden perch captured in the Chowilla anabranch system (Zampatti *et al.*, 2008). In spring/summer 2005 a period of increased discharge (3,800-

15,000 ML/d; DWLBC SWA) is assumed to have facilitated golden perch spawning and this cohort has been found in both 'Katfish Reach' and Chowilla (Leigh *et al*., 2009; Zampatti *et al*., 2008). These data support the notion that golden perch is a flow-cued spawner with variable and episodic recruitment in the regulated rivers of the lower Murray-Darling Basin (Humphries *et al*., 1999; Mallen-Cooper and Stuart, 2003). The recruitment of Murray cod could not be assessed due to low sample size (*n*=4).

A broad size range of silver perch was observed with individuals ranging from 40–500mm TL. Smaller individuals (<100mm TL) present as a relatively defined cohort and are assumed to be YOY suggesting recruitment occurred for this species. Larger individuals (>200mm TL) are estimated to be > 1 year old (e.g. Moiseeva *et al*., 2001).

Habitat availability and fish-habitat use

The condition of the riparian and in stream habitats in 'Katfish Reach' is similar to that present throughout the lower River Murray. The floodplain vegetation shows similar patterns of degradation to that in the Pike and Chowilla anabranch systems with an abundance of areas where salt tolerant vegetation and bare soil prevail (Marsland *et al.*, 2009) and narrow bands of diverse riparian understory and fringing vegetation (Zampatti *et al.*, 2006a; b; Beyer *et al*., 2009). The aquatic habitat is dominated by native submergent species and could be considered as being in relatively good condition similar to the aquatic habitats of the Pike and Chowilla anabranch systems (Zampatti *et al.*, 2006a; b; Beyer *et al*., 2009).

The presence of species such as silver perch, freshwater catfish (protected under the South Australian *Fisheries Management Act 2007*) and Murray cod (listed as threatened under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999), highlights the importance of protecting, restoring and maintaining habitat for fish in 'Katfish Reach'. Freshwater catfish are generally widespread throughout the lower River Murray (Clunie and Koehn, 2001; Lintermans, 2007), but are often captured in low numbers in floodplain systems (Leigh *et al.*, 2009; Beyer *et al.*, 2010). During the present study, freshwater catfish were significantly associated with fast-flowing habitats, but have previously been found to be associated with slow-flowing habitats

(Clunie and Koehn, 2001) suggesting that habitat variability and diversity may be an important for this species (Clunie and Koehn, 2001). This may also be the case for silver perch (Beyer *et al.*, 2010).

Statistically significant micro-habitat associations were observed for all fish species, with the greatest number of habitat associations observed for native Murray-Darling rainbowfish, golden perch, Australian smelt and carp gudgeon (all native) as well as goldfish and Eastern gambusia (non-native). Generally, low numbers of significant micro-habitat associations are assumed to indicate habitat plasticity in fishes and vice versa (Beyer *et al.*, 2007). The higher numbers of habitat associations observed for most native fish species in 'Katfish Reach', may be indicative of their habitat requirements and the availability and quality of the required habitat types.

Woody debris was an important habitat type as it was positively associated with greater numbers and/or the presence a broad range of species including silver perch, carp gudgeon, golden perch and Murray-Darling rainbowfish. Woody debris has also been found to be an important habitat variable for a number of native fishes, including golden perch and Murray cod, throughout the Murray-Darling Basin (Koehn and Nicol, 1998; Crook *et al*., 2001; Lintermans, 2007; Zampatti *et al*., 2009).

Non-native common carp generally display limited habitat associations in the Murray River and this may reflect their generalist nature (Crook *et al*., 2001; Nicol *et al.*, 2004; Zampatti *et al.*, 2009). In the present study only two significant associations (tree roots; Azolla-Elodea complex) were observed. Low habitat affinity in non-native species is thought to reflect their ecological plasticity and therefore their potential to successfully invade a new habitat (Beyer *et al.*, 2007). Goldfish, however, were significantly associated with six habitat types including two algae, one submergent, and the Azolla-Ludwigia and the Azolla-Vallisneria complexes. Similarly, eastern gambusia had six habitat associations including open water, two overhanging and one emergent habitat types, one grass and the Azolla-Ludwigia complex. In the Chowilla anabranch system, goldfish have been found to be significantly associated with at least six submergent, fringing and emergent taxa representing physical habitat, and eastern gambusia with one emergent taxon (*Typha* spp) (Zampatti *et al*., 2009).

Silver perch was significantly associated with coarse woody debris, tree roots, the grass *Phragmites australis*, emergent *Typha* sp and open water. Silver perch has been significantly associated with woody debris within the Chowilla system (Zampatti *et al*., 2009). *Phragmites australis* can form dense stands and may thus provide dense in-stream cover as well as overhanging shade, both important habitat attributes for most fish species.

Pelagic Australian smelt (McDowall, 1996; Lintermans, 2007) were significantly associated with open water as has previously been observed in the Pike Anabranch system (Beyer *et al*., 2009). Freshwater catfish were found to be significantly associated with floating (*Azolla filiculoides*) and overhanging (*Eucalyptus largiflorens*) vegetation and the grass *Phragmites australis*

6. Conclusions

The 2010 fish surveys of 'Katfish Reach' revealed relatively high fish abundances and fish species richness, which is consistent with previous investigations. Annual recruitment was observed in small-bodied fish species while recruitment in medium- and large-bodied species was episodic. The condition of riparian and in stream habitats in 'Katfish Reach' was similar to that present throughout the lower River Murray. The floodplain vegetation was generally degraded, whilst aquatic habitats were dominated by native submergent species and could be considered as being in relatively good condition.

The heterogeneous aquatic meso-habitats of 'Katfish Reach' were characterised by distinct 'indicator species' and individual fish species were shown to be associated with a range of aquatic microhabitats. In general, native species were characterised by a greater number of significant micro-habitat associations than non-native species (e.g. common carp) thus reflecting the generalist nature of non-native species.

The final year of 'before' intervention sampling will be undertaken in 2011 after which a report analysing the results from both 'before' intervention sampling events (2010 and

2011) will be produced. As interventions are implemented, 'after' intervention monitoring will be undertaken and the response of fish and habitat will be assessed.

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8. Appendices

Appendix 1: Links between interventions, goals, hypotheses, monitoring scales and chosen indicators1

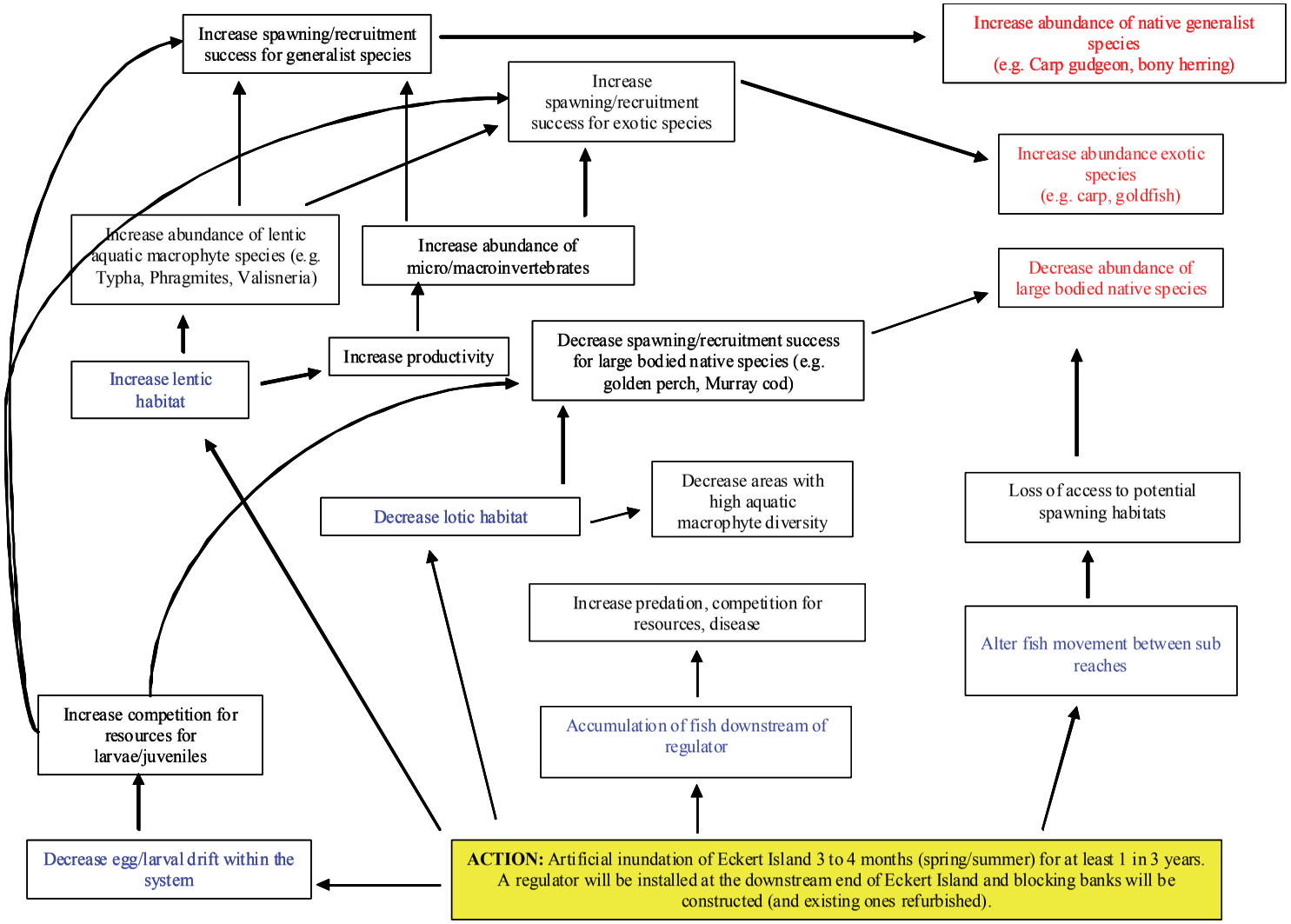
Interventions	Goals	Hypothesised response[1]	Scale of response / measurement		Indicators to be measured
			Temporal (E.g. 0-4 years or ≥ 5 years)	Spatial (E.g. demo reach or sub-reach)	
Intervention 1: Improve spring-summer inundation of Eckert Island at low river flow. [Intervention to be implemented by 2011; Construction of blocking banks by 2010]	**Assets to benefit:** Eckert Creek, The Splash and Sawmill Creek; Temporary freshwater wetlands; Floodplain woodlands; Floodplain shrubland and Open plain. **Threats targeted:** Lack of environmental flows; Lack of fish passage; Locks 3 & 4 (maintenance of stable pool levels).	H1: Temporary artificial inundation may alter the structure of the fish community within the Eckert Island system.	3-5 years	Sub-Reach Scale (e.g. Eckert Creek, Splash, Katarapko Creek)	• Abundance • Species richness • Biomass • Native vs Non native species
Intervention 1: -see above-	-see above-	H2: Temporary artificial inundation may alter habitat availability and subsequently alter the habitat use by fish within	3-5 years	-see above-	• Habitat diversity & abundance • Fish-Habitat associations

[1] This table is to be read in conjunction with the documents prepared by the Katfish Reach Steering Group (2008a, b). Note that the interventions and the goals have been copied directly from this document.

		the Eckert Island system.			
Intervention 1: -see above-	-see above-	H3: Temporary artificial inundation may alter recruitment success in some fish species within the Eckert Island system.	3-5 years	-see above-	• Length/age frequencies; • YOY fish abundance
Intervention 2: Temporarily partially dry and vary pool level of Eckert Creek anabranch system	**Assets to benefit:** Eckert Creek anabranch system **Threats targeted:** Locks 3 & 4 (maintenance of stable pool levels); Lack of flows; Lack of fish passage; Alien fish.	H4: Temporarily drying various reaches of the Eckert Island system may alter fish community structure.	3-5 years	Sub-Reach Scale (e.g. Eckert Creek, Splash)	• Fish abundance • Species richness • Biomass • Native vs Non-native species (see also H1)
Intervention 2: -see above-	-see above-	H5: Temporarily drying various reaches of the Eckert Island system may alter habitat availability and subsequently alter the habitat use by fish.	3-5 years	-see above-	• Habitat diversity & abundance • Fish-Habitat associations (see also H2)
Intervention 2: -see above-	-see above-	H6: Temporarily drying various reaches of the Eckert Island system may alter recruitment success.	3-5 years	-see above-	• Length/age frequencies • YOY fish abundance (see also H3)

Appendix 2: Conceptual models

Conceptual Model for Intervention 1



Conceptual Model for Intervention 2