Department of Sustainability and Environment

Barmah-Millewa Fish Condition Monitoring: 2007 - 2009 Milestone report

M. Rourke and Z. Tonkin

Australian Government | Murray–Darling Basin Authority

NSW Government | Industry & Investment

Victoria The Place To Be

Barmah-Millewa Fish Condition Monitoring: 2007-2009 Milestone Report

Meaghan Rourke[1] and Zeb Tonkin[2]

[1] NSW Department of Industry and Investment.
Narrandera Fisheries Centre,
PO Box 182
Narrandera, NSW 2700.
Phone (02) 6959 9021

[2]Arthur Rylah Institute for Environmental Research
Department of Sustainability and Environment
PO Box 137
Heidelberg, Victoria 3084
Phone (03) 9450 8600

July 2009

In partnership with:

This project is funded by The Living Murray initiative of the Murray-Darling Basin Commission, which has now transitioned to become the Murray Darling Basin Authority

Citation: Rourke, M. and Tonkin, Z. (2009). Barmah-Millewa fish condition monitoring: 2007-2009 milestone report. NSW Department of Industry and Investment and Arthur Rylah Institute for Environmental Research. Department of Sustainability and Environment, Heidelberg, Victoria. Unpublished report submitted to the Murray-Darling Basin Authority.

Front cover photo: Background: Edward River at Gulpa junction; Young-of-year Murray cod, silver perch larvae (Photos: Zeb Tonkin).

Contents

Contents i

List of tables and figures ii
List of tables ii
List of figures ii

Acknowledgements iv

Summary v

1 Introduction 7

2 Methods 9
2.1 River sites 9
2.2 Creek and wetland sites 12
2.3 Riverine larval drift sampling 13

3 Results 15
3.1 Hydrology and total catch data 15
3.2 Rivers 17
3.3 Creeks and Wetlands 24
3.4 Riverine larval drift 28

4 Discussion 32
4.1 Rivers 32
4.2 Creek and Wetlands 35
4.3 Riverine larval drift 37

5 Summary and conclusions 41

6 References 43

7 Appendix 1. Raw catch data for individual sites in each year of the monitoring program 47

List of tables and figures

List of tables

Table 1. Permanent river fish sampling sites in the Barmah-Millewa Forest indicating sites successfully sampled in each year of the study. 10

Table 2. Permanent creek and wetland fish sampling sites in the Barmah-Millewa Forest indicating sites successfully sampled in each year of the study. 13

Table 3. Raw total abundances of species collected in creeks, wetlands (including lakes) and river sites using all methods in 2007, 2008 and 2009). Numbers of fish observed but not collected are in parentheses. 16

Table 4. Raw numbers of eggs and larvae collected drifting from the three Murray River sites in 2009. 29

List of figures

Figure 1. Barmah-Millewa forest (green shading) illustrating locations of river monitoring sites (red triangles). 11

Figure 2. Munyana crab trap used for Murray crayfish sampling in river sites. 12

Figure 3. Side view illustration of the standard passive drift net used in the study. 14

Figure 4. Mean daily discharge at the Murray River @ Tocumwal June 2006 to May 2009. The red line indicates the approximate floodplain inundation height throughout the Barmah-Millewa Forest. Light blue bars represent time of creek/wetland sampling; orange bar represent time of river sampling. 15

Figure 5. a) Aratula Creek showing blackwater, February 2009; b) electrofishing the edge of Pinchgut Lagoon showing dense river red gum regrowth, February 2009. 17

Figure 6. Mean (± SE) fish abundance presented as CPUE (fish per 90 second electrofishing shot) of total fish abundance at (a) each river site in 2007-2009 and (b) each river site for all years combined. ns indicates site not sampled in 2008/09. 18

Figure 7. Mean (± SE) CPUE (fish per 90 second electrofishing shot) of silver perch, carp, golden perch, trout cod, Murray cod and Murray River rainbowfish recorded in 2007-2009 for all sites combined. 18

Figure 8. Mean (± SE) CPUE (fish per 90 second electrofishing shot) of (a) Murray cod and (b) Murray River rainbowfish collected at each River site for all years combined. 19

Figure 9. Mean (± SE) CPUE (fish per 90 second electrofishing shot) of young-of-year Murray cod, trout cod and carp collected from all river sites during 2007-2009. 20

Figure 10. Length frequency histograms of (a) Murray cod; (b) trout cod; (c) golden perch; (d) silver perch; (e) Murray River rainbowfish and (f) carp across all sites and all methods for 2007 to 2009 21

Figure 11. Occipital carapace length (OCL) frequency histogram and (a) sex ratios of Murray crayfish and (b) ratio of mature females in berry collected during the program

(all years and sites combined). Dashed line represents minimum legal recreational fishing size limit........ 22
Figure 12. (a) Mature (left) and immature (right) female Murray crayfish as indicated by setae surrounding gonopores (yellow circles); mature female Murray crayfish not yet in berry (left) and with low numbers of eggs (right); (c) Mature female Murray crayfish in full berry. 23
Figure 13. a) Toupna Creek in February 2009, b) upper Toupna Creek in February 2009. 24
Figure 14. Species composition in individual creek and wetland sites for all years and methods combined........ 25
Figure 15. Two-dimensional solution for MDS ordination of the fish community composition (derived from presence/absence) across (a) habitat types and: (b) each year of surveys. (50 random starts, 100 iterations). Green grouping in (a) illustrates creek sites and Barmah lake which are permanently connected to the Murray River......... 26
Figure 16. Mean (± SE) fish abundance presented as CPUE (fish per 90 second electrofishing shot) of total fish abundance at permanent creek/wetland site in 2007-2009. 27
Figure 17. Daily discharge (blue line) and water temperatures (red line) of the Murray River at Tocumwal in spring / summer 2008. Dashed line represents height of Barmah-Millewa Forest floodplain inundation. Shaded grey regions indicate larval sample dates. 28
Figure 18. Silver perch larvae collected in early November from the Barmah Choke........ 29
Figure 19. Mean ± SE densities of drifting (a) Murray cod, (b) silver perch and (c) carp eggs and/or larvae collected in the Murray River at Barmah choke (blue); Morning Glory (red) and; Ladgroves beach (yellow) on each sample trip in 2008/09........ 31
Figure 20. Drifting densities of trout cod larvae collecting during fortnightly drift sampling (black triangles) across all sites in the Murray River in Barmah-Millewa. Figure from King et al. (2008a) with data collected in 2008/09 included (red box)........ 37
Figure 21. Drifting densities of Murray cod larvae collecting during fortnightly drift sampling (black triangles) across all sites in the Murray River in Barmah-Millewa. Figure from King et al. (2008a) with data collected in 2008/09 included (red box)........ 38
Figure 22. Drifting densities of silver perch eggs collecting during fortnightly drift sampling (black triangles) across all sites in the Murray River in Barmah-Millewa. Figure from King et al. (2008a) with data collected in 2008/09 included (red box)........ 39
Figure 23. Drifting densities of golden perch eggs collecting during fortnightly drift sampling (black triangles) across all sites in the Murray River in Barmah-Millewa. Figure from King et al. (2008a) with data collected in 2008/09 included (red box)........ 40

Acknowledgements

We would like to thank the Barmah-Millewa Coordinating Committee, Barmah-Millewa Technical Advisory Committee and the Living Murray section of the Murray-Darling Basin Commission for their financial and technical support throughout this year of the project. The following staff are thanked for their contribution to field and laboratory work for the 2008/09 season: John Mahoney, David Dawson, Graham Hackett, Justin O'Mahoney, Alison King and Alasdair Grigg (Arthur Rylah Institute); Nathan Reynoldson, Peter McLean, Jonathon Doyle, Jarrod McPherson, Duncan McLay, Chris Smith and Jamie Hutchison (New South Wales Department of Primary Industries). We also thank Lee Baumgartner and Alison King for comments on the draft manuscript. Sampling in NSW waters was conducted under NSW DPI Fish Collection Permit P01/0059 (A). Sampling within Victorian waters was covered under Fisheries Victoria Permit RP 827 and National Parks Victoria (Flora and Fauna Guarantee Act 1988) Permit 10002155. Animal Care and Ethics Approval is granted under the NSW DPI general biodiversity project Number ACEC98/14.

Summary

The Barmah-Millewa Forest (B-MF) is a complex wetland system on the mid-Murray River that provides important habitat for both terrestrial and aquatic fauna. The fish community supported by the forest is particularly important, and is the focus of a condition monitoring program, which has been underway since 2007. This program has been designed to monitor the health and status of the fish community across 20 permanent fish sampling sites distributed across creeks, wetlands and rivers. The sampling protocol augmented this year by the addition of a larval drift component designed to assess fish spawning, which will continue on sampling that has been underway for the past five years, thus continuing to build a long-term data set on fish spawning in the B-M Forest. This report gives a summary of the results of the third year of sampling, and investigates the overall findings of the first three years of the monitoring program.

The B-MF has experienced a third consecutive year of low flows, with several creek and wetland sampling were dry, and one river site was too shallow to be sampled. A total of 4375 fish were collected this year, and a greater total abundance of fish was recorded compared to previous years, largely dominated by small-bodied species. It was evident that some species are resilient to drought conditions, most notably Murray River rainbowfish and carp gudgeons. In contrast, southern pygmy perch and dwarf flat-headed gudgeon have been absent in the last two years of sampling, indicating that these species have been severely impacted by the absence of flows and subsequent reduction in habitat. There are now serious concerns for the distribution of southern pygmy perch in the region.

Of the riverine species, Murray cod and trout cod were in significantly higher abundances in 2007/08 than 2006/07 and 2008/09, a result of increased recruitment during the 2007/08 spring/summer. Analysis of the three years of data also indicated the importance of specific sites for many species; most notably the two most upstream Murray River sites for Murray cod; and the Edward River 5km downstream of the offtake regulator for Murray River rainbowfish. Introduced species were collected at all sites, with carp having successful recruitment in two of the three years. Other species-specific patterns in abundance, distribution and population structures are also discussed.

Forty-seven Murray crayfish were recorded this year, and, like the previous two years, were not recorded in the Edward River. Furthermore, there was a major shift in the ratio of females to males in the Murray River population above the legal recreational size limit, as well as almost half of the mature females still not in a berried condition. This finding suggests a delay or lack of

spawning of almost half of the mature females in the population, potentially due to the shortage of mature males in the population.

Larval drift sampling recorded eggs and larvae from 10 different species including three of the large-bodied native species (silver perch, Murray cod and a single golden perch larva). Trout cod were not detected in egg or larval stage, but were present as young-of-year. In contrast a reasonable number of silver perch eggs were collected, but no young-of-year fish were recorded (as in previous seasons).

Whilst results presented for the past three years were collected during drought conditions, limited conclusions can be made about water management and the fish community utilising the B–MF icon site. This highlights the need for longer term data sets across a variety of environmental conditions status. Nevertheless, information such as threatened species distributions and important sites can be used by managers to maintain the environmental as well as social values (e.g. enhancing recreational fish populations) of the icon site as well as enhance our limited knowledge of the relationships between hydrological regimes and fish spawning and recruitment.

1 Introduction

Condition monitoring of fish, waterbirds and vegetation is necessary to provide ongoing information regarding the 'health' of the Living Murray icon sites (www.livingmurray.mdbc.gov.au). The working draft of the outcomes evaluation framework calls for the establishment of consistent monitoring framework across all icon sites that have agreed benchmarks. Murray-Darling riverine ecosystems are typified by highly variable hydrological conditions, resulting in temporal and spatial variability of its flora and fauna. Therefore, development of long term monitoring programs is essential for reliable interpretation and management of the Basins ecosystems.

The Barmah-Millewa Forest (B-MF) is a 70,000 ha highly complex wetland system on the mid-Murray River near Echuca. The system contains a range of aquatic habitats including rivers, permanent and ephemeral creeks, wetlands, swamps and the floodplain proper which historically contained an abundant and diverse range of native fish (King, 2005). Until around the 1930s, the area also supported the largest inland commercial fishery in Australia, although since the enhanced regulation of the Murray River by dams and weirs, native fish have been substantially reduced in both abundance and diversity, and exotic species are common (King, 2005). Given the importance of the region for a range of flora and fauna, the B-MF is listed as an internationally important wetland under the RAMSAR convention and has subsequently received iconic status under the Murray-Darling Basin Commissions 'Living Murray Initiative'.

In 2007, a condition monitoring program commenced in the B-MF region in order to benchmark the status of fish communities at three major 'ecotypes' throughout the system; rivers, creeks and wetlands (Tonkin and Baumgartner 2007). The overall objectives of the monitoring program seek to:

- Monitor the health and status of the Barmah-Millewa fish community through annual sampling.
- Assess long term changes in fish communities and correlate any observed changes with factors such as flow, climate and thermal regimes.
- To provide information which can feedback into management plans and reporting on condition for the icon site.

The current monitoring design had not included an assessment of fish spawning and recruitment, which is a vital component of interpreting community dynamics. Furthermore, the detection of a link between abundance of drifting eggs and larvae and subsequent abundance of adult fish (in the current monitoring program) will also improve our understanding of adult population dynamics. This information was available in the first years of this program through the fish spawning and recruitment research program in the region (King *et al.* 2008a), which subsequently ended in 2008. Consequently, a reduced cost-effective method to sample only the spawning of large bodied fish was implemented in 2008/09. Specifically, the spawning component of the monitoring program aims to:

- Document the spawning activity of riverine fish species with drifting egg and/or larval stages (Murray cod, trout cod, golden perch, and carp) in the Murray River throughout the region.
- Add confidence to the data collected on large-bodied riverine fish, by giving researchers an indication of fish spawning activity in response to environmental variables such as environmental watering events.
- Continue the long term data set of riverine fish spawning in the region which has been underway since 2003 to enable greater confidence in explaining responses to environmental variables.

This milestone report examines the first three years of the Barmah-Millewa fish condition monitoring program (2007-2009) along with the larval drift data collected in the 2008/09 spawning season which can be directly compared with the results of the previous five year recruitment project in the area.

Murray River at Woodcutters lagoon, Barmah-Millewa Forest, May 2008.

2 Methods

To assess the current condition of fish communities, methods were developed to maintain compatibility with current SRA (Sustainable Rivers Audit) protocols. The program also maintained consistency by balancing the number of sites sampled in each forest (Barmah and Millewa).

2.1 River sites

Previous sampling undertaken within the icon site has identified unique fish communities in four broad regions of the Murray River main channel (King *et al.* 2007). Subsequently, a balanced design was developed with two sites established in each of these four regions (Table 1; Figure 1). Sampling in the river sites (Murray and Edward Rivers) was conducted between April and July from 2007 - 2009, after water levels were reduced to winter base flows. At each site, sampling involved 12 replicates of 90 second electrofishing (or equivalent total time) shots using boat mounted electrofishing units. All sites on the Murray River were sampled with a large electrofishing boat (7.5 KVa Smithroot boat-mounted electrofishing unit), whilst both sites on the Edward River were sampled with a smaller electrofishing vessel (2.5 KVa Smithroot boat-mounted electrofishing unit). In addition to electrofishing, 10 unbaited baittraps (minimum of two hour soak) were set to capture any small fish not efficiently sampled during routine electrofishing. At the completion of each operation, all fish were identified, counted and measured (maximum of 50 individuals per species per site). Ten baited (liver) Munyana crab traps (75 cm diameter) were also set from the onset of electrofishing and retrieved after a minimum of 2 hours to collect Murray crayfish (*Euastacus armatus*) in the river sites (Figure 2) in 2007/08 and 2008/09. Munyana crab traps were incorporated into the sampling design in 2008 as they were shown to have superior capture efficiency for crayfish over the traditional hoopnets that were used in the 2006/07 surveys (see Gilligan *et al.* 2007). Sampling for Murray crayfish in 2008/09 was initially conducted in late April however, due to above average water temperatures (19 °C) no crayfish were collected. Therefore, the sites were re-sampled in June and July when water temperatures had dropped. All crayfish collected were measured for occipital carapace length (OCL) and their sex determined. Females were also assessed for maturation (setae surrounding the gonopores) and for the presence of eggs (berries) on the ventral side of the tail.

Due to large variations in fish numbers collected for each electrofishing shot resulting in non-normal distribution of data, non-parametric measurements were used in analysis. Overall differences in catch per-unit-effort (CPUE: fish per 90 second electrofishing shot) of total fish abundance and individual species collected in high abundances [silver perch (*Bidyanus bidyanus*), golden perch (*Macquaria ambigua*), Murray cod (*Maccullochella peelii peelii*), trout cod (*M. macquariensis*), carp (*Cyprinus carpio*), Murray River rainbow fish (*Melanotaenia fluviatillis*), Australian smelt (*Retropinna semoni*), carp gudgeon (*Hypseleotris* sp.), un-specked hardyhead (*Craterocephalus stercusmuscarum fulvus*) and goldfish (*Carassius auratus*)] were analysed for differences between years and across sites using a Kruskal–Wallis test. CPUE's of young-of-year Murray cod, trout cod and carp (fish < 150 mm) were also analysed using this procedure to assess recruitment strength for each year and at each site. Length-frequency histograms were also generated for each of the individual species to further assess population structure and recruitment strength.

Due to Munyana traps only being used in the last two years of the surveys as well as the high variation in seasonal crayfish activity influencing catch rates, all crayfish data was only assessed for population structure including sex distribution, and size structure with reference to maturation size and legal recreational fish size limits.

Table 1. Permanent river fish sampling sites in the Barmah-Millewa Forest indicating sites successfully sampled in each year of the study.

Site	2007	2008	2009
Murray River			
Downstream Region			
Morning Glory	✓	✓	✓
Barmah/Moria Lake area	✓	✓	✓
Mid Forest Region			
Picnic Point	✓	✓	✓
Woodcutters	✓	✓	✓
Upstream region			
Ladgroves Beach	✓	✓	✓
Gulf Creek area	✓	✓	×
Edward River			
5km downstream offtake regulator	✓	✓	✓
Downstream Gulpa creek confluence	✓	✓	✓

✓ Site contained water and successfully sampled
× Water levels were too low in 2009 to launch a boat. This site will be sampled as soon as water levels rise sufficiently for sampling

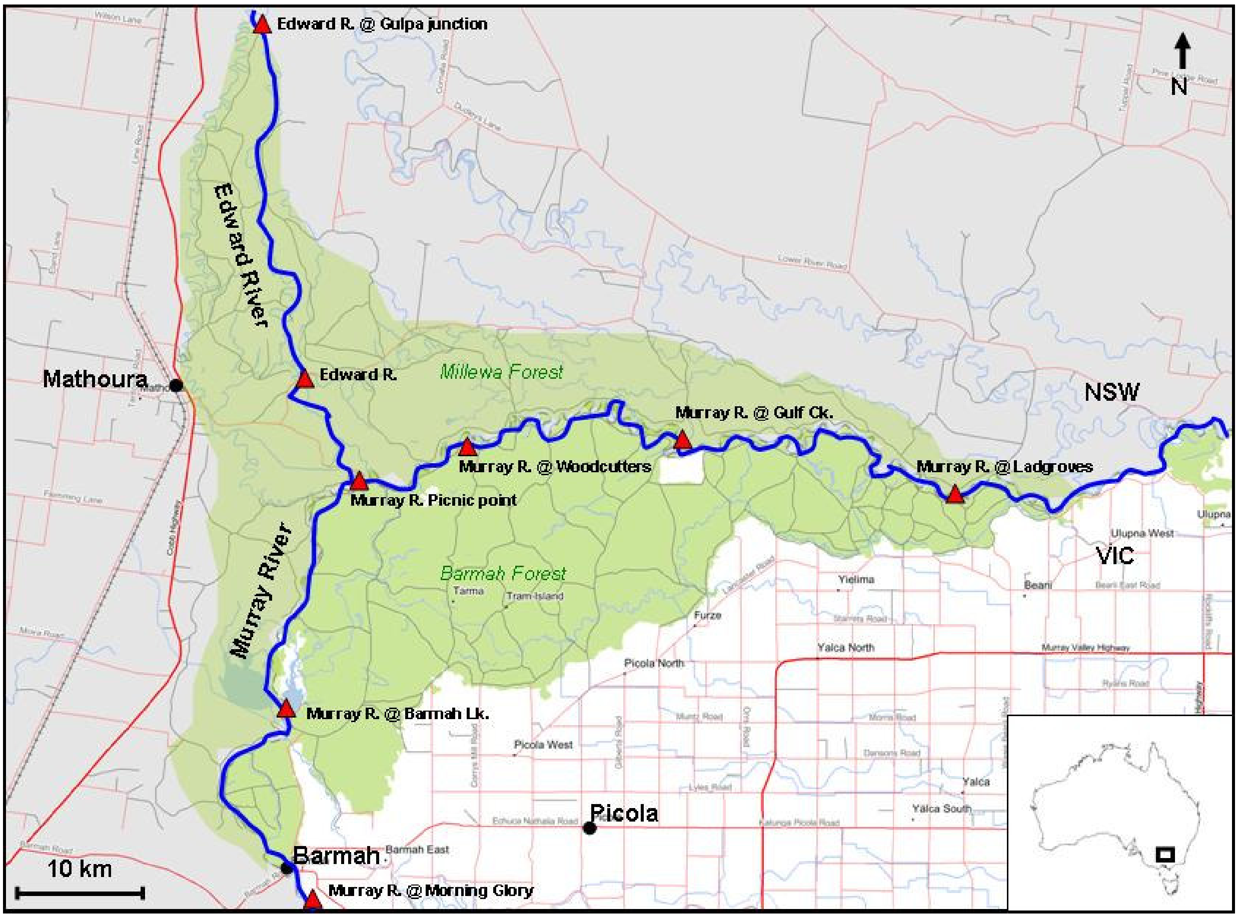

Figure 1. Barmah-Millewa forest (green shading) illustrating locations of river monitoring sites (red triangles).

Figure 2. Munyana crab trap used for Murray crayfish sampling in river sites.

2.2 Creek and wetland sites

The B-MF contains a complex matrix of creek systems and wetlands that contain a wide variety of fish species, some of which are known only to occur in these off-channel habitats (King *et al.* 2007). Therefore, 12 sites were selected for inclusion in annual sampling to represent the fish community of the forest. Sampling was fixed at six creek and six wetland sites within the Forest. These sites were spatially stratified to include six within the Barmah Forest and six within the Millewa Forest (Table 2). An additional creek site on the Gulf Creek was included in 2009 after additional surveys in 2008 revealed it to be an important refuge area for a large number of species (see Tonkin and Rourke 2008). Creek and wetland sampling took place during late February (2007 – 2009) when water levels permit boat access to some sites.

Sites within the forest experience a range of flows over any given year which can greatly affect accessibility. Therefore, sampling effort was slightly reduced from SRA standards, to ensure all sites could be completed in most years. Sampling involved 10 replicates of 90 second boat electrofishing shots at each site (with a 5 shot minimum during low water conditions). If the minimum of five shots could not be completed, 8 replicates of 150 seconds with a backpack electrofishing unit were undertaken. In addition, 10 unbaited baittraps were also set (minimum of two hours soak time) to capture fish not effectively caught using electrofishing techniques. As with river sites, all fish were identified, counted and measured (maximum of 50 individuals per species per site) at the completion of each operation. Due to the prolonged drought conditions in the area, numerous sites were dry, particularly in the last two years of surveys. For this reason, limited analysis of annual patterns across all sites of fish abundance were able to be performed. Therefore, analysis was reduced to four sites to compare overall differences in catch per-unit-effort (CPUE: fish per 90 second electrofishing shot) of total fish abundance to examine differences between years and across sites using a Kruskal–Wallis test. General community structure of each creek/wetland site was first assessed using descriptive measures on catch data from all methods. Multidimensional scaling (MDS) was performed on all fish data to describe fish community structures across habitat types and years. Abundance data was transformed to presence/absence, and a Bray-Curtis similarity matrix constructed before MDS was performed. Following MDS, one-way ANOSIM's were conducted to test for differences across years and habitat types based on 100 permutations. All multivariate statistics were conducted using the statistical package PRIMER.

Table 2. Permanent creek and wetland fish sampling sites in the Barmah-Millewa Forest indicating sites successfully sampled in each year of the study.

Site	Forest	2007	2008	2009
Creek sites				
Tongalong Creek	Barmah	✓	✓	✓
Budgee Creek	Barmah	✓	✓	✓
Tullah Creek	Barmah	✓	×	×
Toupna Creek	Millewa	✓	✓	×
Gulpa Creek	Millewa	✓	✓	✓
Aratula Creek	Millewa	✓	✓	✓
Gulf Creek @ 4 mile*	Barmah	×	×	✓
Wetland/Lake sites				
Barmah Lake	Barmah	✓	✓	✓
Hut Lake	Barmah	×	×	×
Flat Swamp	Barmah	✓	×	×
Moira Lake	Millewa	✓	×	×
Pinchgut lagoon	Millewa	✓	×	✓
Fishermans Bend Billabong	Millewa	✓	✓	✓

*commenced sampling in 2009
✓ Site contained water and successfully sampled
× Site dry and not sampled

2.3 Riverine larval drift sampling

Sampling for eggs and larvae was targeted at four large bodied native species, Murray cod, trout cod, silver perch and golden perch as well as the exotic species carp, which are known to demonstrate drifting behaviours during egg and / or larval life stages. Sampling was conducted fortnightly, from the 21st October until the 17th December. This period encompassed the known core drifting periods for these species (e.g. Humphries 2005; Koehn and Harrington 2006; King *et al.* 2007). Drifting fish eggs and larvae were collected from three sites on the Murray River at Morning Glory, Barmah choke and Ladgroves beach, which are located downstream, mid and upstream of the Barmah-Millewa floodplain respectively (see Figure 1 for site locations). These sites are also sampled as part of the general fish monitoring program. This sampling design was significantly reduced from previous surveys of King *et al.* (2008) but will allow some comparisons in data over the core breeding season for the large bodied species listed.

Collections at each site were made using 1.5 m long passive drift nets with a 0.5 m diameter mouth opening, constructed of 500 µm mesh, tapered to a removable collection jar (Figure 3). A General Oceanics Inc. (Florida, USA) flow meter was fixed in the mouth of each drift net to determine the volume of water filtered, thus enabling raw catch data to be standardised among all nets to the number of eggs/larvae $1000m^{-3}$ of water filtered. For each site, three nets were deployed just below the surface, across the river channel to minimise spatial variability in drifting densities. All nets were set on dusk and retrieved as early as possible the following morning, generally before 1000 hours. Samples were preserved in 95% ethanol in the field and returned to the laboratory for processing. Fish were removed from the samples using a dissecting microscope and identified by experienced staff using available keys (Serafini and Humphries 2004), and by collating a reference collection of successive larval stages. Due to large variations in egg and larval numbers collected, resulting in non-normal distribution of data, non-parametric measurements were used in analysis. Overall differences in standardised densities of silver perch, Murray cod and carp eggs and larvae between the three sites and between the five sample dates were tested using the Kruskal–Wallis test.

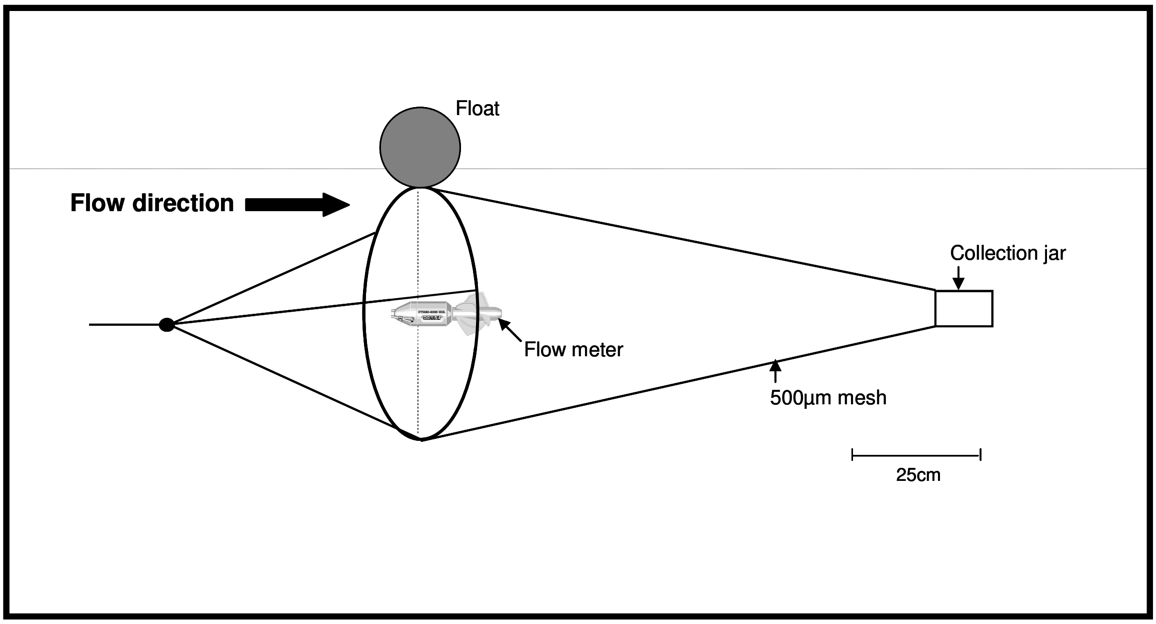

Figure 3. Side view illustration of the standard passive drift net used in the study.

3 Results

3.1 Hydrology and total catch data

Dry conditions continued in the B-MF region throughout 2008/09 and at no time over the entire three-year sampling period did water discharge levels exceed that required for floodplain inundation (Figure 4). The last time a flood was recorded in the B-MF was in October to December 2005 when an environmental flow was used to extend the spring flood event (King *et al.* 2007), but this was a relatively minor flood, inundating approximately 50% of the forest. The lack of flooding subsequently reduced the number of wetland/lake sites that could be sampled over the course of this study. In 2008/09, two of the six creek sites and three of the six wetland/lake sites were dry, while those that could be sampled had very low water levels and poor water quality parameters (Figures 5a). For example Pinchgut Lagoon, which was not sampled last year, had apparently only recently received water given the large mud cracks still present in the substrate and the dense re-growth of young River red gums below the water line (Figure 5b). Only one river site was unable to be sampled during the three-year period (Murray River @ Gulf Creek in 2008/09).

A total of 10356 fish, from 16 species (11 native and 5 exotic species) were collected from the B-MF region during the first three years of the monitoring program (3426, 2297 and 4375 respectively; Table 3). Sampling in riverine habitats contributed 4099 fish from 14 native and 4 exotic species, whilst 5999 individuals from 15 species of native and 5 exotic species were collected from creek and wetland habitats. Native species comprised a higher proportion of the total catch in river sites, in general than creek and wetland sites.

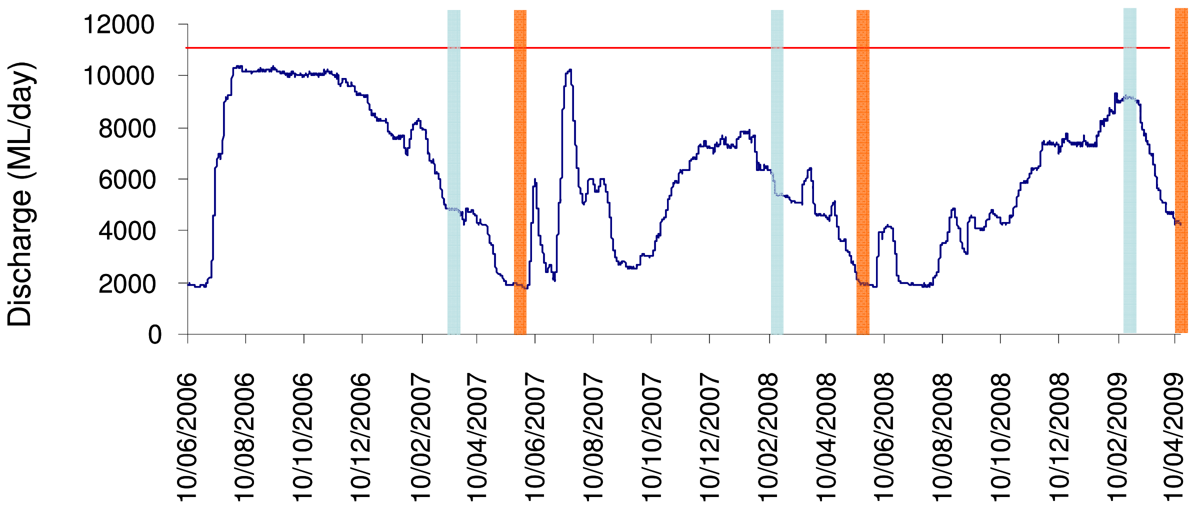

Figure 4. Mean daily discharge at the Murray River @ Tocumwal June 2006 to May 2009. The red line indicates the approximate floodplain inundation height throughout the Barmah-Millewa Forest. Light blue bars represent time of creek/wetland sampling; orange bar represent time of river sampling.

Table 3. Raw total abundances of species collected in forest creeks and wetlands (including lakes) and river sites using all methods in 2007, 2008 and 2009). Numbers of fish observed but not collected are in parentheses.

Common name	**Scientific name**	**Creeks and Wetlands**			**Rivers**			**Total (all years)**
		2007	**2008**	**2009**	**2007**	**2008**	**2009**	
Native								
Australian smelt	*Retropinna semoni*	151 (222)	35 (175)	191 (144)	386 (212)	342 (990)	158 (339)	**1281 (2051)**
carp gudgeons	*Hypseleotris* spp.	1587 (632)	422 (15)	1735 (31)	28 (20)	50 (3)	361 (20)	**4586 (678)**
flat-headed gudgeon	*Philypnodon grandiceps*	49		7			1	**68**
un-specked hardyhead	*Craterocephalus stercusmuscarum fulvus*	32 (71)	1	62 (20)	220 (24)	633 (1316)	511 (804)	**1326 (2162)**
Murray cod	*Maccullochella peelii peelii*	1	3	4	25 (2)	77 (10)	24 (4)	**133 (15)**
trout cod	*Maccullochella macquariensis*				17	43 (1)	18	**77 (2)**
golden perch	*Macquaria ambigua ambigua*	2 (2)	2		18 (5)	17 (2)	14 (3)	**54 (10)**
silver perch	*Bidyanus bidyanus*	1		1	3	23 (2)	3 (1)	**29 (5)**
southern pygmy perch	*Nannoperca australis*	36 (2)						**44 (2)**
Murray River rainbowfish	*Melanotaenia fluviatilis*	4	1	10	89 (18)	41 (47)	281 (636)	**399 (823)**
dwarf flat-headed gudgeon	*Philypnodon macrostomus*	2						
Murray crayfish	*Euasticus armatus*				9	28	47	**83**
Exotic								
carp	*Cyprinus carpio*	95 (25)	110 (82)	118 (41)	152 (65)	254 (129)	109 (39)	**765 (502)**
goldfish	*Carassius auratus*	99 (45)	78 (53)	90 (7)	20	32 (15)	40 (8)	**373 (130)**
redfin perch	*Perca fluviatilis*	35 (16)			1			**38 (16)**
gambusia	*Gambusia holbrooki*	298 (124)	87 (107)	539 (58)		4	20	**973 (299)**
oriental weatherloach	*Misgurnus anguillicaudatus*	66 (166)	14 (7)	31 (25)		(1)		**127 (175)**
Total		**2458 (1305)**	**753 (439)**	**2788 (326)**	**968 (446)**	**1544 (2516)**	**1587 (1854)**	**10,356 (6,870)**

a) b)

Figure 5. a) Aratula Creek showing blackwater, February 2009; b) electrofishing the edge of Pinchgut Lagoon showing dense river red gum regrowth, February 2009.

3.2 Rivers

In 2009, a total of 1540 fish were collected in riverine sites comprising 10 native and three exotic species (Table 3). The catch this season was dominated by un-specked hardyhead (33%), carp gudgeons (23%) and Murray River rainbowfish (18%), while exotic species comprised 11% (n=169) of the total catch.

An analysis of CPUE across all sites for the three years of the program identified significant differences in CPUE of the total abundance of fish among years ($P < 0.05$) and between sites ($P < 0.001$). Total fish abundance was significantly higher in 2008 than 2007 (Figure 6a), with no significant difference in total abundance in 2009 compared to other years due to the high variance in the catch this season. Total fish abundance was also highest at the Edward River site 5 km downstream of the offtake regulator, with numbers largely driven by the high abundance of un-specked hardyhead and Murray River rainbowfish (Figure 6b; Table 3). Furthermore, the two most upstream sites on the Murray River had higher CPUE's than the downstream sites.

Analysis of CPUE for individual species were also undertaken to detect any difference of site and year. Murray cod, trout cod and silver perch were all in significantly higher abundances in 2008 than the other two years ($p < 0.01$, $p < 0.01$, and $p < 0.05$ respectively; Figure 7). Australian smelt were also in significantly higher abundances in 2008 than 2007 ($p < 0.05$). Abundances of golden perch, carp, goldfish, carp gudgeon, Murray River rainbowfish and un-specked hardyhead did not significantly change across years (all $p > 0.05$).

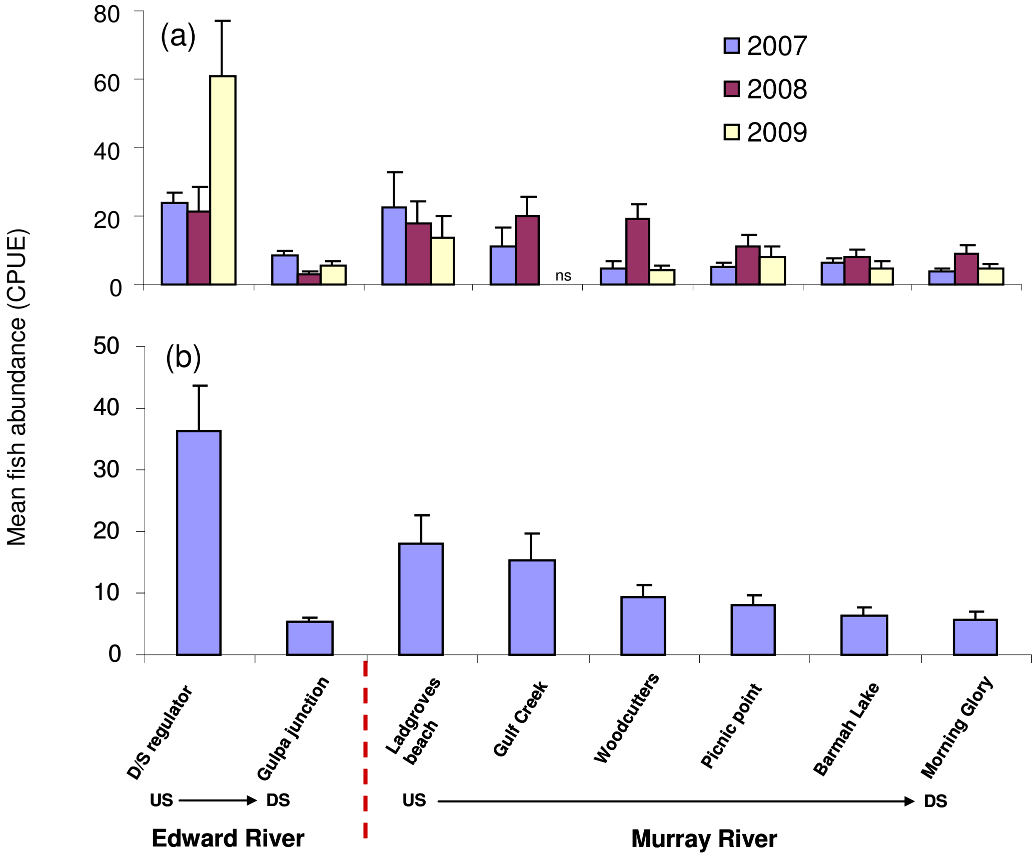

Figure 6. Mean (± SE) fish abundance presented as CPUE (fish per 90 second electrofishing shot) of total fish abundance at (a) each river site in 2007-2009 and (b) each river site for all years combined. ns indicates site not sampled in 2008/09.

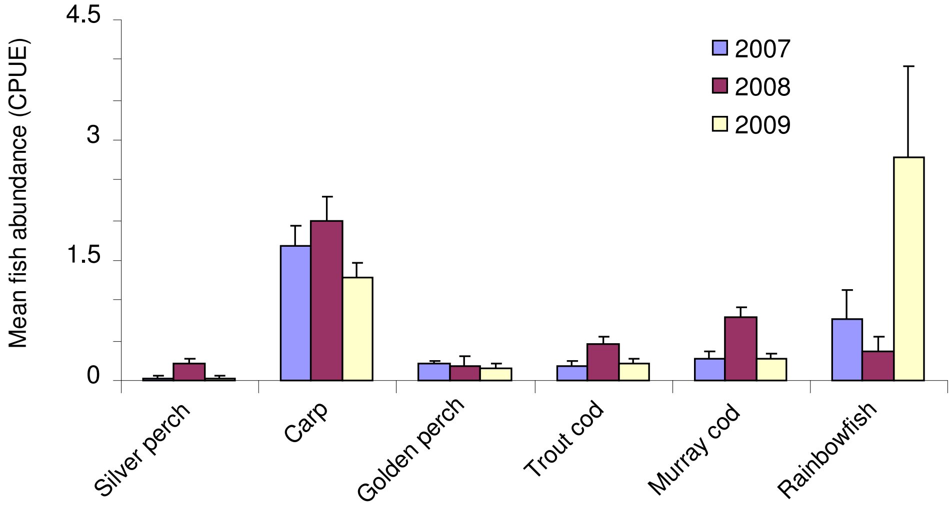

Figure 7. Mean (± SE) CPUE (fish per 90 second electrofishing shot) of silver perch, carp, golden perch, trout cod, Murray cod and Murray River rainbowfish recorded in 2007-2009 for all sites combined.

Abundances of some individual species also differed among sites. Most notably, Murray cod were in significantly greater abundance at the two most upstream Murray River sites ($p < 0.001$;

Figure 8a) and Murray River rainbowfish were in significantly higher abundances in the Edward River sites, particularly the upstream site ($p < 0.001$; Figure 8b). Indeed this site on the Edward River was also significant for goldfish, carp gudgeon, and un-specked hardyhead (all $p < 0.001$). Silver perch were most abundant in the Murray River at Gulf Creek ($p < 0.05$) although sample sizes were small and lacking 2008/09 data.

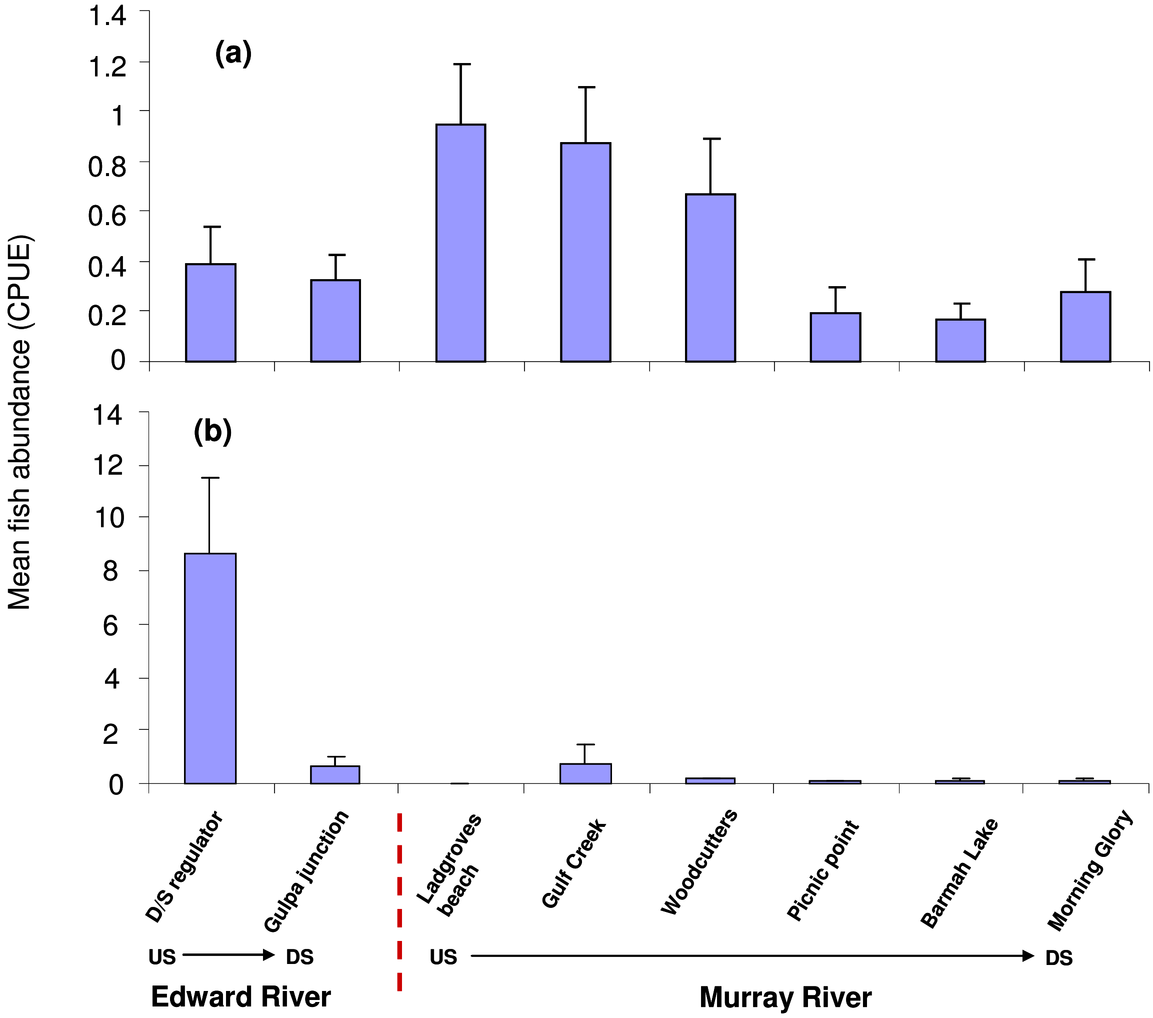

Figure 8. Mean (± SE) CPUE (fish per 90 second electrofishing shot) of (a) Murray cod and (b) Murray River rainbowfish collected at each River site for all years combined.

Young-of-year (YOY) abundance was also significantly different across years for Murray cod, trout cod and carp. Recruitment strength was highest in 2007/08 for both Murray cod and trout cod (both $p < 0.05$), and highest in 2007/08 and 2008/09 compared to 2006/07 for carp ($p < 0.001$; Figure 9). Length frequency plots of these species also represent the high proportion of YOY fish (Figure 10). No YOY of golden perch or silver perch have been collected during the study (Figure 10), with only a few silver perch in 2008 that appeared to be in the 2+ age class (this size class was age-verified by King *et al.* 2008a). Frequency histograms of Murray River rainbowfish demonstrate that most size classes were represented in each year, with a noticeable peak in fish collected that were 30mm or below in 2006/07 (YOY; Figure 10e). There was also a very low frequency of Murray cod above the legal recreational fishing size limit for the species (> 600mm; Figure 10a).

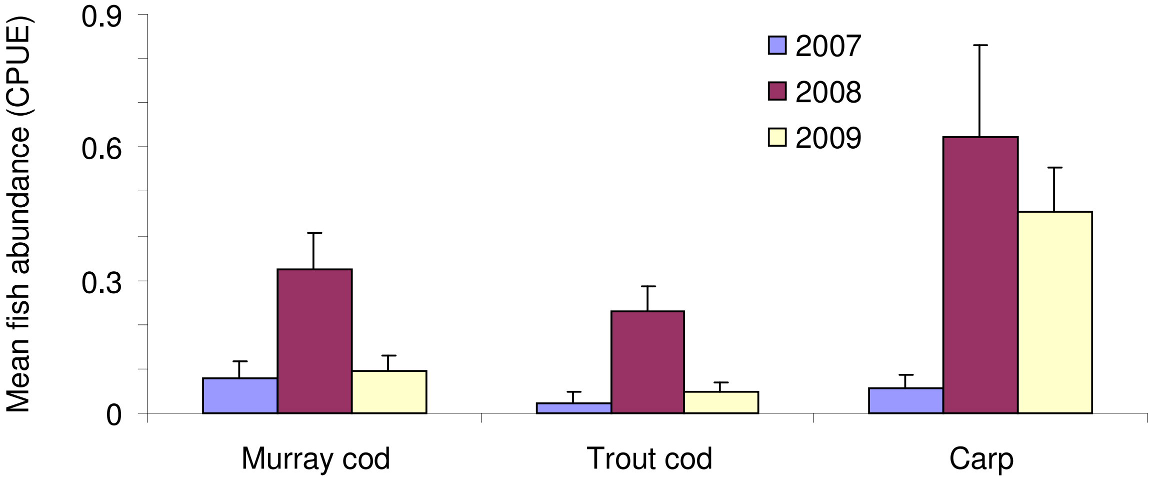

Figure 9. Mean (± SE) CPUE (fish per 90 second electrofishing shot) of young-of-year Murray cod, trout cod and carp collected from all river sites during 2007-2009.

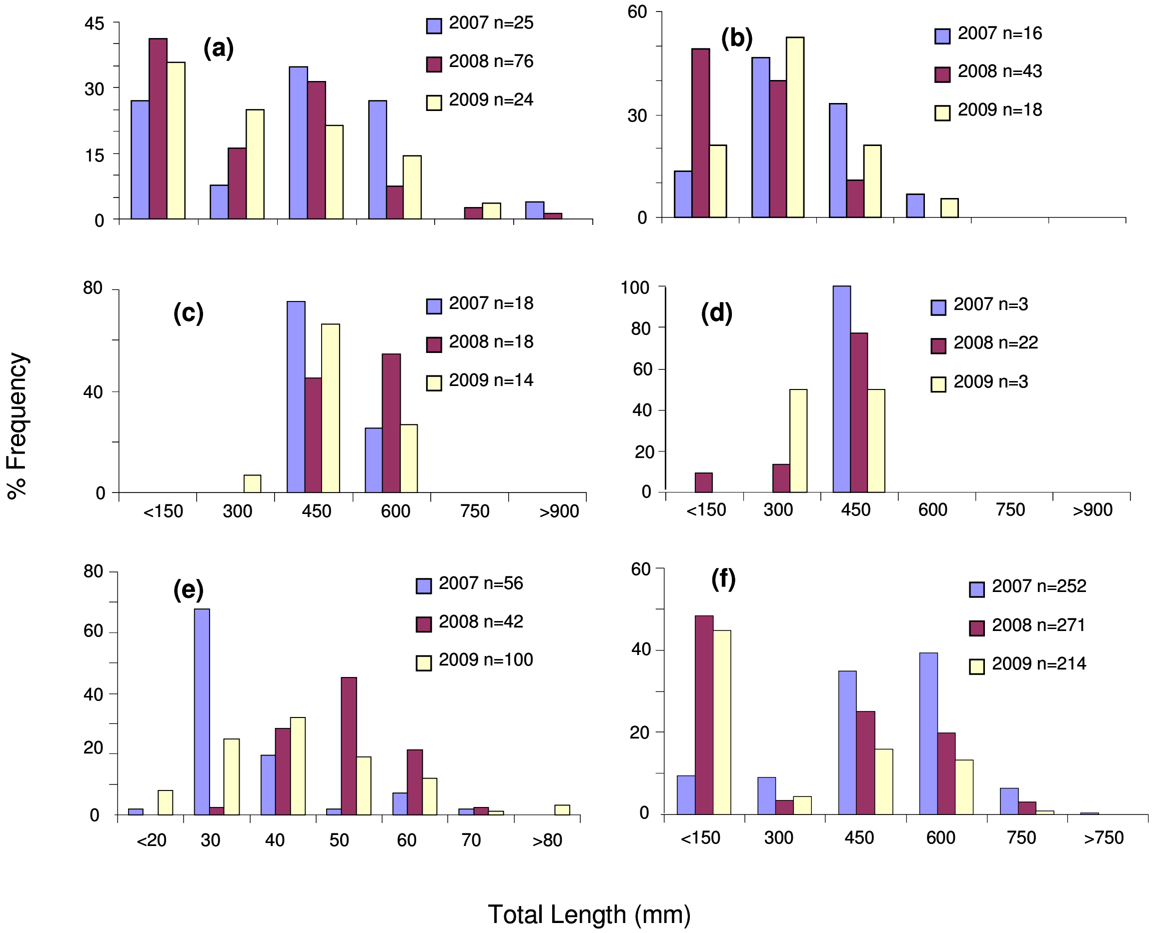

Figure 10. Length frequency histograms of (a) Murray cod; (b) trout cod; (c) golden perch; (d) silver perch; (e) Murray River rainbowfish and (f) carp across all sites and all methods for 2007 to 2009.

Forty-seven Murray crayfish were recorded from three Murray River sites in 2008/09 (Morning Glory, Woodcutters and Picnic Point), which is higher than the previous year. As with previous years, no Murray crayfish were collected in the Edward River sites.

A total of 83 crayfish have been collected during the monitoring program to date, with the ratio of female : male crayfish being 1 : 1.1 below the legal recreational size limit, but 2.5 : 1 above the legal limit (Figure 11a). Furthermore, over 40 % of mature female crayfish (determined by presence of setae surrounding the gonopores; Figure 12a) were not in berried condition (Figure 11b; Figure 12b).

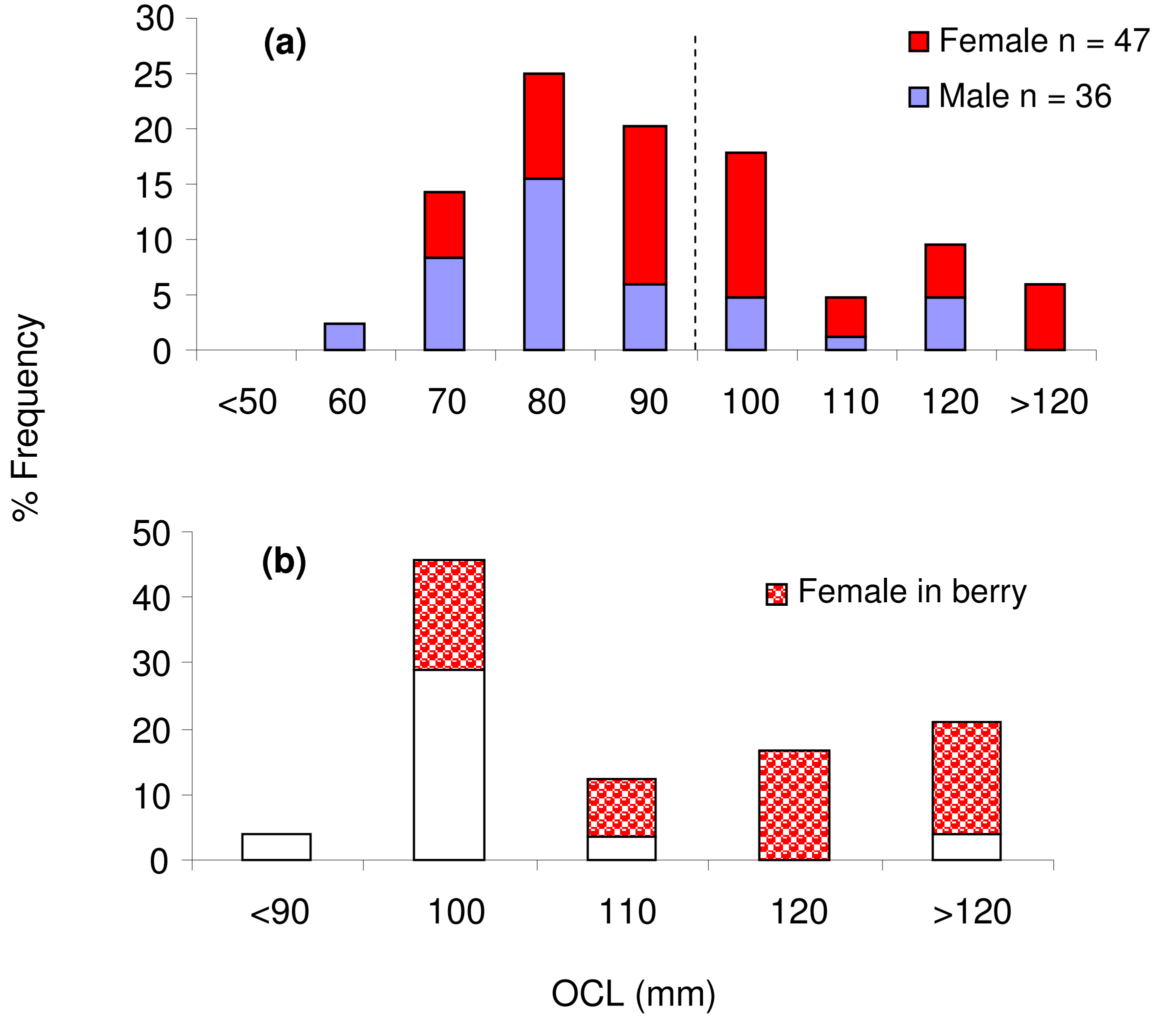

Figure 11. Occipital carapace length (OCL) frequency histogram and (a) sex ratios of Murray crayfish and (b) ratio of mature females in berry collected during the program (all years and sites combined). Dashed line represents minimum legal recreational fishing size limit.

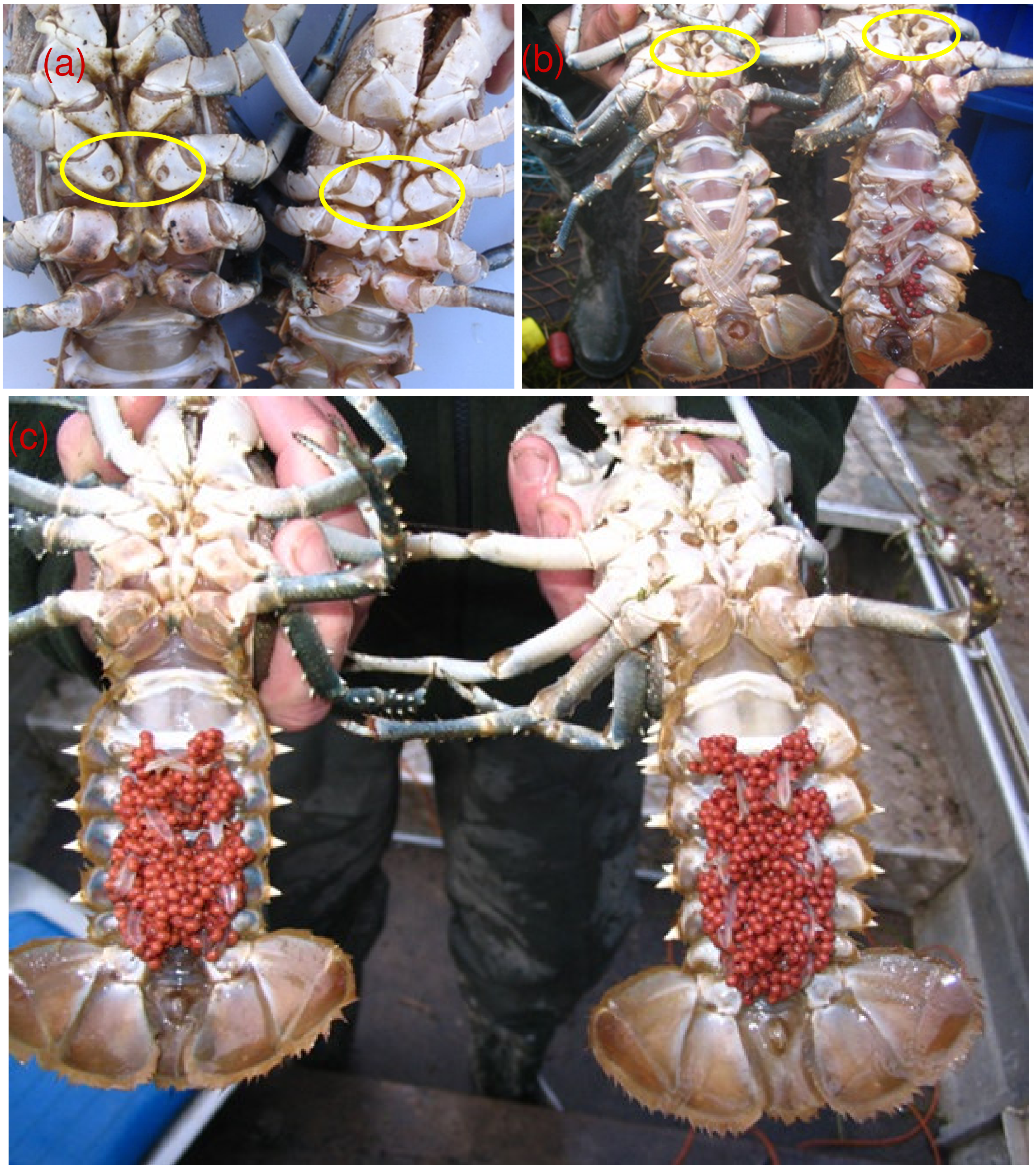

Figure 12. (a) Mature (left) and immature (right) female Murray crayfish as indicated by setae surrounding gonopores (yellow circles); mature female Murray crayfish not yet in berry (left) and with low numbers of eggs (right); (c) Mature female Murray crayfish in full berry.

3.3 Creeks and Wetlands

In 2008/09, a total of 2788 individuals were collected, comprising seven native and 4 introduced species. The number of species in 2008/09 was similar to 2007/08 but much lower than 2006/07, most likely due to a major reduction in available habitats. The most abundant species caught were carp gudgeons (57%), followed by gambusia (*Gambusia holbrooki*) (19%), Australian smelt (11%) and carp (5%) (Table 3).

A notable absence from all sites this year was southern pygmy perch (*Nannoperca australis*). The site where they were once most abundant, Toupna Creek (Tonkin and Baumgartner 2007) was completely dry at the time of sampling (Figure 13a). Remnant water was located further upstream (AMG 338571 E, 6035179 N, Figure 13b) and was intensively electrofished to determine whether the species had followed the retreating water upstream, but no fish were found. Gulf Creek was included in this year's sampling as it was identified as an important wetland refuge site, particularly for southern pygmy perch (Tonkin and Rourke 2008), as it has held permanent water over the course of this study. Given the importance of this site, it was electrofished with two teams, one team undertaking the regular sampling protocol, and the other team electofishing purely to locate Southern pygmy perch. Despite the intensity of sampling, no Southern pygmy perch were found.

a)

b)

Figure 13. a) Toupna Creek in February 2009, b) upper Toupna Creek in February 2009.

For the three years combined a total of 5999 fish were collected from creek and wetland habitats, comprising 11 native and 5 introduced species. The species composition at each site varied greatly, with some sites supporting a high species diversity and/or high abundance of native species (Gulpa Creek, Aratula Creek and Tongalong Creek), while others had were dominated by exotic species (Barmah Lake, Tullah Creek; Figure 14).

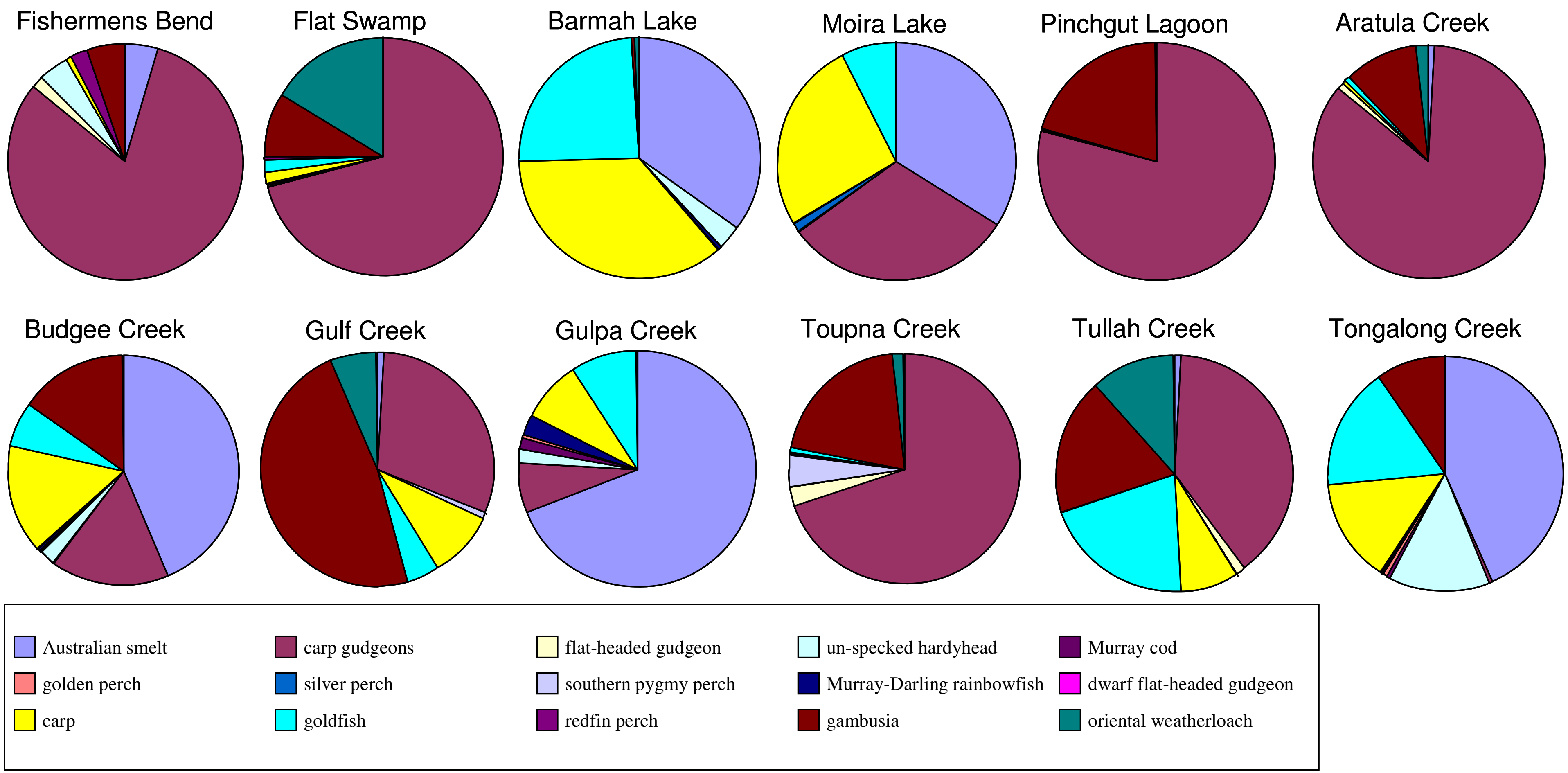

Figure 14. Species composition in individual creek and wetland sites for all years and methods combined

Multivariate analysis using MDS demonstrated the fish community in the BM region is different across habitat types, with a significantly different community structure occupying river sites compared to both creek and wetland habitats (Global R = 0.536, both $p < 0.01$: Figure 15a). Pair wise differences indicated creek and wetland communities were not significantly different, however, more permanent creek and wetland habitats (Gulpa Creek, Tongalong Creek, Budgee Creek and Barmah Lake) had community structures more similar to rivers than more ephemeral sites. There was no significant influence in community structure across the three years in the BM region (Global R = 0.007, $p > 0.05$; Figure 15b).

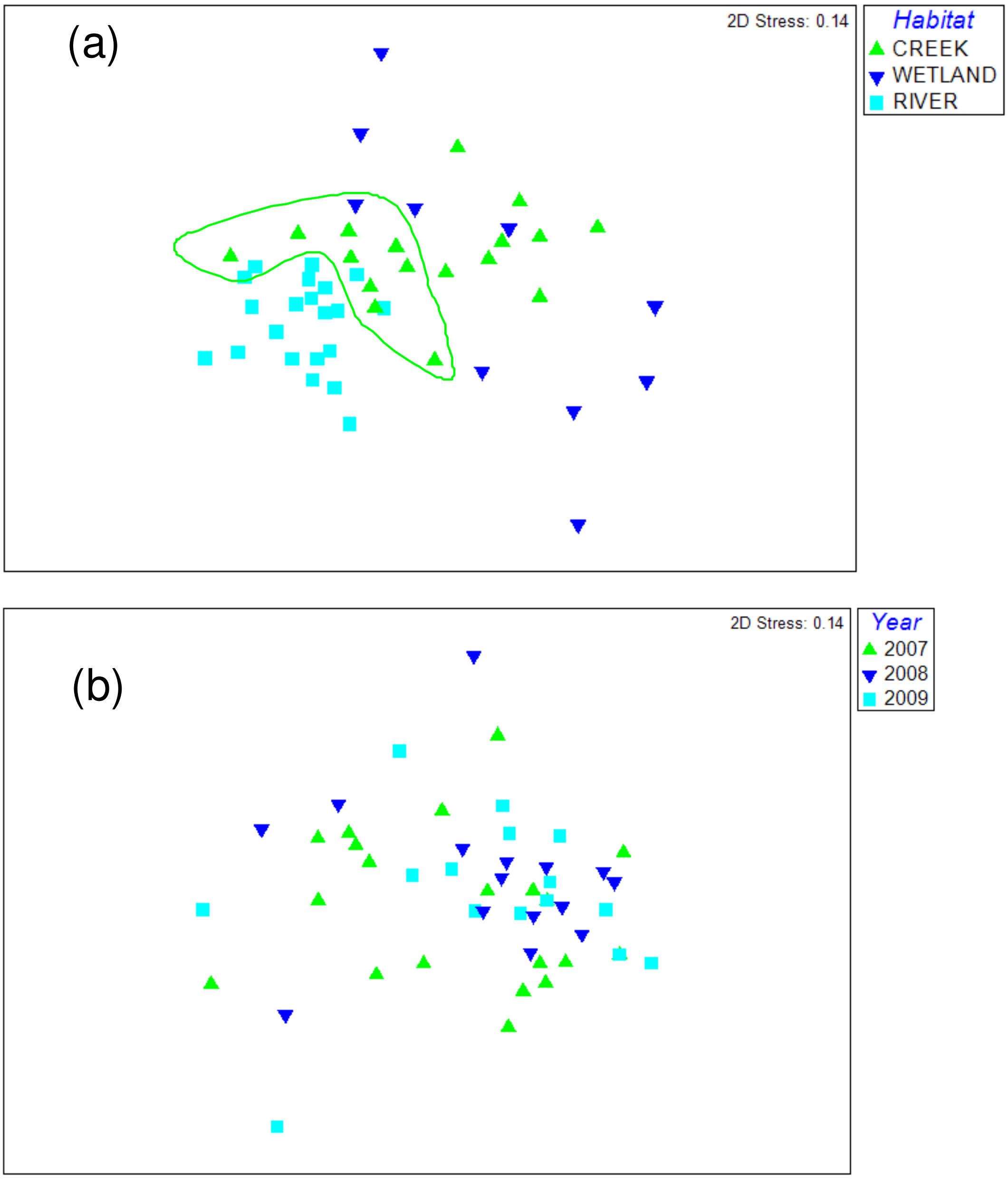

Figure 15. Two-dimensional solution for MDS ordination of the fish community composition (derived from presence/absence) across (a) habitat types and: (b) each year of surveys. (50 random starts, 100 iterations). Green grouping in (a) illustrates creek sites and Barmah lake which are permanently connected to the Murray River.

Given the dry conditions, many sites could not be sampled in all years. Therefore, abundance comparisons across years and between sites were difficult. Nevertheless, three permanent creek sites and Barmah Lake were sampled each year with the same electrofishing methodology, allowing an assessment across years and between these sites. There were significant differences in total fish abundance between years ($p < 0.001$), with a gradual increase in fish abundance at each of these sites since 2007. Not surprisingly, there were also significant differences in fish abundance between sites ($p < 0.001$), with Tongalong Creek and Budgee Creek having significantly higher abundance of fish than Gulpa Creek (Figure 16).

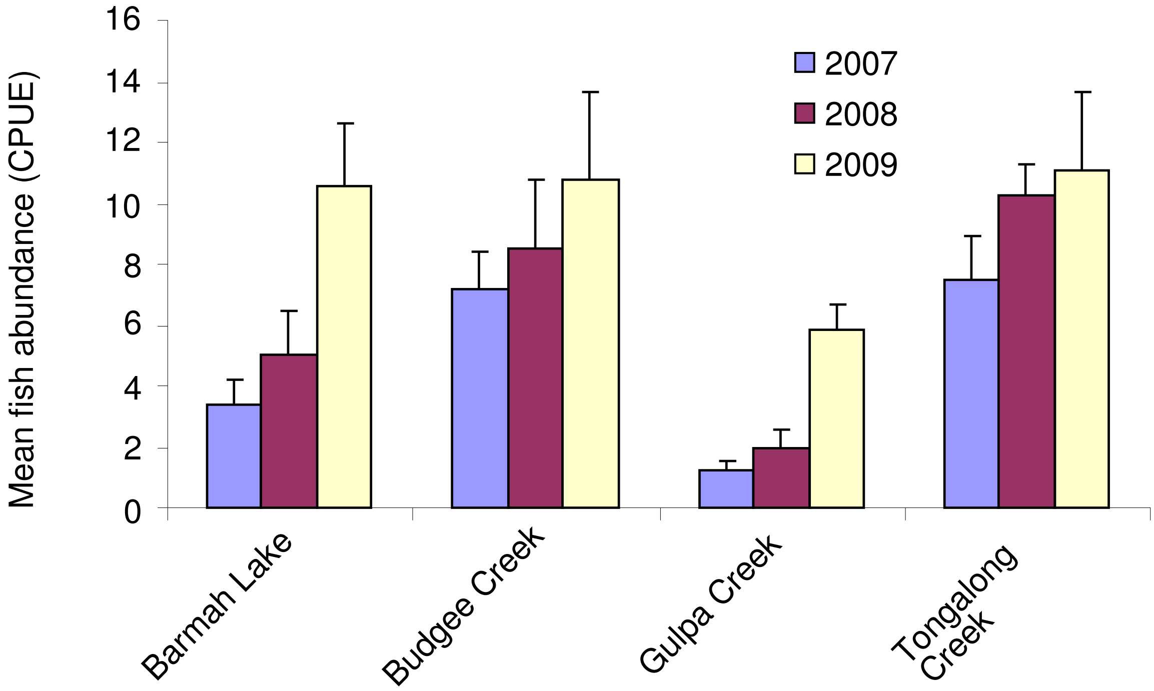

Figure 16. Mean (± SE) fish abundance presented as CPUE (fish per 90 second electrofishing shot) of total fish abundance at permanent creek/wetland site in 2007-2009.

3.4 Riverine larval drift

Consistent with the hydrological conditions of the region throughout the last three years, the 2007/08 spring/summer spawning period had river levels well below average irrigation supply levels (approximately 10000 ML/day; Figure 17). A total of 890 eggs and larvae from 10 species were captured in the spawning study, of which 831 eggs and larvae from six species were native (Table 4). Raw abundances of eggs and larvae collected in drift samples were dominated by Australian smelt (*n* = 462), whilst of the four large bodied native species, silver perch were in greatest abundance (primarily eggs; n = 263 and some larvae; Figure 18), followed by Murray cod (*n* = 42). Only a single golden perch larva was collected in the 2008/09 drift samples, with no eggs collected being confirmed as those of golden perch. There was no confirmation of the presence of trout cod larvae in samples, although there were several cod larvae that could not be confidently assigned to either species. Carp were the most abundant exotic species in the 2008/09 drift samples (*n = 54*).

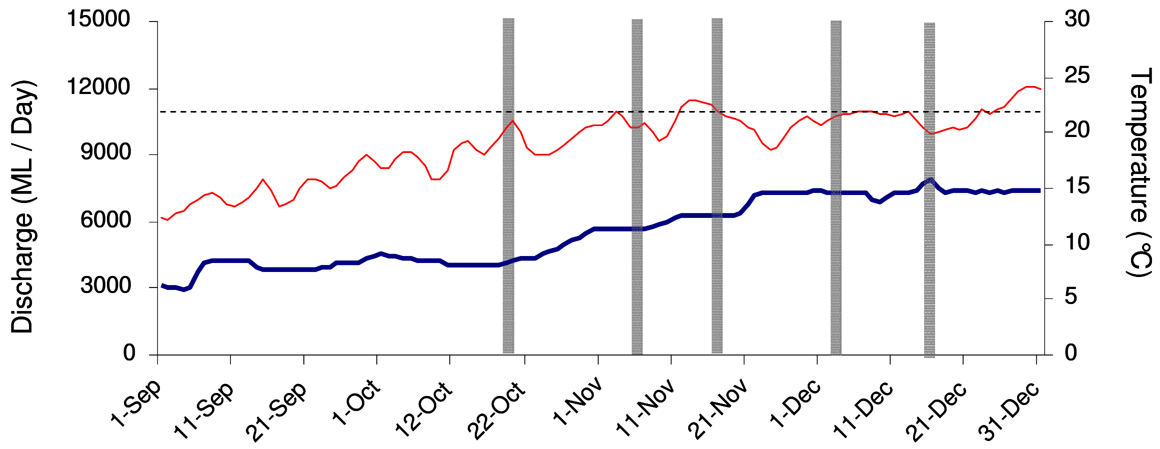

Figure 17. Daily discharge (blue line) and water temperatures (red line) of the Murray River at Tocumwal in spring / summer 2008. Dashed line represents height of Barmah-Millewa Forest floodplain inundation. Shaded grey regions indicate larval sample dates.

Table 4. Raw numbers of eggs and larvae collected drifting from the three Murray River sites in 2009.

		Murray River Site			
Common name	**Scientific name**	Morning Glory	Barmah Choke	Ladgroves Beach	**Total**
Native					
Murray cod	*Maccullochella peelii peelii*	16	22	4	**42**
unidentified cod spp.	*Maccullochella* spp.	1	3	0	**4**
silver perch	*Bidyanus bidyanus*	15	17	231	**263**
golden perch	*Macquaria ambigua*	0	1	0	**1**
carp gudgeons	*Hypseleotris* spp.	1	0	0	**1**
flat-headed gudgeon	*Philypnodon grandiceps*	5	31	22	**58**
Australian smelt	*Retropinna semoni*	129	325	8	**462**
Exotic					
goldfish	*Carassius auratus*	2	0	1	**3**
carp	*Cyprinus carpio*	42	0	12	**54**
eastern gambusia	*Gambusia holbrooki*	0	0	2	**2**
	TOTAL (eggs and larvae)	**211**	**399**	**280**	**890**

Figure 18. Silver perch larvae collected in early November from the Barmah Choke.

Peak densities of drifting Murray cod larvae recorded in 2008/09 were around 26 larvae $1000m^{-3}$ (Figure 19a). Densities of drifting Murray cod larvae were significantly influenced by sample date but not by sample site ($p < 0.01$ and $p > 0.05$ respectively). The highest densities of drifting Murray cod were recorded during the middle three sample trips from 6th November – 3rd December.

Peak densities of drifting silver perch eggs/larvae recorded in 2008/09 were 1575 (± 279) eggs/larvae $1000m^{-3}$ (Figure 19b). Standardised densities of drifting silver perch eggs and larvae were significantly influenced by both site and sample date ($p < 0.05$ and $p < 0.001$ respectively). The highest densities of drifting silver perch eggs/larvae were recorded at Ladgroves beach, during the middle three trips of the study. Peak densities were recorded during the early December sample trip which coincided with relatively stable river levels, but increasing water temperature.

Peak densities of drifting carp larvae were 775 (± 650) larvae $1000m^{-3}$ (Figure 19c). Standardised densities of carp larvae recorded in 2008/09 were significantly influenced by site but not by sample date ($p < 0.01$ and $p > 0.05$ respectively) with the highest densities recorded at Morning Glory. It must be noted that flow meter readings during the time of peak carp densities were very low as a results of the flow velocities at this site during the first trip of the surveys (time of peak carp densities). This may have resulted in an over estimate of drifting densities of carp during this trip.

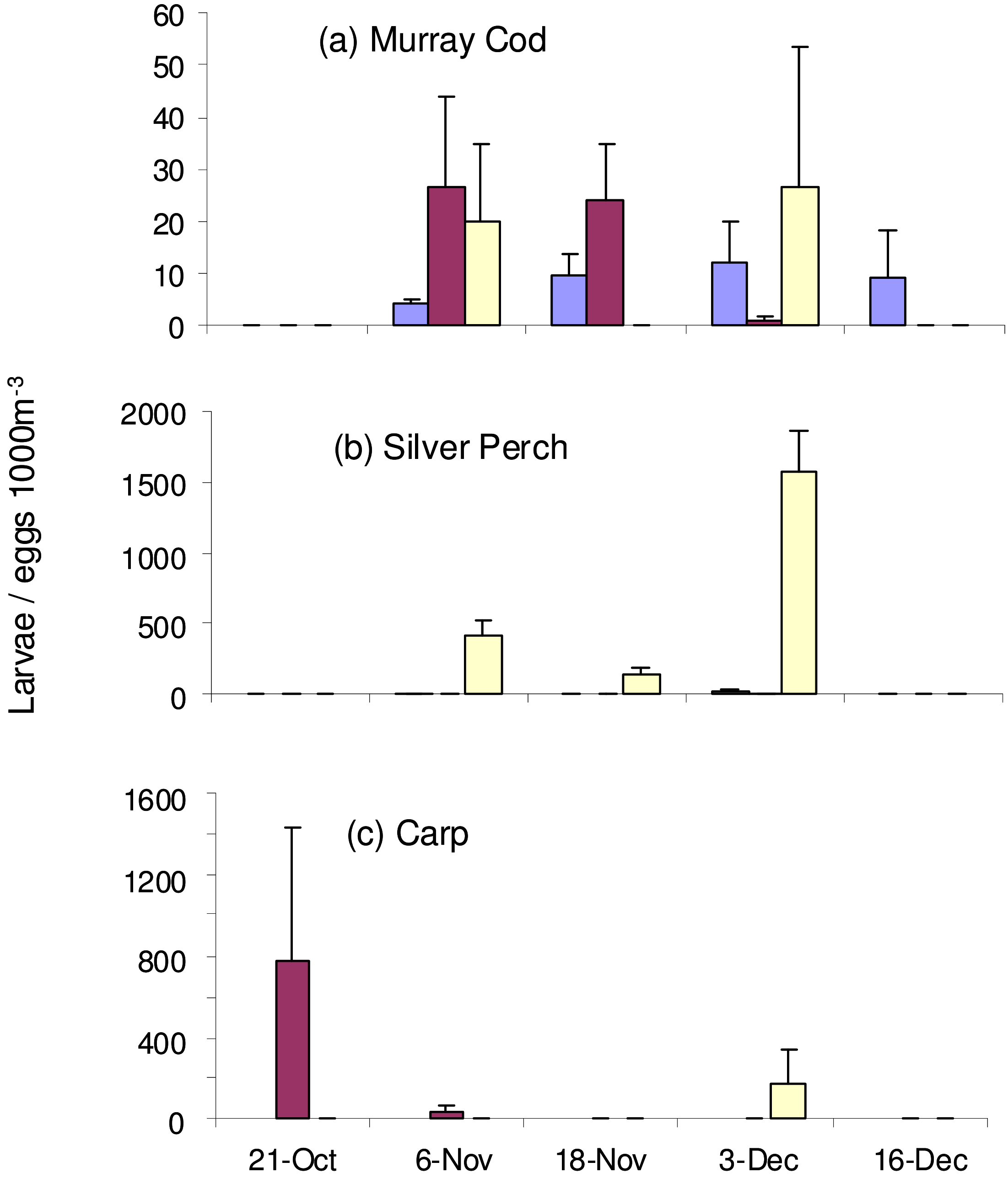

Figure 19. Mean ± SE densities of drifting (a) Murray cod, (b) silver perch and (c) carp eggs and/or larvae collected in the Murray River at Barmah choke (blue); Morning Glory (red) and; Ladgroves beach (yellow) on each sample trip in 2008/09.

4 Discussion

4.1 Rivers

Despite the extended drought conditions limiting flows through the region for the past three years, the rivers in the B-MF continue to support a good range of native fish, but two species were not detected this year, southern pygmy perch and dwarf flat-headed gudgeon (*Philypnodon marcrostomus*). As the current drought continues to persist, it will be interesting to gauge fish responses when higher flows do finally return.

An interesting finding of this project is the greater abundance of Murray cod and trout cod in 2007/08 than 2006/07 and 2008/09. The greater abundance of these species in 2007/08 is largely due to an increase in recruitment strength during this season (as indicated by the high abundance of YOY fish). This may be due to greater catch efficiency in 2007/08, but this seems unlikely given the increased frequency of both Murray cod and trout cod in the 150-300mm TL size class in 2008/09, which is likely to represent the 2008 recruits. King *et al.* (2008a) also reported a high abundance of YOY Murray cod and trout cod in the region in 2007/08. Additionally, there were also far fewer YOY Murray cod and trout cod collected in the Murray River between Lake Mulwala and Cobram (upstream of Barmah-Millewa) in 2008/09 than previous years (Jarod Lyon pers. Comm.). Murray cod and trout cod spawn regardless of flow conditions (Humphries *et al.* 2002. King *et al.* 2008b), however, the mechanisms driving years of increased recruitment are still unclear. It has been suggested that recruitment success is linked to floodplain inundation (e.g. Rowland 1998; Ye et al., 2000; King *et al.* 2008b), however, King *et al.* (2008a) reported the highest recruitment of both Murray cod and trout cod occurred both in a year of floodplain inundation and two years later in a year of severe drought (the 2007/08 season as reported in this study). A possible mechanism for the increased recruitment in 2007/08 (fish spawned in spring/summer 2007/08) relates to the inundation of vegetated benches in the Murray River during this season. Prior to spawning in 2007/08, an early flow spike (see Figure 4) contributed to large amounts of vegetation regrowth along the channel edges which were subsequently inundated during the spawning and rearing season (see Tonkin and Rourke 2008). This inundation of vegetation on benches within the river channel may have been similar to conditions of a low level flood such as that of 2005/06. Tonkin and Rourke (2008) and King *et al.* (2008a) suggested this contributed to high levels of spawning and subsequent recruitment of carp, however whilst spawning levels did not change, it is possible that the improved nursery habitats or food supply for larval and juvenile Murray cod resulted in increased recruitment strength from the 2007/08 spawning season (this may also be the mechanism driving the highest overall abundance of all fish species combined occurring in 2007/08). This is assuming that these fish were naturally recruited although trout cod are not stocked into the Murray River below Lake Hume and, whilst introduced into the Ovens River above Lake Mulwala, have not been stocked here since 2005. Furthermore, Murray cod were collected as larvae as presented in the drift results, which when added to the presence of YOY fish, would suggest natural recruitment is occurring throughout the region. There is the complication that even if the fish are natural recruits that they may have been the result of spawning upstream, and have either drifted downstream or actively migrated to the B-MF. However, this would still be an important finding, indicating that the B-MF is an important nursery area for these two species. Results of continued monitoring in the region will provide further information on factors influencing recruitment of both of these iconic and rare species.

Of concern is the low numbers of Murray cod above the legal size limit of 600mm which is likely to indicate a large amount of recreational fishing pressure on the Barmah-Millewa Murray cod population. Whilst this is the case for the species in most areas of the Murray (e.g. Lyon *et al.* 2008), this low percentage of mature fish is likely to be influencing the amount of recruitment occurring in the region. However, this could also be a reflection of reduced gear efficiency at sampling these larger fish. It is also thought that large fish may be more prone to becoming trapped underwater in submerged woody debris, preventing them from floating to the surface and being caught.

Murray cod were also significantly more abundant at the two most upstream Murray River sites, Ladgroves beach and Gulf Creek, despite the lack of samples for 2008/09 at Gulf Creek. Results also indicate that of the Murray sites, the upstream sites have a higher abundance of fish in general. To our knowledge, this pattern has not been reported before, though King *et al.* (2008a) did report that trout cod YOY were caught more often at Ladgroves Beach than at other sites. One possible explanation for more Murray cod utilising these upstream sites is that the area contains a higher degree of habitat complexity than downstream sites, in particular, backwater habitats and in-channel woody debris. There was however, no significant difference both in densities of drifting Murray cod larvae and abundance of YOY Murray cod between sites. This suggests the larval drift is an effective dispersal mechanism for the species, however the persistence of YOY at a site may be limited by habitat availability.

There were no YOY golden perch or silver perch collected during the three years of the program, despite the presence of spawning activity in the region, particularly by silver perch. King *et al.* (2008a) did not collect any YOY silver perch and only collected YOY golden perch during electrofishing conducted at night, while Lyon *et al.* (2008) did not report any YOY golden or silver perch during daytime electrofishing surveys of the Murray River upstream of Barmah despite a high abundance of adult fish. This may indicate that the current sampling protocol may be an inefficient technique for collecting YOY golden perch and silver perch in the Murray River. Of course, numbers of YOY fish may be too low to detect with the current sampling protocol. The current study did collect a small number of 2+ silver perch in 2008 (cohort was age verified by King *et al.* 2008a) which would suggest they were spawned in the 2005/06 flood year (as did King *et al.* 2008a), however, we can not be confident of the source of these fish given the species is known to move large distances (for example large numbers of these fish are recorded moving through the Torrumbarry fishway (e.g. Mallen-Cooper and Brand 2007; Stuart *et al.* 2007). Regardless of source, the presence of these fish in B-MF indicates the importance of the region for late juvenile and adult stages. Future monitoring after high spring/summer flows in the region will provide further information on mechanisms driving recruitment strength in the region for both these species.

The continued presence and high abundance of Murray River rainbow fish particularly in the Edward River across a broad range of sizes is an important finding of this project. This species is known to spawn in mid-summer often during low flows (Humphries 2002; King *et al.* 2008a). It has been hypothesised that spawning during low flows provides an advantage to larvae by concentrating their food sources into a small area, and therefore fish do not need to utilise the abundant food resources of the floodplain that may not be available on a seasonal basis (Humphries *et al.* 1999). Alternatively, as King *et al.* (2008a) suggested, it could be that low flows have created the ideal conditions for spawning; inundated vegetation and still, warm, water. The Edward River, like the Murray River, has received low flows over the course of this study and has not even reached the level of a minor flood of 4.6m (Anon 2008). Our data for the three years of the present study show that YOY Murray River rainbowfish were at a peak in 2006/07 following low summer flows, but despite similar environmental conditions in 2007/08 and 2008/09, YOY fish were not as abundant. It is difficult to draw firm conclusions from these data given at times the species can form dense schools, which can bias the catch. Nevertheless, it would appear the YOY fish detected in 2006/07 were then detected in the 50mm size range in 2007/08, which were in turn represented in 2008/09, in the larger size ranges, although this observation can not be verified without aging these fish. Our data and that of others (King *et al.* 2008a) suggest that this species is doing well in the present drought.

With three years of catch data of Murray crayfish, some interesting trends are emerging on the B-MF population. Murray crayfish are only present in the Murray River and either not present or in very low numbers in the Edward River, given they have not yet been detected at either sample site. The shift from a 1:1 ratio of females to males less than the recreational size limit (90 mm OCL) to that of 2.5:1 above this limit indicates that recreational fishing may be impacting upon the Murray crayfish population. There is also a high proportion of mature female Murray crayfish, not in berry. Female Murray crayfish have an incubation period (in berried condition) of approximately 20 weeks (Gilligan *et al.* 2007). Thus the absence of berries may imply one of two things. Firstly, that Murray crayfish in the B-MF extends at least a month beyond that of Murray crayfish in the Murrumbidgee River, which are almost all in berry by late May (Gilligan *et al.* 2007). Or secondly, that there are insufficient numbers of mature males in the population to fertilise all the mature females. This seems likely given the major change in the female: male ratio above the legal size limit. Nevertheless, these findings have important implications for the recreational fishery.

Carp were caught in all habitat types during the study, but were particularly prevalent in the river sites. For the second consecutive year carp successfully spawned (presence of larvae) and recruited (presence of YOY) in the B-MF. These processes also took place in the absence of flooding. Similarly, King *et al.* (2008a) also reported carp spawning and recruitment in times of low flow. Consequently, there is now good evidence demonstrating that carp can successfully recruit in the absence of floods, provided vegetation on low-lying benches within the river channel are inundated during the spawning season (Tonkin and Rourke 2008). While the extent of their recruitment success may fall short of that after floodplain inundation (see Stuart and Jones 2006; Macdonald and Crook 2007), it does mean that carp can persist in the fish community in times of drought.

4.2 Creek and Wetlands

The third year of data collection for this project has shown that the B-MF creek and wetland sites continue to be important for adult native fish communities, particularly the small-bodied species. As expected, the most permanent habitats contained fish assemblages more like river habitats. This was particularly evident in Barmah Lake and creek sites which are permanently connected to the river. Where data was available at a site for all three years, it was evident that there was trend of increased fish abundance since 2006/07. This was predominantly driven by the increase in abundance of Australian smelt, carp gudgeons and un-specked hardyhead. This highlights the important role these sites play as drought refugia for small-bodied species as other habitats continue to dry. When floods do return, these are likely to act as source populations for the re-colonisation of newly inundated habitat.

Southern pygmy perch were successfully sampled in 2006/07 in four permanent sampling sites and in three refuge pools in 2008, albeit in very low numbers. This year (2008/09), no southern pygmy perch have been recorded by the current sampling, nor any other projects to our knowledge in the B-MF. . The last time the species was recorded in the B-MF was by the present study in February 2008 (Tonkin and Rourke 2008), and by King *et al.* (2008a), where a single individual was recorded from the Murray River in October 2007. The absence of pygmy perch appears directly related to the low flow conditions and lack of floodplain connectivity preventing successful recruitment and dispersal (Tonkin *et al.* 2008). The B-MF population of southern pygmy perch was previously described as potentially being at risk of local extinction if successful spawning and recruitment did not occur in the 2008/09 season (Tonkin and Rourke 2008; Tonkin 2008). Given that the conditions necessary for spawning and recruitment did not occur for the third consecutive year, and that the species has a very short life-span (Humphries 1995), there is a strong possibility that southern pygmy perch are now absent from the B-MF. If so, there are major implications for potential recovery of these populations given that recent genetic work on the Goulburn and Murray Rivers has shown that pygmy perch exhibit high levels of genetic differentiation across short distances. This suggests major rivers are a significant barrier to population connectivity and that the species is not capable of long distance movements (Cook 2007; Hammer 2001). However, given a single fish was recorded from the Murray River (King *et al.* 2008a), the species may utilise rivers from time to time, perhaps to disperse into new habitats. Although there is a major risk that the species is now locally extinct, it is possible that the species will return to the B-MF either from upstream sources or from remnant populations overlooked in this study. This has occurred in the past where an extensive study in the mid-90's failed to find any southern pygmy perch in the Barmah Forest (McKinnon 1997), but it was subsequently detected there years later.

Exotic species again made up a substantial component of the total fish abundance in creeks and wetlands, particularly gambusia and carp. Redfin perch have not been recorded over the last two years of this study, and few were collected by King *et al.* (2008a) during the 2007/08 season, which was attributed to the reduction in suitable wetland or creek habitats. Nevertheless, the species is expected to increase rapidly in abundance when water flows improve (King *et al.* 2008a). Of the exotic species, the oriental weatherloach is an emerging species of concern that is rapidly increasing its distribution in the southern MDB. It can tolerate a wide range of environmental conditions and could potentially colonise much of the MDB if no controls are implemented (Lintermans *et al.* 2007). The species is undoubtedly now well established in the B-MF given that only two were recorded in the mid 1990s (McKinnon 1997), while more recently they have been detected in much higher abundance in a range of habitats (King *et al.* 2007; this study). Oriental weatherloach were recorded from all habitat types, but they were far more abundant in the creeks and wetlands. They were also more abundant in 2006/07 than in subsequent years due to the reduced number of creek and wetland sites available for sampling rather than a population decline. The species is known to aestivate for long periods deep in the mud of dried out waterbodies (Lintermans *et al.* 2007), however, given much of their major habitats have now been dry for three years, the length of time they can persist in this state is unknown. This study is therefore well placed to record their response to re-wetting of the dry wetlands and creeks, which may have major implications for developing control strategies for the species.

4.3 Riverine larval drift

The results of the 2008/09 drift surveys indicate the B-MF region of the Murray River continues to be utilised as a spawning area by native fish species, despite the third consecutive year of extreme low flows in the region. Six native species, including three of the four large bodied species were recorded spawning in the area in 2008/09. The endangered trout cod was the only large bodied native species that was not detected spawning in the B-MF region of Murray River in 2008/09, although some of the unidentified cod larvae may well be those of trout cod. Furthermore, whilst King *et al.* (2008a) reported the presence of trout cod larvae in the past three years (they were not recorded in 2003 and 2004), their drifting densities were extremely low (2-3 larvae 1000m^{-3}; Figure 20). Nevertheless, the absence of trout cod larvae in the 2008/09 samples may not indicate that the species did not spawn in the region, but could suggest that if spawning was occurring, it is at a level too low to be detected by the sampling regime. Given the subsequent collection of YOY trout cod during the 2008/09 electrofishing surveys, this would appear to be the case, although YOY fish may also be fish that were spawned further upstream or downstream and migrated to these B-MF sites.

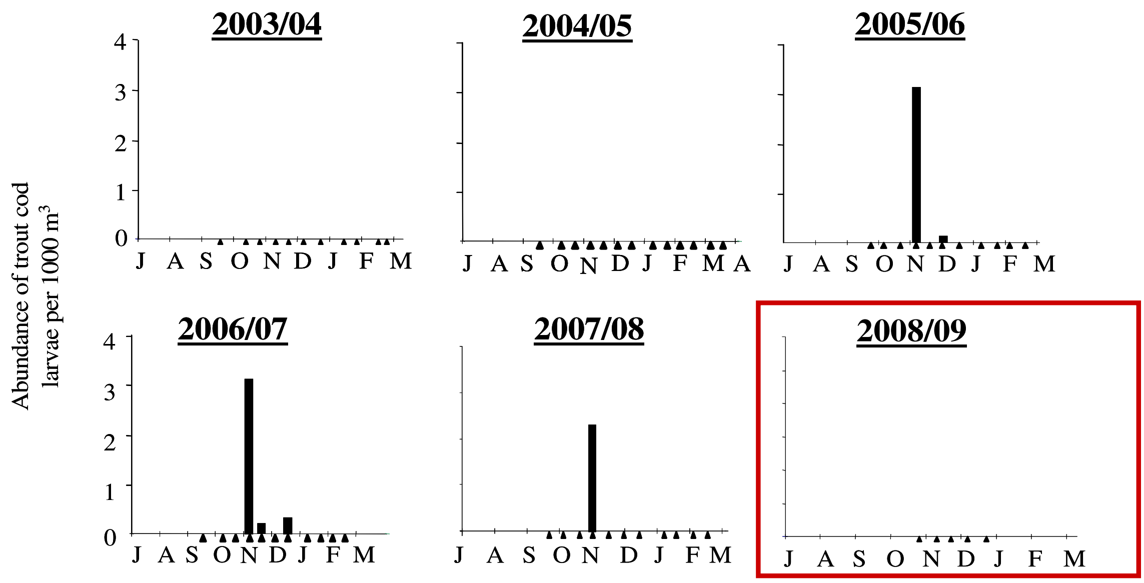

Figure 20. Drifting densities of trout cod larvae collecting during fortnightly drift sampling (black triangles) across all sites in the Murray River in Barmah-Millewa. Figure from King *et al.* (2008a) with data collected in 2008/09 included (red box).

Murray cod larvae were collected from all three sites during 2008/09 with the highest densities recorded through the month of November. The timing of the presence of Murray cod larvae is consistent with numerous other studies (e.g. Humphries 2005; Koehn and Harrington 2006; King *et al.* 2008a). Peak densities of drifting Murray cod larvae recorded in 2008/09 were similar to densities recorded in the previous five spawning seasons in the region by King *et al.* (2008a; Figure 21). This supports the previous work which indicates variable flow conditions have very little influence on the presence and densities of Murray cod larvae (e.g. King *et al.* 2008a; Koehn and Harrington 2006; Humphries 2005).

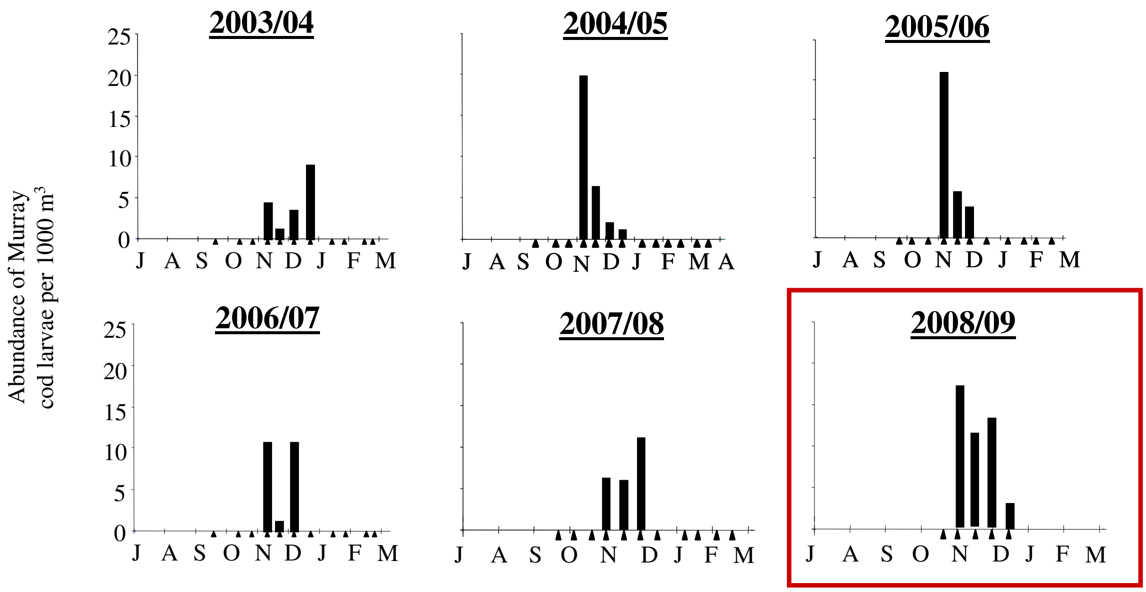

Figure 21. Drifting densities of Murray cod larvae collecting during fortnightly drift sampling (black triangles) across all sites in the Murray River in Barmah-Millewa. Figure from King *et al.* (2008a) with data collected in 2008/09 included (red box).

Results indicate the B-MF region of the Murray River is a consistent spawning site for silver perch. Silver perch eggs and larvae were predominantly collected from the Ladgroves Beach site (which is the site most upstream of the forest) and like Murray cod, from early November to early December which is similar to patterns reported for the region by King *et al.* (2008a). Peak densities of drifting eggs and larvae in 2008/09 similar to densities reported in previous non-flood seasons (King *et al.* 2008a; Figure 22). Furthermore, peak densities occurred during stable river levels, but during an increase in water temperature. The presence of a single larva and absence of eggs indicate golden perch spawning activity in the area was very low in the 2008/09 season. No golden perch eggs or larvae were recorded in the Murray River below Yarrawonga weir (upstream of the current study; Tonkin *et al.* 2009) and low numbers of eggs were collected in the Murray River at Echuca (downstream of the current study; Koster unpublished data) during concurrent studies in 2008/09. Such low levels were recorded in the two years previous to this survey by

King *et al.* (2008a; Figure 23), with the authors suggesting the low densities of drifting golden perch eggs and larvae recorded in 2006 and their absence in 2007 was due to the abnormal low flows in the region during these seasons. The continued low flows in 2008/09 and extremely low densities of golden perch and average densities of silver perch eggs and larvae collected appear to support the trends reported by King *et al.* (2008a) whereby the high levels of spawning of both species are largely governed by overbank flooding during their core spawning period (October-December). However, Tonkin *et al.* (2009) reported that high densities of both silver perch and golden perch eggs (8500 and 6200 eggs 1000m^{-3} respectively) in the Murray River between Lake Hume and Lake Mulwala in November 2008 when an in-channel flow rise coupled with a rise in water temperature occurred, suggesting high levels of spawning are not necessarily driven by overbank flooding (Tonkin *et al.* 2009). Mallen-Cooper and Stuart (2003) found recruitment strength to be highest during in-channel flows in Barmah-Millewa for both golden perch and silver perch, although the extreme low-flow conditions (as experienced in the past three years) were not present during this study. Indeed, the results of both of these studies suggest in-channel flow manipulation may have some implications for the delivery of water through the B-MF region although further work is needed to elucidate the importance of various flow attributes to the spawning of these species.

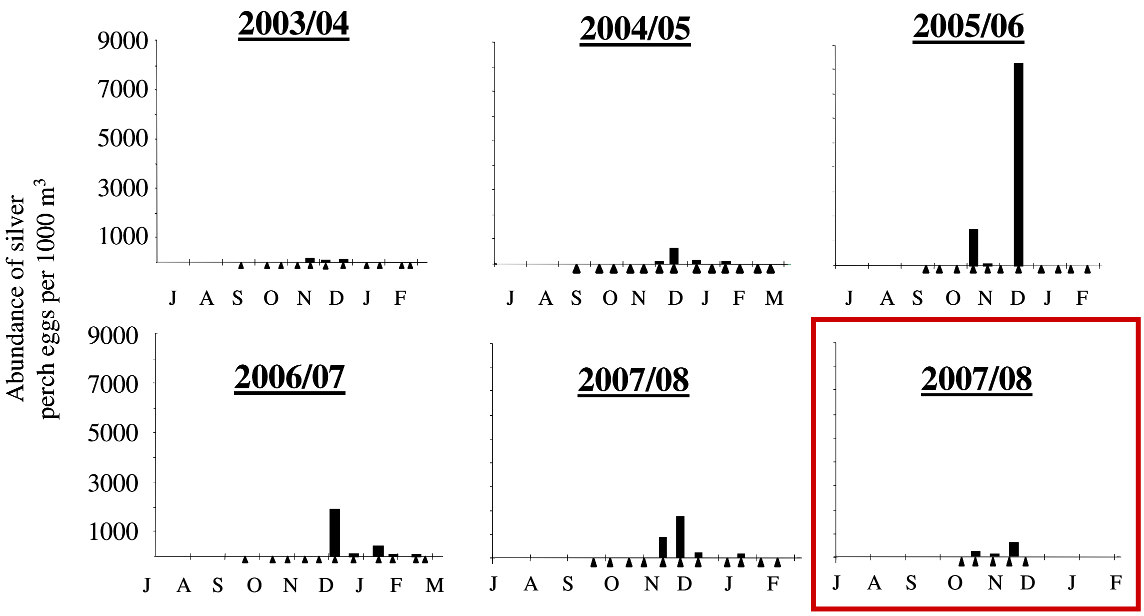

Figure 22. Drifting densities of silver perch eggs collecting during fortnightly drift sampling (black triangles) across all sites in the Murray River in Barmah-Millewa. Figure from King *et al.* (2008a) with data collected in 2008/09 included (red box).

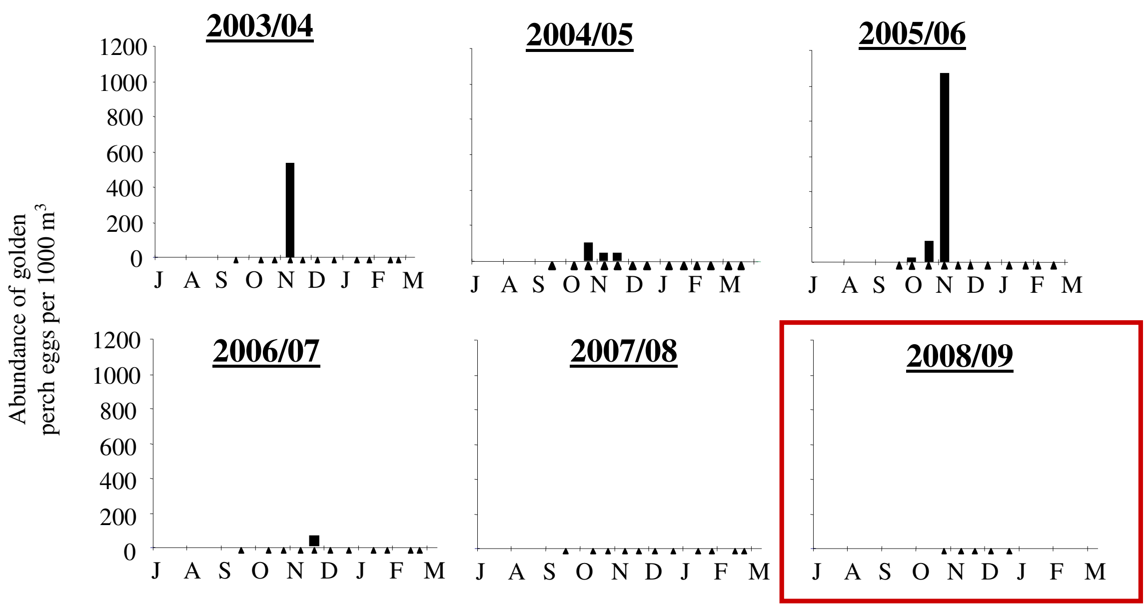

Figure 23. Drifting densities of golden perch eggs collecting during fortnightly drift sampling (black triangles) across all sites in the Murray River in Barmah-Millewa. Figure from King *et al.* (2008a) with data collected in 2008/09 included (red box).

Of the three exotic species collected in the drift samples in 2008/09, carp were by far the most abundant, and indeed, of most relevance to the B-M-F region given the area has been identified as one of the primary recruitment sources of this introduced pest fish in the mid-Murray River (Macdonald and Crook 2007). Peak densities of drifting carp larvae were approximately 775 larvae 1000m^{-3} recorded at Morning Glory during the first trip of the study although this figure is likely to be an overestimate due to flow meters under-representing the volumes of water filtered in the unusually low flow velocities at the site in trip one. Nevertheless, this value is still far below peak densities of carp larvae recorded at the site in high flow years (over 3000 larvae 1000m^{-3}; King *et al.* unpublished data) indicating carp spawning is likely to be highest in the region during years experiencing high spring/summer flows. Of course moderate levels of carp recruitment can still occur during in channel flow events which inundate vegetated benches during these times (see Tonkin and Rourke 2008). Indeed, the increased numbers of YOY carp collected in 2007/08 and in 2008/09 is evidence of such events. The results of this study and that of King *et al.* (2008a) indicate drifting densities of carp in the Murray River are consistently highest at sites immediately downstream of the B-MF (e.g. Morning Glory) further strengthening the regions importance as a spawning and nursery zone for carp (Macdonald and Crook 2007; Stuart and Jones 2006).

5 Summary and conclusions

- The B-MF contains a diverse fish fauna including iconic, threatened and endangered species, as well as those of recreational fishing importance.
- The region provides an important rearing habitat for larval and juvenile fish for a range of species including Murray cod, trout cod, Murray River rainbowfish and carp.
- Healthy populations of Murray River rainbowfish persist in the region, predominantly in the Edward River 5km downstream of the offtake regulator.
- Higher Murray cod abundance was associated with the upstream Murray River sites, perhaps due to increased flow velocities and habitat complexity.
- Both Murray cod and trout cod had much higher recruitment in 2007/08 than 2006/07 and 2008/09, perhaps due to improved nursery habitats or food supply resulting from the inundation of vegetation regrowth along the river channel in this season.
- Murray crayfish are either not present or in very low numbers in both Edward River sites. Furthermore, the Murray River crayfish population in the region appears to be severely influenced by recreational fishers given the major change in sex ratio above the legal size limit. This is likely to be influencing breeding in the species given a large proportion of mature female crayfish have not spawned, or delayed spawning perhaps due to a lack of mature males in the population.
- An increase in fish abundance in the permanent creek and wetland habitats since the start of the program, highlighting their importance as a refuge area as well as colonisation source for other sites which are currently dry.
- Southern pygmy perch have not been recorded in the forest for two years which is of concern given the species is short lived and appear to be reliant on floodplain connectivity for spawning and dispersal. The absence of fish in the Gulf Creek sampling is of particular concern given it was a potential source population for future re-colonisation of the area.
- Despite low flows, there was successful carp recruitment in two of the three years, which is related to inundation of vegetated benches within river channels that provide ideal spawning habitat.
- Continued spawning of several native fish species such as Murray cod despite low flows, whilst spawning appeared to be severely limited in the low flow years for species such as golden perch.

This monitoring program has been undertaken throughout three of the driest years on record, and therefore these patterns may only be a reflection of the fish community under such a prolonged drought. It is therefore important that this project is continued on a long-term basis because it is providing important data into the status and spatial and temporal variability of the fish community utilising the B–MF icon site. Indeed, the program is in a unique position to monitor the response of the fish community when flows return. Information such as threatened species distributions and important sites can ultimately be used by managers to maintain such environmental as well as social values (e.g. enhancing recreational fish populations) of the icon sites as well as further our currently limited knowledge of the relationships between the hydrological pattern and fish spawning and recruitment. This will ultimately lead to more informed management decisions relating to the use of environmental flows and other management interventions affecting fish.

6 References

Anon (2008) NSW State Flood Sub Plan 2008: a Sub Plan of the NSW Disaster Pplan (DISPLAN). State Emergency Service NSW.

Cook, B.D., Bunn S.E., Hughes, J.M. (2007) Molecular genetic and stable isotope signatures reveal complementary patterns of population connectivity in the regionally vulnerable southern pygmy perch (*Nannoperca australis*). Biological Conservation 138, 60-72.

Gilligan, D.M., Rolls, R., Merrick, J., Lintermans, M., Duncan, P. and Koehn, J. (2007) Scoping the knowledge requirements for Murray crayfish (*Euastacus armatus*). NSW Department of Primary Industries - Fisheries Final Report Series No. 89.

Hammer, M. (2001) Molecular systematics and conservation biology of the southern pygmy perch *Nannoperca australis* (Günther, 1861) (Teleostei: Percichthyidae) in south-eastern Australia, honours thesis, Adelaide University 57 pages.

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

Humphries, P., Serafini, L.G. and King, A.J. (2002) River regulation and fish larvae: variation through space and time. Freshwater Biology 47, 1307-1331.

King, A.J. (2005) Fish and the Barmah-Millewa Forest: history, status and management challenges. Proceedings of the Royal Society of Victoria, 117, 117-125.

King, A.J., Tonkin, Z., and Mahoney, J. (2007) Assessing the effectiveness of environmental flows on fish recruitment in Barmah-Millewa Forest. Prepared by Arthur Rylah Institute for Environmental Research, DSE. MDBC Project No. BMF 2004.09.

King, A.J., Tonkin, Z., and Mahoney, J. (2008a) Assessing the effectiveness of environmental flows on fish recruitment in Barmah-Millewa Forest – 2007/08 Progress report. Report to Murray-Darling Basin Commission. Freshwater Ecology, Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment.

King, A.J., Tonkin, Z. and Mahoney, J. (2008b) Environmental flow enhances native fish spawning and recruitment in the Murray River. River Research and Applications DOI: 10.1002/rra.1209.

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

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

Lintermans, M., Raadik, T., Morgan, D. and Jackson, P. (2007) Overview of thee ecology and impact of three alien fish species: Redfin perch, Mozambique mouthbrooder (Tilapia) and oriental weatherloach Emerging issues in alien fish management in the Murray-Darling Basin: Statement, recommendations and supporting papers. Proceedings of a workshop held in Brisbane QLD, 30-31 May 2006. Murray-Darling Basin Commission, Canberra.

Lyon, J., Nicol, S., Kearns, J. and O'Mahony, J. (2008) Monitoring of resnagging between Lake Hume and Yarrawonga - Milestone Report to MDBA TLM Program - December 2008. Unpublished report prepared for the Murray-Darling Basin Commission. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment.

Macdonald, J.I. and Crook, D.A. (2007) A quantitative measure of carp recruitment in the mid-Murray River: continuation of monitoring program 2006/07. Final report to Murray-Darling Basin Commission. Arthur Rylah Institute for Environmental Research, Heidelberg, Victoria.

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

Mallen-Cooper, M. and Brand, D. A. (2007). Non-salmonids in a salmonid fishway: what do 50 years of data tell us about past and future fish passage? Fisheries Management and Ecology. Doi: 10.1111/j.1365-2400.2007.00557.x

McKinnon, L. J. (1997) Monitoring of fish aspects of the flooding of Barmah Forest. Marine and Freshwater Research Institute, Queenscliff, Australia.

Rowland, S.J. (1998) Aspects of the reproductive biology of Murray cod, Maccullochella *peelii peelii*. Proceedings of the Linnean Society of New South Wales 120: 147–162.

Serafini, L. and Humphries, P. (2004) Preliminary guide to the identification of larvae of fish, with a bibliography of their studies, from the Murray-Darling Basin. Identification and Ecology Guide No. 48. Cooperative Research Centre for Freshwater Ecology, Albury, Australia.

Stuart, I.G. and Jones, M. (2006) Large, regulated forest floodplain is an ideal recruitment zone for non-native common carp (*Cyprinus carpio* L.). Marine and Freshwater Research, 57, 333-347.

Stuart, I., Mallen-Cooper, M. and Nicol, S. (2007). Recovery of fish populations 16 years after Torrumbarry fishway. Native Fish Strategy Forum, Mildura.

Tonkin, Z. and Baumgartner, L. (2007) Barmah-Millewa icon site fish monitoring protocol - 2007 annual data summary. Unpublished report to Murray-Darling Basin Commission. Freshwater Ecology, Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment.

Tonkin, Z. and Rourke, M. (2008) Barmah-Millewa Fish Condition Monitoring - 2008 Annual Summary and Refuge Habitat Report. Unpublished report submitted to the Murray-Darling Basin Authority. Arthur Rylah Institute for Environmental Research (Dept Sustainability and Environment) and NSW Dept Primary Industries.

Tonkin Z, King A.J. and Mahoney, J. (2008) Effects of flooding on recruitment and dispersal of the southern pygmy perch (*Nannoperca australis*) at a Murray River floodplain wetland. Ecological Management and Restoration 9, 196-201.

Tonkin, Z., Lyon, J. and Hackett, G. (2009) Native fish spawning in the Lake Hume – Yarrawonga restoration reach of the Murray River: 2009 milestone report. Arthur Rylah Institute for Environmental Research. Department of Sustainability and Environment, Heidelberg, Victoria. Unpublished milestone report submitted to the Murray-Darling Basin Authority.

Ye, Q., Jones, K. and Pierce, B.E. (2000) Murray cod (*Maccullochella peelii peelii*), fishery assessment report to PIRSA for Inland Waters Fishery Management Committee, South Australian Fisheries Assessment Series 2000/17. SARDI, Adelaide, Australia.

7 Appendix 1. Raw catch data for individual sites in each year of the monitoring program

	Species	2007	2008	2009	TOTAL
Aratula Creek	Australian smelt	13			13
	carp		6	2	8
	eastern gambusia	86	5		91
	flat-headed gudgeon	7			7
	goldfish	1	3	4	8
	oriental weatherloach		11		11
	carp gudgeon spp	269	410	120	799
	TOTAL	377	437	129	
Barmah Lake	Australian smelt	11		51	62
	carp	6	18	21	45
	eastern gambusia			2	2
	goldfish	17	12	22	51
	Murray River rainbowfish			2	2
	un-specked hardyhead			11	11
	TOTAL	34	30	109	173
Budgee Creek	Australian smelt	44	13	46	103
	carp	24	28	12	64
	eastern gambusia	1	2	38	41
	golden perch	1			1
	goldfish		24	9	33
	Murray cod		1		1
	Murray River rainbowfish		1	2	3
	un-specked hardyhead			11	11
	carp gudgeon spp	5	6	59	70
	TOTAL	75	75	177	327
Edward River 5km d/s regulator	Australian smelt	18	9	7	34
	carp	8	14	22	44
	eastern gambusia			15	15
	flat-headed gudgeon			1	1
	golden perch	1	3	1	5
	goldfish	9	3	7	19
	Murray cod	9		4	13
	Murray River rainbowfish	67	7	248	322
	trout cod	8			8
	un-specked hardyhead	82	219	366	667
	carp gudgeon spp	12	23	265	300
	TOTAL	214	278	936	1428
Edward River d/s Gulpa Creek	Australian smelt	20	7	11	38
	carp	8	14	16	38
	eastern gambusia			5	5
	golden perch	4		5	9
	goldfish	11	2	4	17
	Murray cod	1	1	8	10
	Murray River rainbowfish	1	2	28	31
	silver perch		2		2
	trout cod			3	3
	un-specked hardyhead	13	7	4	24
	carp gudgeon spp	1	2	26	29
	TOTAL	59	37	112	208

	Species	2007	2008	2009	TOTAL
Fishermans Bend Lagoon	Australian smelt	26			26
	carp	13			13
	eastern gambusia	30	14	40	84
	flat-headed gudgeon	19	9	7	35
	oriental weatherloach			1	1
	redfin perch	31			31
	southern pygmy perch	1			1
	un-specked hardyhead	21	1		22
	carp gudgeon spp	74	346	1284	1704
	TOTAL	215	370	1332	1917
Flat Swamp	Australian smelt	2	ns	ns	2
	carp	9			9
	dwarf flat-headed gudgeon	2			2
	eastern gambusia	31			31
	goldfish	15			15
	oriental weatherloach	46			46
	redfin perch	5			5
	southern pygmy perch	4			4
	carp gudgeon spp	389			389
	TOTAL	503			503
Gulf Creek @ four mile	Australian smelt	ns	2	8	10
	carp		10	80	90
	eastern gambusia		2	423	425
	goldfish		3	43	46
	oriental weatherloach		9	30	39
	redfin perch		1		1
	southern pygmy perch		7		7
	un-specked hardyhead			1	1
	carp gudgeon spp		40	259	299
	TOTAL		74	844	918
Gulpa Creek	Australian smelt	2	12	35	49
	carp	6	5	1	12
	golden perch		1		1
	goldfish	0	2	10	12
	Murray cod	1	1	1	3
	Murray River rainbowfish	1		4	5
	un-specked hardyhead	2			2
	carp gudgeon spp		1	11	12
	TOTAL	12	22	62	96
Moira Lake	Australian smelt	9	ns	ns	9
	carp	14			14
	goldfish	6			6
	silver perch	0			0
	carp gudgeon spp	25			25
	TOTAL	54			54

	Species	2007	2008	2009	TOTAL
Murray River @ Barmah/Moira Lake	Australian smelt	28	50	27	105
	carp	42	22	20	84
	eastern gambusia		3		3
	golden perch	4		3	7
	Murray cod	1	4	1	6
	Murray Crayfish	1	4		5
	Murray River rainbowfish		3		3
	silver perch	0	4	1	5
	trout cod	4	6	5	15
	un-specked hardyhead	1	8		9
	carp gudgeon spp		17		17
	TOTAL	81	121	57	259
Murray River @ Gulf Creek	Australian smelt	21	66	ns	87
	carp	23	52		75
	golden perch	2	12		14
	goldfish		9		9
	Murray cod	7	14		21
	Murray Crayfish	1	1		2
	Murray River rainbowfish		18		18
	silver perch		10		10
	trout cod		4		4
	un-specked hardyhead	78	55		133
	carp gudgeon spp	2	1		3
	TOTAL	134	242		376
Murray River @ Ladgroves Beach	Australian smelt	205	33	40	278
	carp	23	28	15	66
	golden perch	3		1	4
	goldfish		2		2
	Murray cod	6	24	4	34
	Murray Crayfish	1	4		5
	Murray River rainbowfish				
	silver perch		1		1
	trout cod	1	13	6	20
	un-specked hardyhead	33	114	97	244
	carp gudgeon spp	7			7
	TOTAL	279	219	163	661
Murray River @ Morning Glory	Australian smelt	21	46	5	72
	carp	21	20	9	50
	eastern gambusia		1		1
	golden perch		3	3	6
	goldfish		11	21	32
	Murray cod	1	7	2	10
	Murray Crayfish	3	10	39	52
	Murray River rainbowfish		3		3
	oriental weatherloach				
	redfin perch	1			1
	silver perch	1	2	2	5
	trout cod		3	1	4
	un-specked hardyhead		9	12	21
	carp gudgeon spp	3	4		7
	TOTAL	51	119	94	264

	Species	2007	2008	2009	TOTAL
Murray River @ Picnic Point	Australian smelt	38	57	60	155
	carp	14	15	18	47
	golden perch	2		1	3
	goldfish			7	7
	Murray cod		5	2	7
	Murray Crayfish	1		1	2
	Murray River rainbowfish		3	4	7
	silver perch		1		1
	trout cod	3	8	2	13
	un-specked hardyhead	4	45	6	55
	carp gudgeon spp	1	26	36	63
	TOTAL	63	161	137	361
Murray River @ Woodcutters	Australian smelt	36	84	8	128
	carp	10	25	9	44
	golden perch	2			2
	goldfish		5	1	6
	Murray cod		21	3	24
	Murray Crayfish	1	9	7	17
	Murray River rainbowfish		1	1	2
	silver perch	2	2		4
	trout cod		9	1	10
	un-specked hardyhead	11	83	26	120
	carp gudgeon spp	2		34	36
	TOTAL	64	239	90	393
Pinch Gut Lagoon	eastern gambusia	76	ns		76
	southern pygmy perch	1			1
	carp gudgeon spp	241		2	243
	TOTAL	318		2	320
Tongalong Creek	Australian smelt	48	7	51	106
	carp	8	28	2	38
	eastern gambusia		1	36	37
	golden perch	1	1		2
	goldfish	5	42	2	49
	Murray cod		1	3	4
	Murray River rainbowfish			2	2
	silver perch			1	1
	un-specked hardyhead	11	1	39	51
	carp gudgeon spp	2	1		3
	TOTAL	75	82	136	293

*Ns = not sampled

	Species	2007	2008	2009	TOTAL
Toupna Creek	carp	1		ns	1
	eastern gambusia	34	79		113
	flat-headed gudgeon	20			20
	goldfish	6	1		7
	Murray River rainbowfish	1			1
	oriental weatherloach	7	3		10
	southern pygmy perch	31			31
	carp gudgeon spp	434	19		453
	TOTAL	534	102		636
Tullah Creek	Australian smelt	4	ns	ns	4
	carp	23			23
	eastern gambusia	49			49
	flat-headed gudgeon	5			5
	goldfish	54			54
	oriental weatherloach	20			20
	carp gudgeon spp	127			127
	TOTAL	282			282

*Ns = not sampled