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Barmah-Millewa Fish Condition Monitoring:
2010/2011 Annual Report

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Barmah-Millewa Fish Condition Monitoring: 2011 Annual Data Summary

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Front cover photo: Background: Murray River at Barmah (Photo: Scott Raymond).

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Acknowledgments

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Summary

The Barmah-Millewa Forest (B-MF) is a wetland complex 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 2006/07 as part of The Living Murray (TLM) assessment program. This program has been designed to monitor the health and status of the fish community across 21 fish sampling sites distributed across river, creek, lake and wetland habitats. A larval drift component was incorporated into the project from 2008/09 onwards to assess fish spawning. This report gives a summary of the results of the fifth year of sampling in relation to all previous years.

After five years of drought, 2010/11 was characterised by widespread and protracted flooding of the Murray River and B-MF with peak flows in excess of 100,000 ML/Day. The flooding subsequently triggered a significant hypoxic blackwater event in the Murray River from mid-November to mid-March that affected Barmah Lake and the Murray River downstream of Barmah Lake to at least Echuca (King *et al*. 2011). The current project will allow an assessment of the changes in the fish community as a result of flooding and the ability of the fish community to respond to the end of the recent drought.

A total of 9,644 fish from nine native and four alien species were collected this year (caught and observed) within four habitat types (rivers, creeks, lakes and wetlands). Fish community composition across all years was significantly different between habitat types, with the exception of creeks and lakes where the fish community was very similar, indicating that some habitat types contain unique compositions of fish. Pairwise comparisons of river sites indicated significant differences across years, particularly in comparisons involving 2006/07 and 2010/11 data. These were largely due to fluctuations in abundance of Murray-Darling Rainbowfish, Un-specked Hardyhead and Goldfish. In contrast, there was no evidence that the fish community in creek, wetland and lake sites had varied across years, suggesting a relatively stable fish assemblage in these habitat types for the last five years.

While all of the large-bodied native fish species (Murray Cod, Trout Cod, Golden Perch and Silver Perch) were collected within the B-MF this year, Young-Of-Year (YOY) fish were either absent or in very low numbers. The total number of YOY Murray Cod collected declined from 31 to three individuals from 2009/10 to 2010/11 while a single YOY Trout Cod was captured in both sample years. No YOY Golden or Silver Perch were caught in 2010/11, similar to 2009/10 data where a single YOY Golden Perch was recorded. Reduced electrofishing efficiency due to higher

water levels in river sites may account, in part, for the decreased detection rates of native fish species within the B-MF in 2010/11.

The abundance of YOY Common Carp increased from 307 individuals in 2009/10 to 517 individuals in 2010/11, providing further evidence that B-MF is an important nursery site for this species. The higher water levels throughout the B-MF following recent floods favour Common Carp over many native fish species because floodplain inundation is a major spawning cue for this species. The greater tolerance of Common Carp to hypoxic conditions compared with native fish, their ability to re-colonise habitat faster than natives and the negative impact on spawning, recruitment, re-colonisation and survival of native fish species has placed Common Carp at an advantage over native fish species when blackwater is present and/or following a blackwater event.

The abundance of Murray Crayfish declined by an order of magnitude over the past three years with only five individuals captured in 2010/11. While the number of sites from which Murray Crayfish were captured has declined, two females were in berry in 2010/11 while no berried females were captured during the 2009/10 survey. The lack of Murray Crayfish from Morning Glory is a concern as they have been found in comparatively good numbers over the previous four years of sampling. Murray Crayfish have not been recorded from the Edwards River since the current monitoring program was initiated five years ago, suggesting they are absent or in low numbers in this reach of the river. The recent blackwater event may have impacted the Murray Crayfish population.

Murray Cod, Golden Perch, Carp Gudgeons, Flat-headed Gudgeons, Australian Smelt, Common Carp and Goldfish were all recorded spawning in the Murray River sites in spring/summer 2010/11 (as demonstrated by the presence of eggs and/or larvae). In contrast with 2009/10, no Trout Cod or Silver Perch drifting larvae and/or eggs were captured from the Murray River sites during the 2010/11 sampling program, however, Silver Perch eggs were recorded from Ladgroves Beach in February 2011 (King *et al.* 2011). Spawning levels of Murray Cod were comparable with the last two years; however, larvae were only captured from Ladgroves Beach in 2010/11. This finding is consistent with the majority of Golden Perch eggs and Carp Gudgeon larvae, indicating that the ‘blackwater event’ may have had a significant negative impact on spawning or larval survival for a number of native fish species. Australian Smelt and Goldfish larvae and/or eggs were found in equal numbers in all three Murray River sites while Common Carp larvae were only recorded from Morning Glory suggesting that alien fish species may have a competitive advantage over many small and large-bodied native fish species during and following blackwater events.

The fifth year of sampling has provided additional evidence of the importance of the B-MF to native and alien fish species and has highlighted that large-scale flooding and/or increased flows do not always result in a short-term benefit to native fish species. It is likely that the blackwater conditions that arose during the floods had a negative impact on the native fish community within the B-MF. The paucity of information on the effect of hypoxia on the physiology and behaviour of native and alien fish species has highlighted the need for future research. Parameters to be investigated may include assessments of: survivorship, reproduction, movement (away from hypoxic conditions and/or predator evasion), growth and development under a range of increasingly hypoxic conditions.

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.mdba.gov.au/programs/tlm). 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, which have probably resulted in temporal and spatial variability of its flora and fauna. Therefore, the development of long-term monitoring programs is essential for reliable interpretation and management of the Basins' ecosystems.

The Barmah-Millewa Forest (now the 'Barmah and Murray Valley National Parks' [as of April, 2010]) is a 66,000 ha wetland complex on the mid-Murray River, up-stream of Echuca. For simplicity, the Forest will be referred to as the Barmah-Millewa Forest (B-MF) throughout this report. The system contains a range of aquatic habitats including rivers, permanent and ephemeral creeks, wetlands, swamps and the floodplain proper; historically these habitats contained an abundant and diverse range of native fish (King 2005). Until the 1930s, the area also supported the largest inland commercial fishery in Australia. However, since the regulation of the Murray River by dams and weirs, native fish have been substantially reduced in both abundance and diversity, and alien 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 Authority's (MDBA) 'Living Murray Initiative'.

In 2006/7, 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 (including lakes) (Tonkin and Baumgartner 2007). The investigation of fish communities and ecotypes is an ongoing component of the fish condition monitoring program within the B-MF. The overall objectives of the monitoring program are to:

- Monitor the health and status of the B-MF 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.
- Provide information which can feed back into management plans and reporting on condition for the icon site.

In 2008/09, a spawning component was introduced to the project in order to continue a monitoring regime that has been underway in the region since 2003 (King *et al*. 2009). These data will enable the detection of potential links between river flows and the abundance of drifting eggs and larvae.

Specifically, the spawning component of the monitoring program aims to:

- Document the presence of spawning of riverine fish species which have drifting egg and/or larval stages (Murray Cod, *Maccullochella peelii*, Trout Cod, *Maccullochella macquariensis*, Silver Perch, *Bidyanus bidyanus*, Golden Perch, *Macquaria ambigua ambigua*, and introduced Common Carp, *Cyprinus carpio*) in the Murray River within the B-MF.

- Continue the long-term data set of sampling for riverine fish eggs and larvae in the region, which has been underway since 2003. This will enable greater confidence in explaining responses to environmental variables, such as flow (environmental watering).

After five years of drought, the B-MF floodplain was substantially inundated in July 2010, and multiple flood peaks exceeding 11,000 ML/d (approximate flow required for commencement of floodplain inundation) were recorded up until June 2011, peaking at 107,572 ML/d on the 12th of December 2010 (Figure 1). The flooding triggered a significant hypoxic blackwater event in the Murray River, from mid-November to mid-March, affecting Barmah Lake and the Murray River downstream of Barmah Lake to at least Echuca (King *et al.* 2011). This was not an isolated event as hypoxic blackwater also affected many rivers and creeks in the southern Murray-Darling Basin, including the Edward-Wakool River system (Lugg 2011), the Lower Murrumbidgee River, Billabong Creek, Broken Creek, Goulburn River, Loddon River Avoca River and the Lower Darling River (King *et al.* 2011).

The Murray River was affected by hypoxic blackwater from Barmah all the way to South Australia. Stressed fish and fish kills were reported in many areas including the Wakool River, Gulpa Creek, Edward River, Billabong Creek and Little Merran Creek (Lugg 2011). In addition, there were reports of Murray Crayfish escaping the hypoxic blackwater in the Murray River downstream of Barmah by climbing up onto the banks, placing them at increased risk of poaching and predation. It is unclear if the B-MF lakes, creeks and/or wetlands were impacted by blackwater and if so, how these blackwater events impacted local fish communities. This year marks the fifth year of sampling and is the first time since the commencement of the project that sampling has occurred following substantial floodplain inundation. In addition, some of the sampling sites were also affected by a hypoxic blackwater event that has been implicated in major fish kills (King *et al*. 2011). This report summarises the results of data collection for the fifth year of fish condition monitoring, which incorporates sampling for Murray Crayfish and spawning success of four primarily riverine large-bodied fish species.

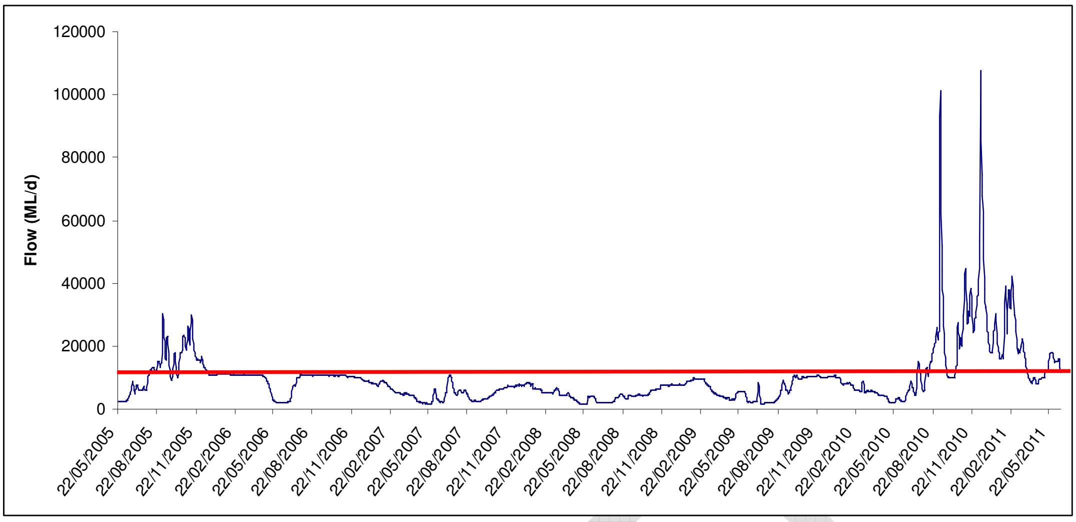


Figure 1. Flows downstream of Yarrawonga Weir from 2005 to 2011. The red line indicates the approximate flow B-M floodplain begins to be inundated.

2 Methods

To assess the current condition of fish communities within the B-MF, 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 Sampling

In previous years of the study, the creek, lake and wetland sites were sampled in February when water levels were still high enough to allow effective sampling, and the river sites (Murray and Edward Rivers) were sampled in May after water levels were reduced to winter base flows, and to ensure that water temperatures were low enough to successfully sample Murray Crayfish. However, flooding in 2010/11 meant that B-MF was inaccessible in February, and therefore, river, creek, lake and wetland sampling took place from April to June. The larval drift component of the B-MF fish condition monitoring program was conducted from 18th October to 15th December 2010 as this is the known spawning season for many of our native fish species.

River sampling

Previous sampling undertaken within the icon site 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 (Figure 2, Table 1). At each River 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), while 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 bait-traps (minimum 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 for total length (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 3). All crayfish collected were measured for occipital carapace length (OCL) and their sex determined where possible. Females were also assessed for maturation (setae surrounding the gonopores) and for the presence of eggs (berries) on the ventral side of the tail (Figure 4).

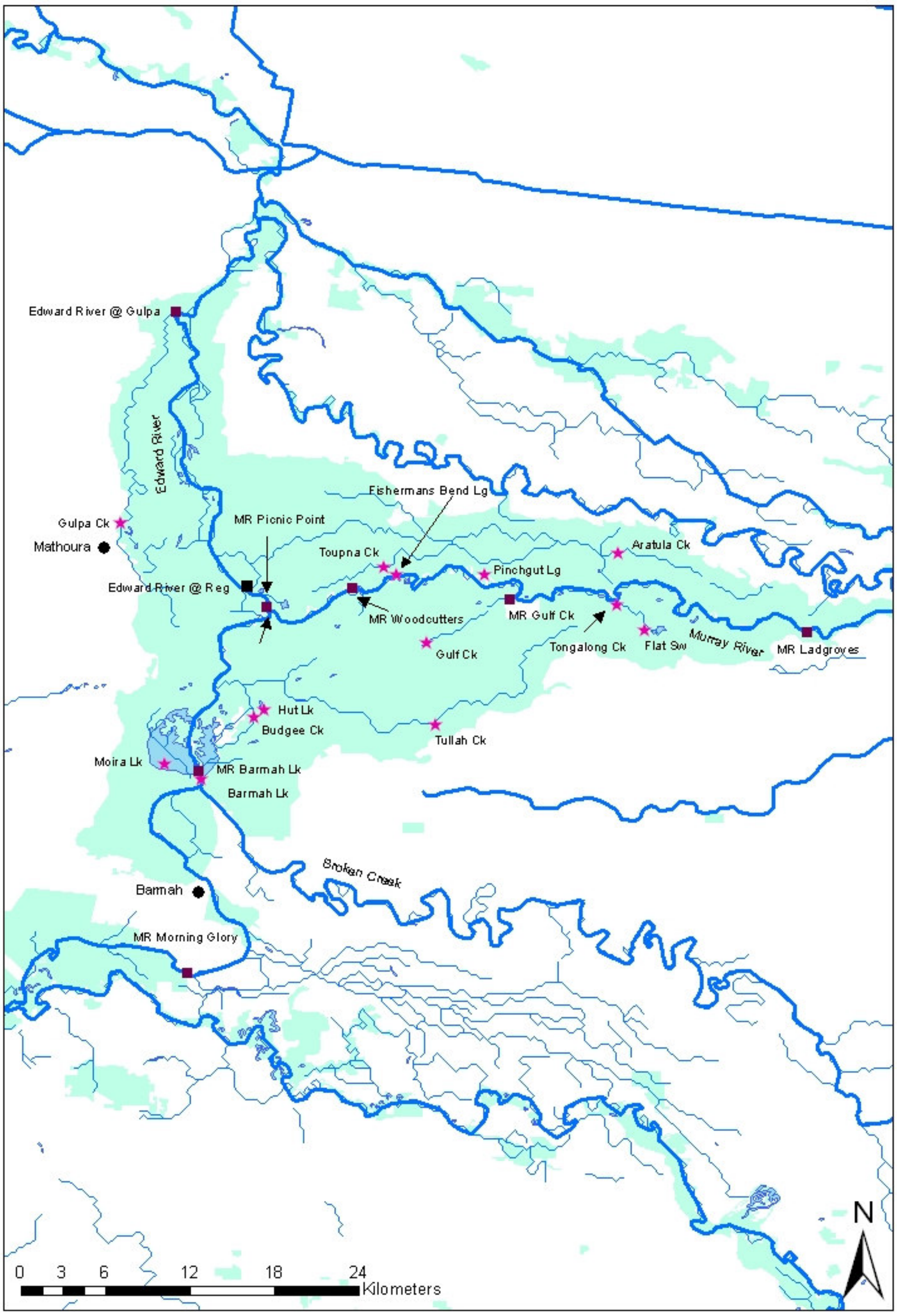


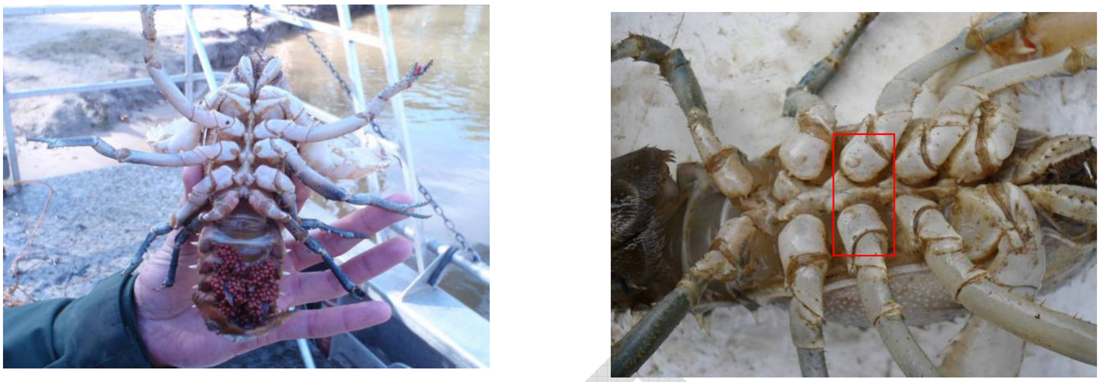
Figure 2. Barmah-Millewa Forest (green shading) illustrating locations of river (squares) and creek and wetland (stars) fish monitoring sites

Table 1. River sites in the B-MF indicating sites successfully sampled in each year of the study

Site	2006/07	2007/08	2008/09	2009/10	2010/11
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 successfully sampled
†Site inaccessible

Figure 3. Munyana crab trap used for sampling Murray Crayfish



(a) (b)

Figure 4. Mature female Murray Crayfish in berry (a) and immature female Murray Crayfish as indicated by lack of setae surrounding gonopores.

Creek, lake and wetland sampling

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). Twelve off-channel sites were selected for inclusion in annual sampling to represent the fish community of the B-MF. Sampling was fixed at six creek and six wetland/lake sites within the B-MF. 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 Gulf Creek was included in 2009 after surveys in 2008 revealed it to be an important refuge area for a large number of species (see Tonkin and Rourke 2008).

Sites within the BM-F experience a range of flow or water regimes over any given year, and this can greatly affect accessibility and the area available to be sampled. Therefore, where necessary, sampling effort was slightly reduced from SRA standards, to ensure all sites could be completed in most years. Sampling involved 10-12 replicates of 90 second boat electrofishing shots at each site (with a 5 shot minimum during low water conditions). If the minimum of five boat shots could not be completed due to reduced wetland area or depth, 8 replicates of 150 seconds with a backpack electrofishing unit were undertaken at each site. In addition, 10 unbaited bait-traps 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. Young-of-year (YOY) fish were classified based on their total length (Murray Cod and Trout Cod <150 mm, Golden Perch <100 mm, Silver Perch <100 mm and Common Carp <150 mm; King *et al*. 2008).

Table 2. Creek and wetland fish sites in the B-MF indicating sites successfully sampled in each year of the study

Site	Forest	2006/07	2007/08	2008/09	2009/10	2010/11
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
Site was inaccessible
† An additional search comprising of 1,500 electrofishing seconds was conducted in an attempt to locate southern pygmy perch. None were found.

2.2 Data analysis: River, Creek, Lake and Wetland Sites

Over the course of this study, several sites were not sampled because they were dry or inaccessible. However, the analyses presented in this report consider habitat types (river, creek, lake and wetland) as the unit of interest. Therefore, individual sites are considered replicate samples for each habitat type in each year, and missing sites were not excluded from the analyses. It is only necessary to have a complete data set when making comparisons of the fish community from individual sites. However, this type of analysis is not particularly meaningful in this study given that river sites are interconnected, allowing fish to move freely among sites, while creek, lake and wetland sites are periodically connected via flooding. Consequently, refuge sites within the BM-F will vary from year to year, depending on the availability of water. Thus, there is greater value in identifying the habitat type that is critical for sustaining individual species, rather than the individual study site.

Data analysis was conducted using PRIMER (Version 6.1.11) statistical software (Clarke and Gorley 2006) and SPSS (Version 11.0.1). Raw abundance data collected from all years (2007 to 2011) of the study were standardised by electrofishing time (catch per minute) and fourth root transformed. To determine if there were significant differences in fish community structure among the four habitat categories across all years, fish abundance data was converted to Brays-Curtis similarity values and one-way-factor Analysis of Similarity (ANOSIM) with pairwise comparisons conducted using habitat type (river, creek, lake or wetland) as a factor. A Principle Component Analysis (PCA) using a vector correlation value of 0.22 was conducted to visualise fish community data from all habitat types (river, creek, lake and wetland) in two dimensions, and to identify the main species contributing to these differences. A one-way ANOSIM with pairwise comparisons was also performed on each habitat type with year as a factor to determine if there were significant differences in the species composition in each habitat type over the course of the study. Finally, two-sample Kolmogorov-Smirnov tests were performed on the length frequency distributions of Common Carp (from all sites) among all years (2006/07-2010/11) to determine if there were significant differences in the size classes that dominated in each year. Given that this test requires multiple comparisons, the Dunn-Šidák method was used to adjust the error rate to reduce the probability of type I errors (Sokal and Rohlf 1995).

2.3 Riverine larval drift sampling

Sampling for drifting eggs and larvae targeted four large bodied native species: Murray Cod, Trout Cod, Silver Perch and Golden Perch as well as Common Carp, all of which are known to demonstrate drifting behaviours during egg and/or larval life stages. Sampling was conducted fortnightly, from the 18th October to the 15th December 2010. This period encompassed the known core drifting periods for these species (Humphries 2005; Koehn and Harrington 2006; King *et al.* 2007). Drifting fish eggs and larvae were collected from three sites on the Murray River: Morning Glory, Barmah Choke and Ladgroves Beach, which are located downstream, mid and upstream of the Barmah-Millewa floodplain respectively (see Figure 2 for site locations).

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 5). 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 and/or larvae 1000 m^{-3} of water filtered. At each site, three nets were deployed just below the surface, across the river channel to account for spatial variability in drifting densities. All nets were set on dusk and retrieved as early as possible the following morning, generally before 10am. 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.

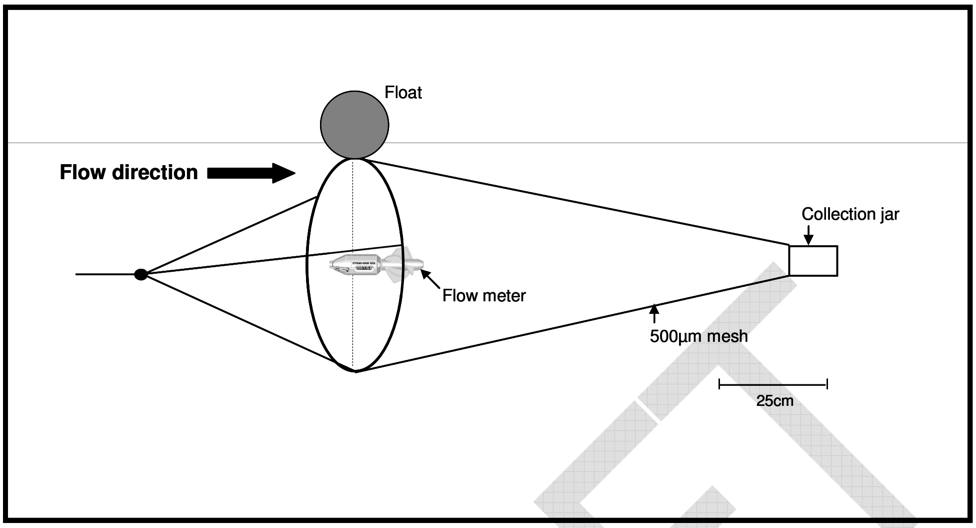


Figure 5. Side view diagram of the standard passive drift net used in the study.

3 Results

3.1 Hydrology and total catch

The current sampling year was typified by prolonged and extensive flooding that began in July 2010 and extended through to June 2011, with only minimal periods where the floodplain was not receiving water (<11,000 ML/d) (Figure 6). Prior to 2010/11, the B-MF had not flooded since October to December 2005 when approximately 50% of the BM-F flooded (Figure 1). The flooding of 2010/11 was far more extensive, covering approximately 90% of the floodplain (King *et al.* 2011).

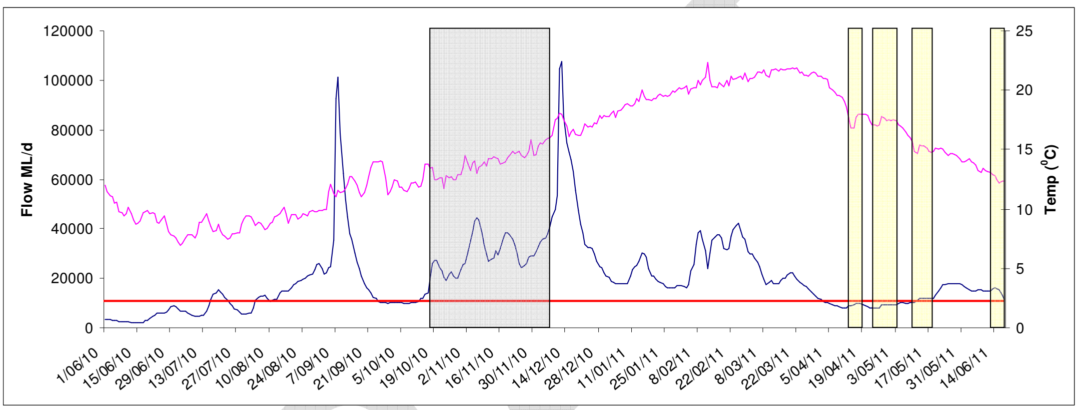


Figure 6. Mean daily discharge of the Murray River downstream of Yarrawonga Weir from June 2010 to June 2011. The red line indicates the approximate floodplain inundation height throughout the B-MF and the pink line indicates water temperature. The grey bar represents the time of egg and larval sampling while yellow bars indicate creek, wetland, lake and river sampling events.

Total catch

A total of 9,644 (caught and observed) fish were sampled in the B-MF in 2010/11, representing nine native and three alien species. This represents a reduction of 3,950 individuals and the loss of three species (including two native species) compared with 2009/10 findings despite three more sites being sampled this year compared with 2009/10. Bony Herring (*Nematalosa erebi*), Flat-headed Gudgeon (*Philypnodon grandiceps)* and the alien Redfin Perch (*Perca fluviatilis*) were not captured in 2010/11. The decrease in the Total Fish Count (TFC) from 2009/10 to 2010/11 was predominantly driven by a reduction (53%) in Australian Smelt (*Retropinna semoni)*, Murray-Darling Rainbowfish (*Melanotaenia fluviatilis)* (75%) and Carp Gudgeons (*Hypseleotris spp.*) (91%). Conversely, the abundance of alien fish species increased: Common Carp (78%), Eastern Gambusia (*Gambusia holbrooki)* (43%) and Goldfish (*Carassius auratus)* (54%).

A further 214 eggs and larvae from five native and two alien fish species were collected in drift net sampling over the core spawning period. Of the five large-bodied fish species (four native and Common Carp), Murray Cod dominated the abundance of larval fish (n=48) while Golden Perch dominated the abundance of fish eggs (n=30). No drifting Trout Cod or Silver Perch larvae and/or eggs were sampled over the 2010/11 core spawning period. However, Silver Perch eggs were sampled at Ladgroves Beach in February 2011 (King *et al*. 2011).

Total catch (2007-11)

One-way Analysis of Similarity (ANOSIM) indicated a significant difference in the fish community composition across all years and habitat types (rivers, creeks, lakes and wetlands) ($R = 0.57$, $P = <0.01$). Pairwise comparisons revealed that all habitat pairs were significantly differentiated ($P = <0.05$, with the exception of the creeks and lakes ($P = >0.05$) that had a similar fish assemblage. The Principal Component Analysis (PCA) presents fish abundance relationships among each habitat type. Principle Component (PC) one accounts for 41.6% of the variation in the data, while PC two accounts for 15.0% of the variation in the data, representing a total of 56.6% of the variation in the data. The PCA results support that of the ANOSIM in that rivers, wetlands and creeks do not overlap, while lakes and creeks overlap. The vectors on the PCA indicate which species contribute most to the structure of the fish community. Lake sites were characterised by Goldfish, Common Carp, Australian Smelt and Un-specked Hardyhead (*Craterocephalus stercusmuscarum fulvus*) while river sites were characterised by Un-specked Hardyhead, Murray River Rainbowfish, Australian Smelt, and Murray Cod. Creek sites were characterised by Murray River Rainbowfish, Carp Gudgeons and Eastern Gambusia while wetlands were characterised by Carp Gudgeons and Eastern Gambusia (Figure 7).

YOY Common Carp have been sampled in each year of the study, though they were in much greater abundance this year. Figure 8 presents the length - frequency distribution of Common Carp sampled from river, creek and lake sites (not enough were sampled from wetlands to be included in the analysis). YOY Common Carp are evident in three habitat types from 2008 onwards, while adult fish were only consistently sampled in the river sites each year, albeit in reduced abundances in 2009/10 and 2010/11. There is no clear pattern of YOY Common Carp progressing through to the next size class in subsequent years, indicating a lack of survival or migration away from the study area. Kolmogorov-Smirnov tests (with significance adjusted to $P = <0.067$ to account for multiple comparisons) confirmed that Common Carp length-frequency data was different with every pair of years examined, with the exception of 2008 and 2009 that had a similar length-frequency distribution ($P>0.067$).

Table 3. Total abundance (caught and observed) of fish collected from B-MF from 2007-2011 using all collection methods.

Common name	Scientific name	2006/07	2007/08	2008/09	2009/10	2010/11
Native						
Australian smelt	*Retropinna semoni*	947	1547	1790	4297	2,017
Bony herring	*Nematalosa erebi*				59	
Dwarf Flat-headed gudgeon	*Philypnodon macrostoma*	2				
Flat-headed gudgeon	*Philypnodon grandiceps*	50		9	36	
Golden Perch	*Macquaria ambigua*	26	22	25	20	36
Murray Cod	*Maccullochella peelii*	29	90	45	85	39
Murray Crayfish	*Euastacus armatus*	9	28	52	24	5
Murray-Darling Rainbowfish	*Melanotaenia fluviatilis*	210	89	935	607	149
Silver Perch	*Bidyanus bidyanus*	5	24	12	10	21
Southern pygmy perch	*Nannoperca australis*	39				
Trout Cod	*Maccullochella macquariensis*	16	47	25	34	2
Gudgeon	*Hypseleotris spp.*	2252	553	2142	1951	169
Unidentified cod	*Maccullochella sp.*		2	1		
Un-specked hardyhead	*Craterocephalus stercusmuscarum fulvus*	349	1944	1533	3505	65
total natives		**3,934**	**4,346**	**6,569**	**10,628**	**2,503**
Alien						
Common carp	*Cyprinus carpio*	349	624	392	632	2,885
Eastern gambusia	*Gambusia holbrooki*	464	284	617	1899	3,309
Goldfish	*Carassius auratus*	164	175	146	409	883
Oriental weatherloach	*Misgurnus anguillicaudatus*	214	26	61	24	64
Redfin perch	*Perca fluviatilis*	52			2	
total aliens		**1,243**	**1,109**	**1,216**	**2,966**	**7,141**
Total Fish Count		**5,177**	**5,455**	**7,785**	**13,594**	**9,644**

Table 4. Total abundances (caught and observed) of fish species collected in river sites from 2007 to 2011 using all collection methods.

Common name*	Species	2006/07	2007/08	2008/09	2009/10	2010/11
Native						
Australian Smelt	*Retropinna semoni*	615	1,350	1,455	4,254	1,015
Bony Herring	*Nematalosa erebi*				59	
Flat-headed Gudgeon	*Philypnodon grandiceps*			1		
Golden Perch	*Macquaria ambigua ambigua*	24	20	25	19	31
Murray Cod	*Maccullochella peelii*	28	87	41	82	28
Murray crayfish	*Euastacus armatus*	9	28	52	24	5
Murray-Darling Rainbowfish	*Melanotaenia fluviatilis*	208	88	925	577	37
Silver Perch	*Bidyanus bidyanus*	4	24	11	9	13
Trout Cod	*Maccullochella macquariensis*	16	47	25	34	2
Carp Gudgeon	*Hypseleotris spp.*	48	77	376	96	4
Unidentified *Maccullochella*	*Maccullochella sp.*		2	1		
Un-specked Hardyhead	*Craterocephalus stercusmuscarum fulvus*	245	1,943	1,451	3,498	0
Alien						
Common Carp	*Cyprinus carpio*	217	453	232	381	902
Common Carp - Goldfish hybrid	*Cyprinus carpio/Carassius auratus*		1			
Eastern Gambusia	*Gambusia holbrooki*		4	20	35	53
Goldfish	*Carassius auratus*	21	45	51	139	275
Oriental Weatherloach	*Misgurnus anguillicaudatus*		1	2		
Redfin Perch	*Perca fluviatilis*	1			2	
Total		**1,436**	**4,170**	**4,668**	**9,209**	**2,365**

* fish species characteristic of habitat type are bolded

Table 5. Total abundances (caught and observed) of fish species collected in creek sites from 2007 to 2011 using all collection methods.

Common name*	Species	2006/07	2007/08	2008/09	2009/10	2010/11
Australian Smelt	*Retropinna semoni*	194	197	233	40	584
Flat-headed gudgeon	*Philypnodon grandiceps*	29			17	
Golden Perch	*Macquaria ambigua ambigua*	2	2		1	5
Murray Cod	*Maccullochella peelii*	1	3	4	3	11
Murray-Darling rainbowfish	*Melanotaenia fluviatilis*	2	1	8	30	74
Silver Perch	*Bidyanus bidyanus*			1	1	8
Southern Pygmy Perch	*Nannoperca australis*	33				
Carp Gudgeon	*Hypseleotris spp*	1,064	476	480	1,399	69
Un-specked Hardyhead	*Craterocephalus stercusmuscarum fulvus*	13	1	71	5	53
Common Carp	*Cyprinus carpio*	75	110	116	144	1,616
Eastern Gambusia	*Gambusia holbrooki*	232	280	553	984	1,178
Goldfish	*Carassius auratus*	91	110	68	111	449
Oriental weatherloach	*Misgurnus anguillicaudatus*	57	25	58	24	46
Total		1,793	1,205	1,592	2,759	4,093

* fish species characteristic of habitat type are bolded

Table 6. Total abundances (caught and observed) of fish species collected in lake sites from 2007 to 2011 using all collection methods.

Common name*	Species	2006/07	2007/08	2008/09	2009/10	2010/11
Australian Smelt	*Retropinna semoni*	33		102	3	242
Murray-Darling Rainbowfish	*Melanotaenia fluviatilis*			2		6
Silver Perch	*Bidyanus bidyanus*	1				
Carp Gudgeon	*Hypseleotris spp*	25			9	5
Un-specked Hardyhead	*Craterocephalus stercusmuscarum fulvus*			11		5
Common Carp	*Cyprinus carpio*	36	60	44	105	335
Eastern Gambusia	*Gambusia holbrooki*			2	15	227
Goldfish	*Carassius auratus*	35	20	27	159	146
Oriental Weatherloach	*Misgurnus anguillicaudatus*	2				
Total		132	80	188	291	966

* fish species characteristic of habitat type are bolded

Table 7. Total abundances (caught and observed) of fish species collected in wetland sites from 2007 to 2011 using all collection methods.

Common name*	Species	2006/07	2007/08	2008/09	2009/10	2010/11
Australian Smelt	*Retropinna semoni*	105				176
Dwarf Flat-headed Gudgeon	*Philypnodon macrostomus*	2				
Flat-headed Gudgeon	*Philypnodon grandiceps*	21		8	19	
Murray-Darling Rainbowfish	*Melanotaenia fluviatilis*					32
Southern Pygmy Perch	*Nannoperca australis*	6				
Carp Gudgeon	*Hypseleotris spp*	1,115		1286	447	91
Un-specked Hardyhead	*Craterocephalus stercusmuscarum fulvus*	91			2	7
Common Carp	*Cyprinus carpio*	21			2	32
Eastern Gambusia	*Gambusia holbrooki*	232		42	865	1,851
Goldfish	*Carassius auratus*	17				13
Oriental Weatherloach	*Misgurnus anguillicaudatus*	155		1		18
Redfin Perch	*Perca fluviatilis*	51				
Total		1,816		1,337	1,335	2,220

* fish species characteristic of habitat type are bolded

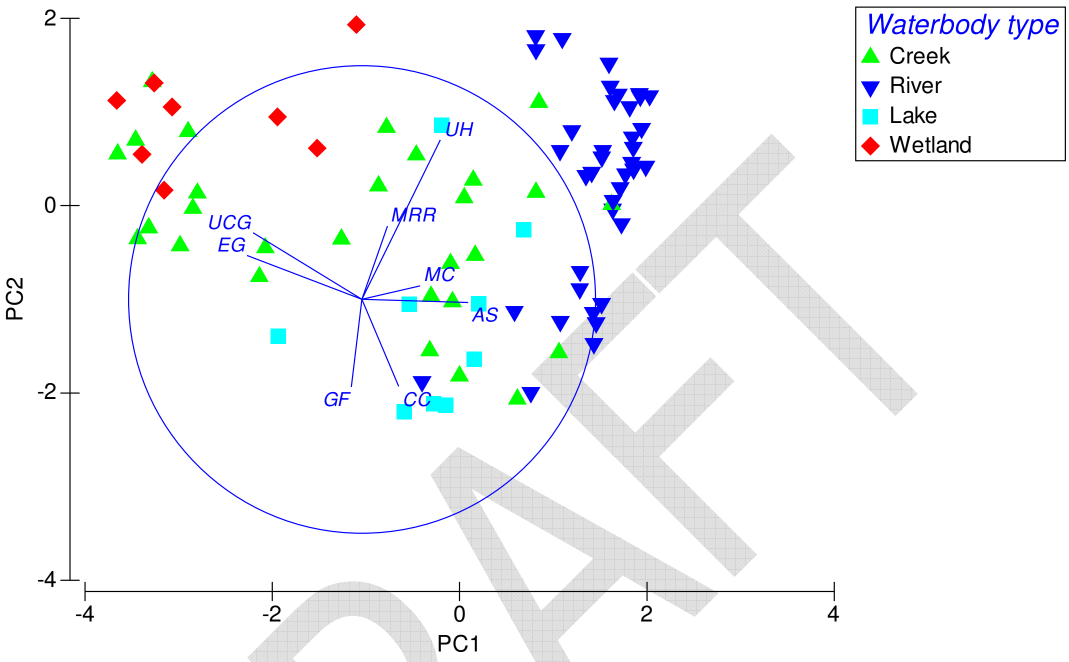


Figure 7. Principle Components Analysis of the first two axes of variation [PC1 (41.6%) and PC2 (15%) – explaining nearly 56% of the total variation] based on catch per minute unit effort electrofishing data from all sites and years (Murray Crayfish excluded from analysis). Species codes: UH (Un-specked Hardyhead), MRR (Murray River Rainbowfish), MC (Murray Cod), AS (Australian Smelt), CC (Common Carp), GF (Goldfish), EG (Eastern Gambusia) and UCG (Unidentified Carp Gudgeon).

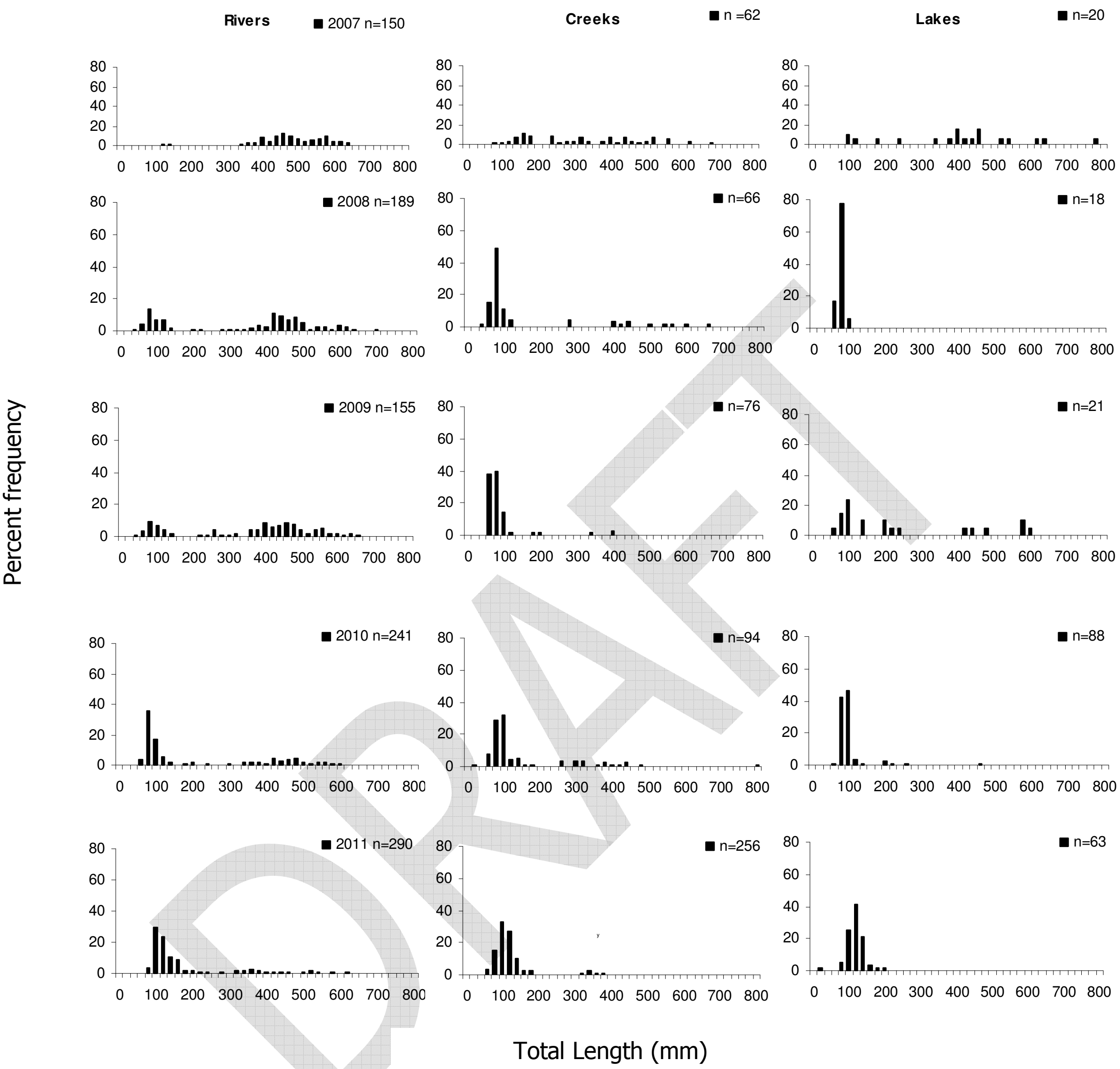


Figure 8. Length-frequency distributions of carp from rivers, creeks and wetlands for each year of the study. YOY Common Carp are those < 150 mm.

3.2 Temporal patterns within habitats

The B-MF fish condition monitoring program was designed to monitor the health and status of the fish community across a number of habitat types; river, creek, wetland and lakes.

3.2.1 Rivers

The general trend in the B-MF riverine fish community from 2009/10 to 2010/11 was one of decreasing abundance of native fish species in conjunction with an increase in the abundance of alien fish. In 2010/11, a total of 2,365 fish were collected (caught and observed) comprising of eight native and four alien species, (Table 4). This represents a reduction of 6,844 individuals and the loss of three species compared with 2019/10 findings. One of the Murray River sites (Woodcutters) was not sampled this year due to unsuitable access. The catch was dominated by Australian Smelt (43%), Common Carp (38%) and Goldfish (12%). All of the large-bodied native species previously caught at river sites (Murray Cod, Trout Cod, Golden Perch and Silver Perch) were collected, though both cod species and Silver Perch were in substantially lower abundances. Of the 26 Murray Cod sampled (not including those observed), nine were over the recreational size limit (>600 mm), which is higher than last year when only three fish from a total of 79 fish were of legal size. Un-specked Hardyhead, a species that contributed to 38% (n=3,498) of the total river fish catch in 2009/10 was not captured or observed from river sites in 2010/11.

The Murray River at Morning Glory was heavily impacted by blackwater throughout the 2010/11 B-MF monitoring program. The general decrease in native fish abundance and corresponding increase in alien fish abundance was most pronounced at both Edwards River and Morning Glory sites on the Murray River. The Morning Glory fish community was heavily dominated by Common Carp this year compared to Australian Smelt and Un-specked Hardyhead dominating in 2009/10. The 2010/11 total catch and species richness for individual river sites are presented in Appendix 1.

ANOSIM results indicated there was a significant difference in the fish community in the river sites through time (Global R = 0.32, P<0.05), which was primarily due to differences between 2006/07 and 2010/11 (Table 8). In both of these years, the differences in the fish community were driven by abundances of Murray River Rainbowfish, Un-specked Hardyhead and Goldfish. The riverine fish community was also significantly different between 2009/10 and 2010/11 and the difference was driven by the same three species. This suggests the numbers of other species remained reasonably stable over the course of the study.

Table 8. R (above diagonal) and P values (below diagonal) for pairwise comparisons of fish abundance at river sites (standardized for electrofishing CPUE). NS = not significant.

	2007	2008	2009	2010	2011
2007	*	0.37	0.02	0.36	0.32
2008	<.01	*	0.06	0.08	0.68
2009	NS	NS	*	0.18	0.43
2010	<.01	NS	<0.05	*	0.68
2011	<.01	<.01	<.01	<.01	*

YOY fish were collected for three large-bodied species this year; Murray Cod (n=3) Common Carp (n=1,105) and Trout Cod (n=1). These figures represent a significant increase in the abundance of YOY Common Carp compared with 2009/10 data. YOY Murray Cod, Trout Cod and Common Carp have been collected every year of the study, albeit in low abundances in some years.

Murray Crayfish

Five Murray Crayfish were sampled this year from the Murray River at Picnic Point, bringing the total collected to 118 over the course of this monitoring program. No Murray Crayfish were sampled from the blackwater-affected Murray River at Morning Glory, a site where they have previously been consistently sampled. Two of the Murray Crayfish were male, one was an immature female and two were mature females in full berry. All Murray Crayfish except for one immature female were over the legal size limit.

Table 9. Number of Murray Crayfish captured from Murray River monitoring sites, 2007 to 2011. ns = not sampled

Site name	2006/07	200708	2008/09	2009/10	2010/11	Total
Ladgroves Beach	1	4		5		**10**
Murray River @ Gulf Creek	2	1	5	3		**11**
Woodcutters	1	9	7	2	ns	**19**
Picnic Point	1		1	8	5	**15**
Barmah - Moira Lake area	1	4		1		**6**
Morning Glory	3	10	39	5		**57**
Total	**9**	**28**	**52**	**24**	**5**	**118**

3.2.2 Creeks

All large-bodied native fish species found within creeks increased in raw abundance compared with 2009/10 results (Table 5), while the abundance of small-bodied natives was varied. Australian Smelt (n=584) and Un-specked Hardyhead (n=53) abundances increased by an order of magnitude while the Carp Gudgeon population plummeted from 1399 individuals in 2009/10 to 69 individuals in 2010/11. All of the large-bodied fish species recorded from creek habitats came from Tongalong Creek with good flows in 2010/11 replacing no-flow conditions during 2009/10 (Table 5). The percentage of native fish sampled from creeks in 2010/11 (20%) decreased over the past year (54% in 2009/10) due to the large decrease in Carp Gudgeon and increases in all alien fish abundances. Common Carp and Eastern Gambusia dominated the fish count in creeks, accounting for 40 and 29% of the total fish catch, respectively (Table 5). Despite the apparent differences in fish community composition within creek sites as indicated by the PCA, ANOSIM results indicated there was no significant difference in the fish community in the creek sites over all years of this study (P=0.46) .

3.2.3 Lakes

Alien fish continue to dominate the fish assemblage of the B-MF lakes, accounting for 73% of the TFC in 2010/11. The abundance of Eastern Gambusia (n=227) has increased by an order of magnitude over the last year while Common Carp (n=335) numbers have tripled. The only native fish species found in reasonable abundances in the lake fish community was Australian Smelt which accounted for 25% of the total catch, up from 1% in 2009/10. No large-bodied native fish species have been recorded in the B-MF lakes since a single Silver Perch was sampled in 2006/07 (Table 6). ANOSIM results indicated there was no significant difference in the fish community in the creek sites over all years (P=0.70).

3.2.4 Wetlands

Eastern Gambusia dominated the 2010/11 B-MF wetland fish assemblage, accounting for 83% (n=1,851) of the total catch. Small (<35 individuals) numbers of Common Carp, Goldfish and Oriental Weatherloach contributed to the total alien fish count. Australian Smelt (n=176), Carp Gudgeon (n=91) and Murray-Darling Rainbowfish (n=32) made up the total native fish community in the wetlands. This represents the first record of Murray Darling Rainbowfish from the wetlands since the project was initiated in 2006/07 and the first record of Australian Smelt since 2006/07 (Table 7). ANOSIM results indicated that there were no significant differences in the fish community in wetland sites over all years (P=0.06). Thus the fish community has remained relatively stable in creek, lake and wetland sites over the course of this study.

3.3 Riverine larval drift

River discharge during the 2010/11 spring/summer spawning period was well above average irrigation supply levels (Figure 6). This stood in marked contrast with drought conditions that typified the region over the previous five years. A total of seven species were recorded spawning in the Murray River as indicated by the presence of 214 larvae and/or eggs captured in the drift sampling, of which 93% were native. This contrasts with the 985 eggs/larvae recorded in 2009/10. The abundance and location of larvae and/or eggs changed considerably from previous sample years (Table 10).

Peak and average densities (expressed as the number of larvae/eggs sampled per 1000 m^{-3} of filtered water) of drifting Murray Cod, Trout Cod, Silver Perch, Golden Perch and Common Carp varied from 2009/10 findings, a year which exhibited a very different hydrological regime (see Rourke *et al.* 2009 for comparisons). The peak density of drifting Murray Cod larvae recorded from the B-MF in 2010/11 was approximately 11 larvae / 1000 m^{-3} with an average of 5 larvae / 1000 m^{-3} per sampling trip. This is considerably lower than the 65 larvae / 1000m^{-3} (peak density) and 14 larvae 1000m^{-3} (average per sample trip) collected in 2009/10. The highest density of drifting Murray Cod larvae was recorded during the last week of November 2010/11 with smaller numbers recorded from the beginning of November to mid December (Figure 9). In contrast, drifting Murray Cod larvae were not captured in late November/December in 2009/10. The majority (79%) of drifting Murray Cod larvae were captured from Ladgroves Beach (furthest upstream site) with the remaining larvae captured from Barmah Choke (middle sampling site). These findings contrast with 2008/09 and 2009/10 data, where the majority of larvae were sampled from Barmah Choke and Morning Glory (furthest downstream site). Blackwater was observed spilling into the Murray River halfway along the Barmah Choke site from Barmah Lake

No drifting Trout Cod or Silver Perch larvae and/or eggs were captured during the 2010/11 sampling of the B-MF. This is in contrast with 2009/10 data where the peak density of drifting Silver Perch eggs was 592 / 1000 m^{-3} with an average of 398 / 1000 m^{-3} per trip (Rourke *et al.* 2010).

The peak density of drifting Golden Perch larvae recorded from the B-MF was approximately 30 eggs 1000m^{-3} with an average of seven eggs 1000m^{-3} per sampling trip. In contrast, the peak density of drifting Golden Perch eggs in 2009/10 was 10 / 1000m^{-3} with an average of 2 / 1000^{m-3} per sample trip. The majority (97%) of drifting Golden Perch eggs were recorded from Ladgroves Beach and Barmah Choke (not affected by blackwater) while a single drifting egg was recorded from Morning Glory (blackwater affected site) in the first week of November (Figure 9).

The peak density of drifting Common Carp larvae recorded from the B-MF was approximately three larvae / 1000 m^{-3} with an average of less than one larva / 1000 m^{-3} per sampling trip. These values are lower than the peak densities of 50 and 259 in 2009/10 and 2008/09 respectively, and the average drifting densities of 17 and 66 in 2008/09 and 2009/10 respectively. The greatest density of drifting Common Carp larvae was recorded in the first week of November, two weeks after the recorded peak densities observed in 2008/09 and 2009/10 (Figure 8). All drifting Common Carp eggs were collected from Morning Glory, the only river site affected by the blackwater event.

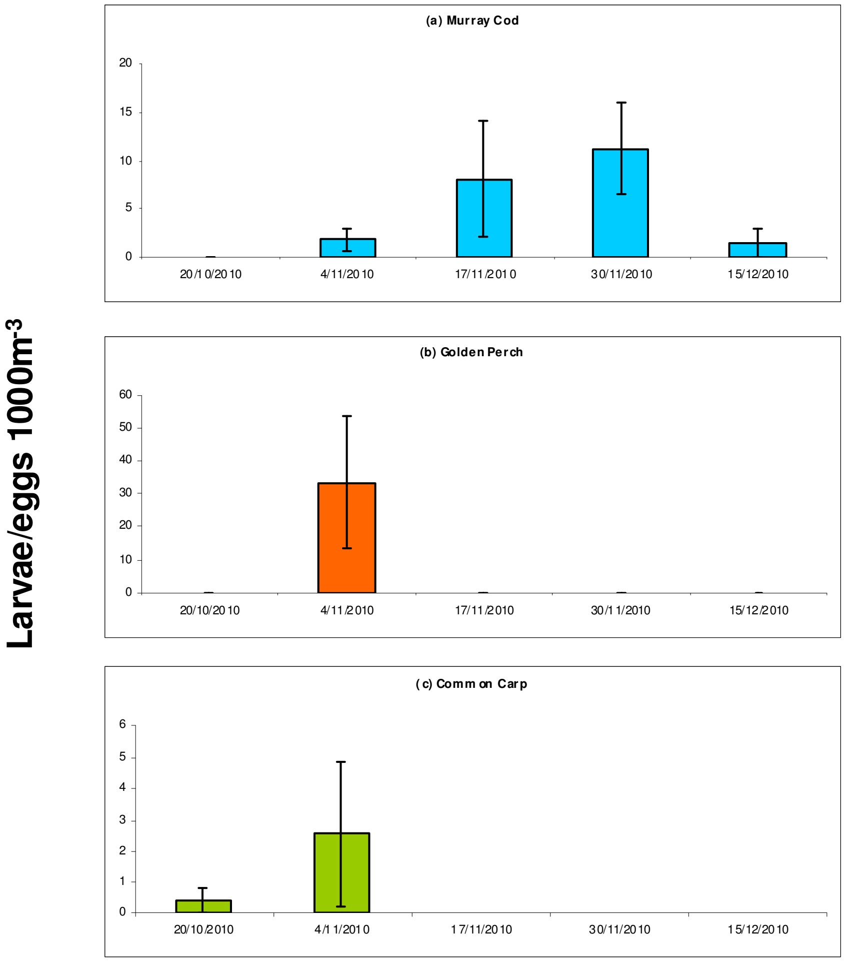


Figure 9. Mean (+/-) S.E. densities per 1000m-3 of drifting (a) Murray Cod, (b) Golden Perch and (c) Common Carp eggs and/or larvae collected from three Murray River sites within the B-MF in 2010. Note the different y-axis scale for each species.

Table 10. Raw abundances of larvae and eggs (in parentheses) collecting drifting from the three Murray River sites in 2008, 2009 and 2010.

		Murray River monitoring sites									
		Morning Glory			Barmah Choke			Ladgroves Beach			**Total (2010/11)**
Common name	**Scientific name**	2008/09	2009/10	**2010/11**	2008/09	2009/10	**2010/11**	2008/09	2009/10	**2010/11**	
Native											
Murray Cod	*Maccullochella peelii*	16	10	**0**	22	26	**10**	4	0	**38**	**48**
Trout Cod	*Maccullochella macquariensis*	0	0	**0**	0	4	**0**	0	0	**0**	**0**
Unidentified cod spp.	*Maccullochella spp.*	1	0	**0**	3	0	**0**	0	0	**0**	**0**
Silver Perch	*Bidyanus bidyanus*	0 (15)	0 (234)	**0**	2 (15)	2 (154)	**0**	0 (231)	0 (426)	**0**	**0 (1075)**
Golden Perch	*Macquaria ambigua ambigua*	0	3	**0 (1)**	1	3	**0 (7)**	0	0	**0 (22)**	**30 (30)**
Carp Gudgeons	*Hypseleotris spp.*	1	0	**1**	0	0	**0**	0	0	**7**	**8**
Flat-headed Gudgeon	*Philypnodon grandiceps*	5	20	**0**	31	28	**0**	22	11	**5**	**5**
Australian Smelt	*Retropinna semoni*	129	7 (4)	**4 (31)**	325 (3)	2 (1)	**0 (26)**	8 (1)	29 (29)	**2 (46)**	**109 (141)**
Alien											
Goldfish	*Carassius auratus*	2	0	**2**	0	0	**3**	1	0	**1**	**6**
Common Carp	*Cyprinus carpio*	42	14	**8**	0	6	**0**	12	2	**0**	**8**
Eastern Gambusia	*Gambusia holbrooki*	0	0	**0**	0	0	**0**	2	0	**0**	**0**
	TOTAL (eggs and larvae)	211	292	**47**	402	226	**46**	277	497	**121**	**2123**

4 Discussion

Widespread and protracted flooding of the B-MF occurred in 2010/11, ending five years of drought in the region. The flooding triggered a significant hypoxic blackwater event in the Murray River from mid-November to mid-March, leading to DO levels < 1 mg/L at a number of sample sites. Four years of pre-existing data mean that the project can assess changes in the fish community, although the capacity of the study to link these changes to hydrology (flooding) has been hampered by the blackwater event. The negative impacts of hypoxia mean that it is unsuitable to assess resilience of the B-MF fish community to drought-breaking flows.

Fish communities of the BM-F responded to large-scale protracted flooding in a variety of ways depending on habitat type and fish species. The region continues to support a range of native fish habitat conducive to successful survival, spawning and recruitment of fish. A detailed discussion of riverine and non-river habitats is presented below.

4.1 Rivers

The structure of the fish community within river sites was significantly different across years, particularly 2006/07 and 2010/11. These differences were largely attributed to changes in the abundances of Murray-Darling Rainbowfish, Un-specked Hardyhead and Goldfish. These inter-annual changes in fish abundance are likely to be related to flooding / blackwater induced death or recruitment success, and / or altered sampling efficiency due to high water levels. In 2010/11 the decline in small-bodied native fish species within the riverine environment (most notably Un-specked Hardyhead that were not sampled) was unexpected given that these species were predicted to benefit from the more favourable environmental conditions associated with the flooding and because blackwater conditions did not affect all of the river sites. It is possible that the proliferation of alien species in the main channel and particularly in nursery habitat provided by the creeks, wetlands and lakes, may have impacted on the spawning success of these native species through either direct competition for resources, or by predating on their eggs/larvae. The observation that many small-bodied natives tend to be short lived and the boom-bust population cycles due to specific life-history characteristics may also explain, in part, the influence of small-bodied natives as a driving force in the structure of riverine fish communities. In blackwater affected areas, small-bodied fish species may have been unable to swim against higher flows (especially when stressed) to escape the blackwater or they may have actively moved away from blackwater affected regions.

McNeil (2004) and McNeil and Closs (2007) found that Australian Smelt were unable to survive when oxygen levels fell below 1 mg/L (levels <1 mg/L recorded during 2010/11) while Common Carp were considerably more tolerant of hypoxic conditions compared to many native species (McNeil 2004; McNeil and Closs 2007). The collection of Australian Smelt larvae and eggs from riverine sites prior to the onset of blackwater, but not following it, suggests that the hypoxic conditions have contributed to the reduction in their abundance by limiting spawning and recruitment and possibly survival. Alternatively, the change in Australian Smelt larvae and eggs may merely reflect natural spawning times and movement patterns of this species. Further research into the tolerance of fish species (particularly Un-specked Hardyhead) would benefit our knowledge and management of fish species to future flood/blackwater events.

The four large-bodied native fish species known to inhabit the region were all recorded from the Murray River in 2010/11. Trout Cod were limited to the riverine environment, consistent with the previous four years of monitoring. Murray Cod and Trout Cod abundance declined in river sites in 2010/11 and this was largely attributed to decreased electrofishing efficiency as a result of higher water levels. This assertion is supported by Lyon (2011) who recorded a significant reduction in the electrofishing efficiency of cod within the Murray River in early 2011. As both cod species have shown high site fidelity and a preference for large woody debris, their habitats were significantly deeper during 2010/11 sampling compared with previous drought years when water levels were much lower. The greater abundance of Murray Cod larvae captured during the 2010/11 drift sampling, but only in upstream non-blackwater affected sites, indicates that the Murray Cod population is successfully spawning.

The reduction in Murray Cod larvae and adults in the blackwater affected Morning Glory site (compared with up-stream sites Ladgroves Beach and Barmah Choke) suggests that Murray Cod either died or moved away from blackwater affected areas of the river and that they have not recolonised this region after the cessation of blackwater. This may be due to the lack of food such as crustaceans that were observed in their tens of thousands (all dead) along the river bank during the blackwater event. It is likely that large-bodied native fish will recolonise blackwater affected sites such as Morning Glory when their food source is returned and that sites previously affected by blackwater will rely on immigration from upstream sites such as Ladgroves Beach and Barmah Choke. It is interesting to note that while the abundance of Murray Cod was lower in 2010/11 compared with 2009/10, the number of legal size fish (600mm +) increased from three to nine individuals.

Over the five years of this study, only one YOY Silver Perch (2009/10) and two YOY Golden Perch (2008/09; 2009/10) were collected, suggesting that electrofishing may be an unsuitable method to sample this life stage of these species. Alternatively, this life stage may not have been present at the sampling sites, either because recruitment has been poor or because recruitment occurred elsewhere. However, the presence of Golden Perch eggs does not support this latter idea. Other studies have also found it difficult to collect

YOY golden and Silver Perch, even following flood events (Lyon et al 2008; King et al 2009), adding further support to the current opinion that electrofishing is not the ideal method to sample this life stage.

In 2010/11 the river sites continued to support an abundance of alien species, particularly Common Carp and Goldfish. Abundances of these species in 2010/11 were more than double that recorded in 2009/10 and were higher than any other year of the study. This rise in abundance was largely due to an increase in the abundance of YOY (<150 mm fork length) fish following extended floodplain inundation. This provides evidence that the B-MF continues to be an important spawning and nursery ground for these alien species.

Length-frequency data for Common Carp across all habitats within B-MF show that the population predominantly consists of YOY fish with very few individuals from older age cohorts. Crook and Gillanders (2006) argue that while the B-MF floodplain provides a particularly important spawning ground for carp in the Murray River many of these fish end up further downstream. Using Common Carp otolith chemical signatures Crook and Gillanders (2006) estimated that the majority (98%) of fish collected from Torrumbarry Weir (100km downstream of B-MF) were most likely recruited from Barmah and Moira Lakes.

Interestingly, in excess of 90% of Common Carp and Goldfish were captured from Morning Glory (n=591) and the Edwards River sites, both of which were heavily impacted by the blackwater event. This indicates that either Common Carp were able to re-colonise these sites much faster than small-bodied native species or that the large number of Common Carp and Goldfish recruits coming off the floodplain (where they were spawned) are heading downstream explaining why low numbers were recorded upstream of Barmah and Moira Lakes.

With five years of catch data on Murray Crayfish, some interesting trends are emerging on the B-MF population. Murray Crayfish are only present in the Murray River and are either not present or in very low numbers in the Edward River. In 2010/11 only five Murray Crayfish were caught in the Murray River at Picnic Point, representing a decline in distribution from all Murray River sites in 2009/10 (n=24) and 2008/09 (n=52). While Murray River at Woodcutters was not surveyed this year, only two of 24 Murray Crayfish were found at this site last year. This is the first year that Murray Crayfish were not captured from Morning Glory since the inception of the program, indicating that recent blackwater events may have contributed to the decline in the species as this site has previously contained good numbers of crayfish. The personal observation by field-staff of Murray Crayfish walking out of the water and hiding amongst tree roots on the riverbank at Morning Glory supports suggestions that the recent blackwater event had a significant detrimental impact on the crayfish population at this site and possibly sites further upstream. The low number of Murray Crayfish captured in 2010/11 compared with 2009/10 and 2008/09 and their restricted distribution within the B-MF Murray River sites is cause for concern. These findings suggest that there needs to be additional research conducted on this species in the Murray River. It is suggested that research targets the timing and cues of reproduction and movement patterns. Additional data on the population ecology of the species and their ability to build up numbers following a catastrophic event such as the blackwater event in late November 2010/11 may be crucial to the effective management of the recreational fishery for this species.

4.2 Creeks, lakes and wetlands

The total abundance of fish captured from creek sites (n=4,093) during the 2010/11 survey accounted for 42% of the total catch from all habitat types and was higher than previous survey years. The fish community composition within creek sites was largely driven by small-bodied native fish species such as Carp Gudgeon, Murray-Darling Rainbowfish and Un-specked Hardyhead. The abundance of natives recorded from creek sites accounted for only 20% of the creek total catch in 2010/11 compared with 54% in 2010 indicating that the large increase in fish abundance in creek sites was primarily due to the greatly increased abundance of alien fish. The majority of native fish populations also increased within creek sites over the past year (albeit on a much smaller scale than alien fish) with the exception of the Carp Gudgeon population that declined by more than 95%.

The total abundance of fish captured from wetland sites (n=2,220) during the 2010/11 survey of the B-MF accounted for 23% of the total catch from all habitat types and was higher than the previous four years of sampling. However, statistically, there was no change in the fish community in this habitat type over the course of the study. Australian Smelt and Murray-Darling Rainbowfish were recorded in wetland sites for the first time since 2006/07. Access to wetland sites from the main river channel due to recent flooding may explain the occurrence of these two native species which are predominantly found in the slow-flowing margins of rivers and creeks.

The total abundance of fish captured from lake sites (n=966) during the 2010/11 survey of the B-MF accounted for 10% of the total catch from all habitat types and was comparably higher than the previous four sample years largely due to increases in alien species. However, these differences were not statistically significant, suggesting the fish assemblage in lakes has remained relatively stable over the course of this study. Slightly higher numbers of large-bodied native fish (Murray Cod, Silver and Golden Perch) were recorded from creek habitats in 2010/11 compared with 2009/10. This increase in large-bodied fish species was predominantly the result of higher numbers of large-bodied natives captured within Tongalong Creek which has re-filled with water following a number of dry years. Large-bodied natives may be utilising creek habitats to escape unfavourable conditions in the main river channel (blackwater events, etc.) or may be re-colonising the sites following improved flow conditions.

Carp Gudgeons were caught in substantially lower numbers in creek and wetland habitats in 2010/11. This species complex is predominantly found in slow flowing waters or in ponds, pools and billabongs associated with aquatic vegetation (Allen 2002). Increased flows and reduced water temperatures may not be conducive to Carp Gudgeon spawning as this species is thought to be a low flow specialist (Humphries et al 2002). The decrease in the Carp Gudgeon abundances may also be linked with their short life span combined with previous drought conditions. Carp Gudgeons are a relatively short-lived species (1-2 years) and as such, appear to be susceptible to periods of prolonged drought conditions such as those recorded over the past five years within the B-MF. Previously, two of the wetland sites that contained low numbers (<50 individuals) of Carp Gudgeons retracted in size with the remaining wetland (Flat Swamp) staying dry. Many of the creek habitats were also significantly lower during the drought. The low water levels within creeks and retraction in wetland size (surface area and depth) led to a reduction in available aquatic habitat used by Carp Gudgeons for spawning. Carp Gudgeons may also have been displaced from creeks and wetlands during recent high flows, partially explaining the reduced abundance of the species within these habitats. It is likely that the replenished wetlands and creeks within the B-MF will result in an increase in the abundance of Carp Gudgeons over the next year or two due to more favourable environmental conditions.

In contrast, the remaining small-bodied species such as Australian Smelt, Murray-Darling Rainbowfish and Un-specked Hardyhead are typically captured from faster flowing waters along river margins. Recent high flows provided many small-bodied native fish species with access to new habitat and/or habitat with more favourable environmental conditions (higher DO levels) compared with the main river channel. However, despite these more favourable conditions, there was not a concomitant increase in abundance of these small-bodied species this year. As indicated earlier, this may be due to increased competition for resources with alien species and/or due to alien species predating upon native fish eggs and larvae.

Higher water levels during the recent floods connected aquatic habitats within the forest for the first time in six years and had a positive impact on alien fish species. The increase in Common Carp and Goldfish may be related to floodplain inundation triggering spawning in these species in late spring/early summer 2010. Subsequent reductions in water volume in late summer/early autumn 2011 would have created habitats with lower flows (compared with the river), which may have been more suitable habitat for larval survival. This increase in water volume within wetlands during summer also provided Eastern Gambusia with a large increase in preferred habitat (shallow marginal water levels, vegetation and warmth) suitable for breeding. The species ability to rapidly colonise newly inundated habitats (see Tonkin *et al.* 2011) is likely to have contributed to their dominance over native species at these sites after refilling.

With the exception of Carp Gudgeons, native fish abundances within creek, lake and wetland habitats remained stable compared with previous years. The large increase in the TFC within these habitats was the result of increasing abundances of Common Carp, Goldfish and Eastern Gambusia, suggesting that environmental conditions in creek, wetland and lake sites in 2010/11 were more suitable for alien fish species compared with natives.

The continued absence of the Southern Pygmy Perch reinforces concerns that the species may be locally extinct in the B-MF. This is likely to be due to the prolonged absence (2006 to 2011) of flooding that is required for successful recruitment of this short-lived species (Tonkin *et al*. 2008). The higher water levels this year may allow this species to recolonise from sites upstream of the B-MF, however, we will have to wait for water levels to subside and populations to establish to determine if successful re-colonisation has occurred. Ideally, additional sites within the B-MF would be surveyed to increase the likelihood that small, isolated populations are detected. If the species fails to return following increased flows this year, a stocking program may be considered to return the species to suitable habitat within the B-MF. Ideally, this would be in an area that can be readily provided with environmental water over the spawning season (Tonkin *et al.* 2008) in the coming years to maximise the chance of successful spawning and recruitment.

4.3 Riverine spawning assessment

The fourth year of egg/larval sampling has shown that the main channel of the Murray is a spawning habitat for five species of native fish, including three large-bodied native species (Murray Cod, Golden and Silver Perch). While Silver Perch eggs were not recorded during the current study they were recorded from Ladgroves Beach during February 2011 (King *et al*.2011). This late spawning is consistent with the delay in signs of spawning of another large-bodied species, Macquarie Perch (*Macquaria australasica*) noted from within the southern Murray-Darling Basin (MDB) (Zeb Tonkin 2011, pers.comm). Relatively low numbers of both Silver and Golden Perch eggs were recorded even though previous research indicates that spawning in these species is cued by flooding (King 2007, 2008 and 2009). While Golden Perch eggs and Murray Cod larvae were recorded in low numbers (n=30 and 38, respectively), the majority (>95 and 74%, respectively) of eggs/larvae were sampled from river sites not affected by blackwater (Ladgroves Beach and Barmah Choke). This suggests that Golden Perch and Murray Cod spawned within or directly upstream of these sites highlighting the potential impact of blackwater on spawning of large-bodied native fish. The lack of larval Murray Cod captured within blackwater affected sites, in conjunction with the increased abundance of Murray Cod larvae from upstream sites, suggests that some adult Murray Cod may have moved further upstream to spawn in 2010/11 in response to altered environmental conditions.

Murray Cod larval drift densities were predominantly collected in late November, two weeks after drifting larval cod in the previous year. Nevertheless, the timing of the drifting larval Murray Cod is consistent with numerous other studies (Humphries 2005; Koehn and Harrington 2006; King 2009). Average densities in 2010/11 were around five larvae 1000 m^{-3} compared with 14 and 9 in 2009/10 and 2008/9, respectively.

These findings support previous studies which indicate that flow conditions have very little influence on the presence and densities of Murray Cod larvae (Humphries 2005; Koehn and Harrington 2006; King 2008).

5 Conclusion

The results of this study have demonstrated that the B-MF River, creek, lake and wetland sites continue to provide important habitat for native and alien fish communities. Each habitat type is clearly characterised by a different suite of species. Rivers are characterised by Murray Cod, Australian Smelt and Un-specked Hardyhead, creeks and lakes are characterised by Goldfish, Common Carp, Australian Smelt, Un-specked Hardyhead, Murray-Darling Rainbowfish, Carp Gudgeons and Gambusia, while wetlands are characterised by Carp Gudgeons and Gambusia. River sites have experienced a significant change in the fish community structure over the course of this study, most notably in 2006/07 and 2010/11, which were largely due to fluctuating abundances of Murray-Darling Rainbowfish, Un-specked Hardyhead and Goldfish. In contrast, despite the apparent differences in the fish community composition within creek, wetland and lake sites, these were not statistically significant. Consequently, the fish community in these habitat types has remained relatively stable in each of these habitat types throughout the course of this study. Nevertheless, it was clear that Common Carp, Gambusia and Goldfish had had an exceptionally good recruitment year, particularly in the creek sites. The 2010/11 B-MF fish community was represented by a reduction in small-bodied native fish (primarily Australian Smelt, Un-specked Hardyhead, Murray-Darling Rainbowfish and Carp Gudgeon) and an increase in alien fish species across all four habitats, particularly creeks and wetlands. Consequently, despite apparent good conditions following the flooding, the native fish community as a whole did not have a detectable positive response to flooding. Of course, the large scale flooding did refill and repopulate many creek and wetland sites following the prolonged drought conditions reported in previous studies. It is therefore possible that there will be a lag time from flooding to a strong native fish response that may be detected in subsequent sampling years.

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Appendix 1.

Total catch (caught + observed) and species richness for eight river sites sampled in 2010/11 using all sample methods.

Common name	Edward River 5km DS regulator	Edward River DS Gulpa Creek	Murray River @ Ladgroves Beach	Murray River @ Gulf Creek	Murray River @ Picnic Point	Murray River @ Barmah - Moira Lake area	Murray River @ Morning Glory	**Total**
Native								
Australian Smelt	311	98	257	79	180	77	13	**1,015**
Golden Perch	1	2	1	2	1	22	2	**31**
Murray Cod		5	6	3	6	8		**28**
Murray-Darling Rainbowfish	35		2					**37**
Silver Perch	1			2	2	6	2	**13**
Trout Cod			1	1				**2**
Unidentified carp-gudgeon	3						1	**4**
Murray Crayfish					5			**5**
Alien								
Common Carp	217	53	9	14	12	6	591	**902**
Gambusia	50	2					1	**53**
Goldfish	32	149	2	6		1	85	**275**
Species richness	8	6	7	7	6	6	7	
Total	**650**	**309**	**278**	**107**	**206**	**120**	**695**	**2,365**

Appendix 2.

Total catch (caught + observed) and species richness for nine creek, wetland and lake sites sampled in 2010/11 using all sample methods.

Common name	Aratula Creek	Barmah Lake	Fishermans Bend Lagoon	Flat Swamp	Gulf Creek @ Four Mile	Gulpa Creek	Hut Lake	Moira Lake	Pinch Gut Lagoon	Tongalong Creek	Toupna Creek	Tullah Creek	Total
Native													
Australian Smelt	139	54		150	30	25	1	187	26	121	12	257	**1,002**
Golden Perch										5			**5**
Murray Cod										11			**11**
Murray-Darling Rainbowfish	19	2		21		35	4		11	18	1	1	**112**
Silver Perch										8			**8**
Carp Gudgeon	15	3	41	1	1	43		2	49	9	1		**165**
Un-specked hardyhead	5	1		6	1	2	4		1	45			**65**
Alien													
Common Carp	48	327	1	16	1	176	3	5	15	294	73	1024	**1,983**
Gambusia	39	217	124	1,194	14	240	10		533	97	573	215	**3,256**
Goldfish	66	137		12		218	2	7	1	41	14	110	**608**
Oriental Weatherloach	24		1	12	3	2			5	12	5		**64**
Species richness	8	7	4	8	6	8	6	4	8	11	7	5	
Total	**355**	**741**	**167**	**1,412**	**50**	**741**	**24**	**201**	**641**	**661**	**679**	**1,607**	**7,279**

Appendix 3.

Raw catch data using all sample methods (caught and observed) for individual sites from 2006 to 2011. NS; site not sampled.

Site name	Common name	2006/7	2007/8	2008/9	2009/10	2010/11
Aratula Creek	Australian smelt	13				139
	Common carp		6	3	3	48
	Eastern gambusia	104	11		489	39
	Flat-headed gudgeon	4			17	
	Goldfish	1	7	3	3	66
	Murray-Darling Rainbowfish				11	19
	Oriental weatherloach		17		2	24
	Unidentified carp-gudgeon	376	424	120	921	15
	Un-specked hardyhead				2	5
Barmah Lake	Australian smelt	6		102	3	54
	Common carp	15	60	44	22	327
	Eastern gambusia			2		217
	Goldfish	29	20	27	149	137
	Murray-Darling rainbowfish			2		2
	Oriental weatherloach	2				
	Unidentified carp-gudgeon				5	3
	Un-specked hardyhead			11		1
Budgee Creek	Australian smelt	99	98	66	25	NS
	Common carp	26	38	26	39	NS
	Eastern gambusia	1	52	37	2	NS
	Golden perch	1				NS
	Goldfish		16	11	10	NS
	Murray cod		1			NS
	Murray-Darling rainbowfish		1	2		NS
	Silver perch				1	NS
	Unidentified carp-gudgeon	3	6	89	24	NS
	Un-specked hardyhead			14		NS

Fishermans Bend Lagoon	Australian smelt	101	NS			
	Common carp	9	NS		2	1
	Eastern gambusia	60	NS	42	865	124
	Flat-headed gudgeon	20	NS	8	19	
	Oriental weatherloach		NS	1		1
	Redfin perch	47	NS			
	Southern pygmy perch	1	NS			
	Unidentified carp-gudgeon	99	NS	1284	447	41
	Un-specked hardyhead	91	NS		2	
Flat Swamp	Australian smelt	2	NS	NS	NS	150
	Common carp	12	NS	NS	NS	16
	Dwarf flat-headed gudgeon	2	NS	NS	NS	
	Eastern gambusia	81	NS	NS	NS	1194
	Goldfish	17	NS	NS	NS	12
	Murray-Darling rainbowfish		NS	NS	NS	21
	Oriental weatherloach	155	NS	NS	NS	12
	Redfin perch	4	NS	NS	NS	
	Southern pygmy perch	4	NS	NS	NS	
	Unidentified carp-gudgeon	667	NS	NS	NS	1
	Un-specked hardyhead					6
Gulf Creek @ Four Mile	Australian smelt	NS	NS	8		30
	Common carp	NS	NS	80	26	1
	Eastern gambusia	NS	NS	473	333	14
	Goldfish	NS	NS	42	68	
	Oriental weatherloach	NS	NS	58	22	3
	Unidentified carp-gudgeon	NS	NS	259	149	1
	Un-specked hardyhead	NS	NS	1		1
Gulpa Creek	Australian smelt	6	54	59		25
	Common carp	7	7	2	4	176
	Eastern gambusia					240
	Golden perch		1			
	Goldfish	1	6	10	1	218
	Murray cod	1	1	1	3	

	Murray-Darling rainbowfish	1		4		35
	Oriental weatherloach					2
	Unidentified carp-gudgeon		1	12		43
	Un-specked hardyhead	2				2
Hut Lake	Australian smelt	NS	NS	NS	NS	1
	Common carp	NS	NS	NS	NS	3
	Eastern gambusia	NS	NS	NS	NS	10
	Goldfish	NS	NS	NS	NS	2
	Murray-Darling rainbowfish	NS	NS	NS	NS	4
	Un-specked hardyhead	NS	NS	NS	NS	4
Moira Lake	Australian smelt	27	NS	NS		187
	Common carp	21	NS	NS	83	5
	Eastern gambusia		NS	NS	15	
	Goldfish	6	NS	NS	10	7
	Silver perch	1	NS	NS		
	Unidentified carp-gudgeon	25	NS	NS	4	2
Pinch Gut Lagoon	Australian smelt	2	NS		NS	26
	Common carp		NS		NS	15
	Eastern gambusia	91	NS		NS	533
	Flat-headed gudgeon	1	NS		NS	
	Goldfish		NS		NS	1
	Murray-Darling rainbowfish		NS		NS	11
	Oriental weatherloach		NS		NS	5
	Southern pygmy perch	1	NS		NS	
	Unidentified carp-gudgeon	349	NS	2	NS	49
	Un-specked hardyhead		NS		NS	1
Tongalong Creek	Australian smelt	72	45	100	15	121
	Common carp	8	59	5	26	294
	Eastern gambusia		5	43	2	97
	Golden perch	1	1		1	5
	Goldfish	3	79	2	7	41
	Murray cod		1	3		11
	Murray-Darling rainbowfish			2	2	18

	Oriental weatherloach					12
	Silver perch			1		8
	Unidentified carp-gudgeon	2	1		12	9
	Un-specked hardyhead	11	1	56	3	45
Toupna Creek	Australian smelt			NS		12
	Common carp	1		NS	46	73
	Eastern gambusia	51	212	NS	158	573
	Flat-headed gudgeon	20		NS		
	Goldfish	7	2	NS	22	14
	Murray-Darling rainbowfish	1		NS	17	1
	Oriental weatherloach	9	8	NS		5
	Southern pygmy perch	33		NS		
	Unidentified carp-gudgeon	524	44	NS	293	1
Tullah Creek	Australian smelt	4	NS	NS	NS	257
	Common carp	33	NS	NS	NS	1024
	Eastern gambusia	76	NS	NS	NS	215
	Flat-headed gudgeon	5	NS	NS	NS	
	Goldfish	79	NS	NS	NS	110
	Murray-Darling rainbowfish		NS	NS	NS	1
	Oriental weatherloach	48	NS	NS	NS	
	Unidentified carp-gudgeon	159	NS	NS	NS	
Edward River 5km DS regulator	Australian smelt	33	9	7	50	311
	Common carp	8	15	36	42	217
	Eastern gambusia			15	1	50
	Flat-headed gudgeon			1		
	Golden perch	1	3	4	3	1
	Goldfish	9	3	9	9	32
	Murray cod	9	2	5	6	
	Murray-Darling rainbowfish	207	11	879	102	35
	Redfin perch				1	
	Silver perch			1		1
	Trout cod	8			1	
	Unidentified carp-gudgeon	32	23	285	17	3
	Un-specked hardyhead	82	436	1031	512	

Edward River DS Gulpa Creek	Australian smelt	105	10	11	18	98
	Common carp	15	27	17	27	53
	Eastern gambusia			5	1	2
	Golden perch	5		5	3	2
	Goldfish	12	2	4	2	149
	Murray cod	2	1	8	6	5
	Murray-Darling rainbowfish	1	3	31	5	
	Silver perch		2			
	Trout cod			3	1	
	Unidentified carp-gudgeon	1	2	21	15	
	Unidentified Maccullochella			1		
	Unindentified hardyhead			1		
	Un-specked hardyhead	23	7	5	8	
Murray River @ Gulf Creek	Australian smelt	52	177	933	424	79
	Bony herring				53	
	Common carp	43	117	78	153	14
	Golden perch	4	14	8	9	2
	Goldfish		14		20	6
	Murray cod	8	14	13	15	3
	Murray crayfish	2	1	5	3	
	Murray-Darling rainbowfish		38	5	240	
	Oriental weatherloach			2		
	Silver perch		11	7	3	2
	Trout cod		4	6	2	1
	Unidentified carp-gudgeon	2	4		7	
	Un-specked hardyhead	90	442	92	1941	
Murray River @ Ladgroves Beach	Australian smelt	264	254	121	811	257
	Common carp	33	64	15	58	9
	Eastern gambusia				1	
	Golden perch	4		1		1
	Goldfish		2		12	2
	Murray cod	7	24	5	14	6
	Murray crayfish	1	4		5	
	Murray-Darling rainbowfish		4		30	2

	Silver perch		1		2	
	Trout cod	1	15	6	10	1
	Unidentified carp-gudgeon	7			14	
	Un-specked hardyhead	33	508	164	474	
Murray River @ Barmah - Moira Lake area	Australian smelt	44	375	47	566	77
	Common carp	58	46	32	9	6
	Eastern gambusia		3		10	
	Golden perch	4		3		22
	Goldfish				4	1
	Murray cod	1	4	1	6	8
	Murray crayfish	1	4		1	
	Murray-Darling rainbowfish		6		41	
	Silver perch	1	5	1	1	6
	Trout cod	4	6	4	6	
	Unidentified carp-gudgeon		17		1	
	Un-specked hardyhead	1	10		31	
Murray River @ Morning Glory	Australian smelt	26	171	6	209	13
	Bony herring				5	
	Common carp	26	29	10	35	591
	Eastern gambusia		1			1
	Golden perch		3	3	1	2
	Goldfish		17	26	84	85
	Murray cod	1	9	3	7	
	Murray crayfish	3	10	39	5	
	Murray-Darling rainbowfish		13			
	Oriental weatherloach		1			
	Redfin perch	1			1	
	Silver perch	1	2	2	2	2
	Trout cod		3	1	2	
	Unidentified carp-gudgeon	3	5		26	1
	Un-specked hardyhead		19	22	163	
Murray River @ Picnic Point	Australian smelt	46	157	300	990	180
	Bony herring				1	

	Common carp	20	25	29	49	12
	Common carp - goldfish hybrid		1			
	Eastern gambusia				1	
	Golden perch	2		1	3	1
	Goldfish		1	11	8	
	Murray cod		6	2	19	6
	Murray crayfish	1		1	8	5
	Murray-Darling rainbowfish		11	9	158	
	Silver perch		1			2
	Trout cod	3	9	4	7	
	Unidentified carp-gudgeon	1	26	36	9	
	Unidentified Maccullochella		1			
	Un-specked hardyhead	4	145	60	337	
Murray River @ Woodcutters	Australian smelt	45	197	30	1186	NS
	Common carp	14	130	15	8	NS
	Eastern gambusia				21	NS
	Golden perch	4				NS
	Goldfish		6	1		NS
	Murray cod		27	4	9	NS
	Murray crayfish	1	9	7	2	NS
	Murray-Darling rainbowfish		2	1	1	NS
	Silver perch	2	2		1	NS
	Trout cod		10	1	5	NS
	Unidentified carp-gudgeon	2		34	7	NS
	Unidentified Maccullochella		1			NS
	Un-specked hardyhead	12	376	76	32	NS