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Front cover photo: Young-of-the-year trout cod, PIT and Dart tags (Justin O'Mahony).

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Summary

The Barmah-Millewa Forest (B-MF) is a wetland complex adjoining 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 fish condition monitoring program. The condition monitoring has been designed to assess the health and status of the fish community across 21 sampling sites distributed across two strata; permanent flowing (riverine) and semi-permanent flowing (creeks, lakes and wetlands) habitats. This report provides a summary of the results of the 2016 sampling season and relates these to the previous nine years of sampling, excluding 2015 where no sampling was undertaken. Fish condition is reported using community (abundance, biomass and fish species that are native) and population (recruitment, expectedness, size structure and distribution of native fish) indices. Each index and sub-indices were allocated scores from 0 (worst condition) to 1.0 (best condition) along with an associated grade (A to E) with a change in grade from the previous survey reflected as increasing (+) or decreasing (-). We also present descriptive data representing rare native species; Murray cray and riverine spawning of large bodied species based on the objectives of the icon site.

In 2016, the B-MF fish score of a B- overall for community indices and a D for the population indices, with the majority of indices stable or improving since the last round of sampling. In general, native fish recruitment was high (100%) and stable across strata and years, expectedness was low (<50%) within and between strata with recent improvement, nativeness was variable across strata and years, and large-bodied native fish showed a greater population size structure indicative of enhanced stability and resilience. Generally, population indices (proportions of abundance, species and biomass that are native) were higher in Permanent flowing habitats than semi-permanent habitats. Trends in B-MF fish within and between strata and across years, along with the factors likely to have influenced these trends, are discussed, including; flows, emigration, electrofishing efficiency, blackwater induced death, habitat preference, connectivity, population dynamics, system productivity and alien fish.

Riverine spawning indicated that Murray and trout cod, golden perch, silver perch, carp gudgeons, flat-headed gudgeon and Australian smelt all spawned during the spring/summer of 2016. Moderate numbers of golden perch (22) and silver perch (160) eggs/larvae were sampled in 2015 compared with the last eight years, and likely reflect a decline in flow related spawning cues (eg. In-channel pulse and flow variability) during peak spawning periods for these species. The capture of Murray cod larvae from Morning Glory (site) in the past three years, after their absence in 2011, indicates that either some adult Murray cod persisted in this reach during the blackwater that adult fish recolonised the area from surrounding areas, or that downstream larval drift is occurring.

Murray cray numbers declined post 2011, likely as a result of a hypoxic blackwater event that impacted lower B-MF river sites. Whilst variable, the population is showing signs of a recent recovery. However, their continued absence from their pre-blackwater stronghold (Murray River at Morning Glory) is cause for concern.

The BM-F fish condition monitoring program has developed into a valuable long term dataset, providing considerable insight into the dynamics of a floodplain fish community and its populations. Whist the program will continue to provide valuable information about the overall condition of its fish populations, identifying the specific mechanisms driving these trends, particularly aspects of the icon sites watering regime, remain uncertain (excluding the riverine spawning component). Therefore, whilst this long term monitoring program will continue to provide overarching trends in the condition of fish populations in BM-F, targeted intervention monitoring is best placed to identify cause and effect of these dynamics.

1 Introduction

The Living Murray (TLM) initiative (established in 2002) is a partnership of the Australian federal government and the governments of the Australian Capital Territory, New South Wales, South Australia and Victoria, coordinated by the Murray-Darling Basin Authority (MDBA). The Living Murray program aims 'to improve the environmental health of six Icon sites chosen for their significant ecological, cultural, recreational, heritage and economic values' (MDBA 2013). The six Icon sites are;

1. Barmah-Millewa Forest
2. Gunbower-Koondrook-Perricoota Forest
3. Hattah Lakes
4. Chowilla Floodplain and Lindsay-Wallpolla Islands
5. River Murray Channel
6. Lower lakes, Coorong and Murray mouth

Condition monitoring of fish, waterbirds and vegetation is necessary to provide ongoing information used to assess the 'health' of the Murray River (MDBA 2012). An outcome/evaluation framework was established to ensure consistent monitoring and agreed benchmarks across all Icon sites. Murray-Darling Basin (MDB) riverine ecosystems are typified by variable hydrological conditions, which have resulted in temporal and spatial variability of its flora and fauna. The development of long-term monitoring programs is essential for reliable interpretation and management of the MDB ecosystems.

The Barmah-Millewa Forest (B-MF) is a 66,000 ha wetland complex on the mid-Murray River, up-stream of Echuca (Figure 1). The B-MF contains a range of aquatic habitats including permanent and semi-permanent flowing habitats. 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 (Rowland 1989). Since the regulation of the Murray River by dams and weirs, native fish abundance and diversity have been substantially reduced and alien species have become common (King 2005). The B-MF is listed as a wetland of international significance under the Ramsar Convention because of its flora and fauna values.

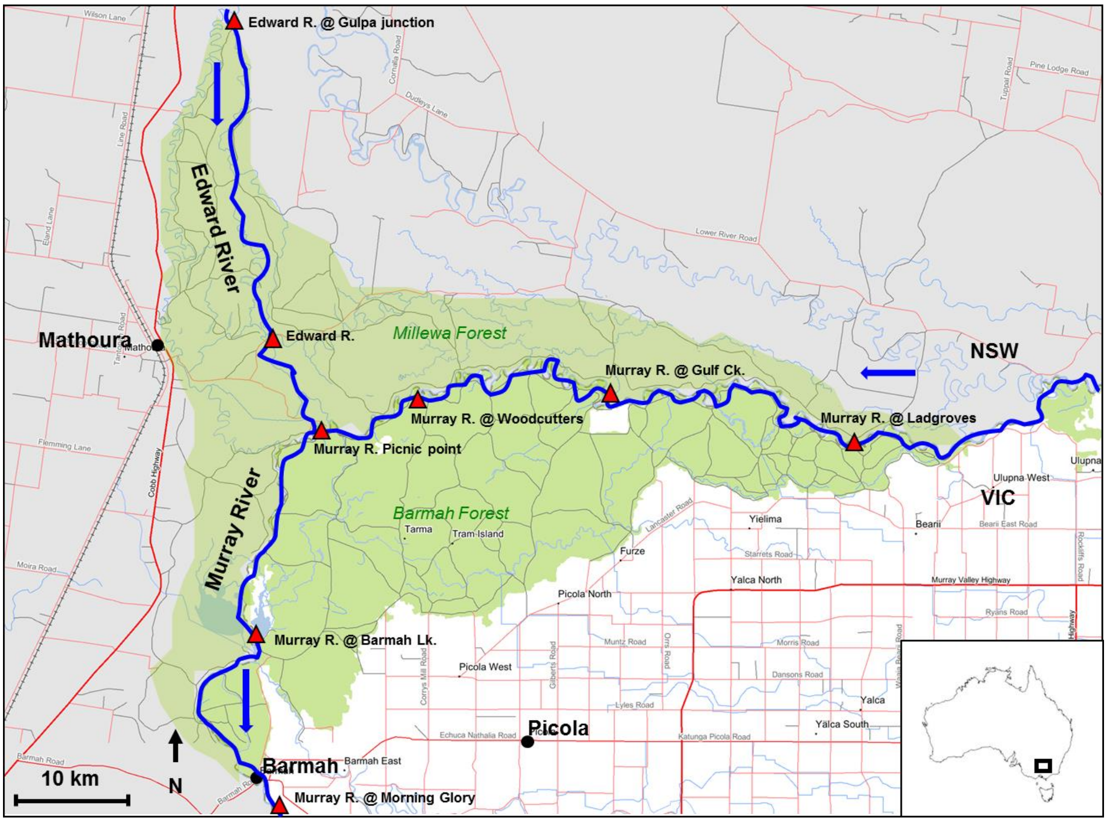

Figure 1. The Barmah-Millewa Forest (shaded green). Red triangles represent riverine sample sites and blue arrows indicate direction of water flow.

In 2007, a condition monitoring program commenced in the B-MF region to benchmark the status of fish communities at three major waterbody types; rivers, creeks and wetlands (Tonkin and Baumgartner 2007). Reporting on large-bodied native fish and exotic common carp *Cyprinus carpio* (hereafter referred to as carp) are a key objective of the condition monitoring program. The overall objectives of the monitoring program were to:

- monitor the health and status of the B-MF fish community through annual sampling
- assess long-term changes in fish community structure and correlate changes with environmental factors
- report on icon site condition and provide information to guide management plans.

In 2009, a spawning component was introduced to the project because a key environmental watering objective for BM-F is to enhance large-bodied native fish spawning.

The spawning component of the monitoring program aimed to document the presence of spawning of riverine fish species (Murray cod *Maccullochella peelii*, Trout cod *Maccullochella macquariensis*, Silver perch *Bidyanus bidyanus*, Golden perch *Macquaria ambigua ambigua*, and exotic carp), that have drifting egg and/or larval stages, within a portion of the B-MF.

In 2016, based on the recommendations of Robinson (2015), the condition reporting was stratified by habitat, ie. permanent flowing (river) and semi-permanent (wetlands, lakes and creeks) flowing sites. This report summarises the results of data collected during the tenth year of fish condition monitoring, which also incorporates sampling for Murray crayfish (*Euastacus armatus*) and spawning assessments of five primarily riverine large-bodied fish species, and compares these data with previous survey years. Refined methods for reporting against TLM icon site objectives for fish in the B-MF Icon Site for data collected in 2016. The results are compared with earlier sampling rounds of the program (2007 – 2014). Additional sampling of two semi-permanent flowing habitats in 2016 was included to improve capacity to assess change within this stratum.

This year is the tenth year of sampling of the program, six years since substantial floodplain inundation and five years since a blackwater event that affected some of the sampling sites (King et al. 2012, Beesley et al. 2012, McCarthy et al. 2014).

2 Methods

2.1 Annual fish condition monitoring

Fish monitoring of the B-MF was undertaken within two major habitat types; permanent flowing (Murray and Edwards rivers) and semi-permanent flowing habitats (creeks, lakes and wetlands). To assess the condition of fish communities within the B-MF, methods were developed to maintain compatibility with current Sustainable Rivers Audit (SRA) protocols (MDBA 2004). The program maintained consistency from 2007 to 2016 by sampling similar numbers of sites in the Barmah Forest and Millewa Forest. Sites within the Millewa Forest were not sampled in 2014 and no B-MF sites were sampled in 2015. In 2016, all forest sites were sampled along with two additional semi-permanent sites in Barmah Forest; Gundrys Bridge and Tarma lagoon, based on the outcome of the B-MF refinement report (Robinson 2015) (Figure 2). Water discharge (ML/d) and temperature (^{0}C) data were collected to determine their relationship with the timing of egg/larval drift and to provide long-term discharge rates covering the duration of the study.

2.1.1 Permanent flowing sites

River sites were sampled in June/July, after water levels declined to winter base flows, to maximise fish detection and to ensure that water temperatures were low enough to sample Murray crayfish. Previous sampling undertaken within B-MF identified unique fish communities in four broad river reaches; lower, mid and upper Murray River main channel and the Edwards River main channel (Figure 2; King et al. 2007). Subsequently, a balanced design was developed with two sites sampled in each of these four regions, with the exception of 2014, where Edward River sites were not sampled and 2015 where sampling was not undertaken. All permanent flowing Murray River sites were sampled using a 7.5 KVA, Smithroot boat-mounted electrofishing unit (1000v, 120 pulses/second, 40 hertz), while sites on the Edward River were sampled using a 2.5 KVA, Smithroot boat-mounted electrofishing unit (1000v, 120 pulses/second, 40 hertz). Twelve replicates of 90 second electrofishing shots were conducted at each river site. In addition, 10 unbaited bait-traps were set at each site for 2 hrs to sample small fish not sampled during routine electrofishing. At the completion of each operation, all fish were identified to species, counted (maximum of 50 individuals per species per site) and measured for total length (to the nearest mm). Once processed, all fish were returned to the site of capture.

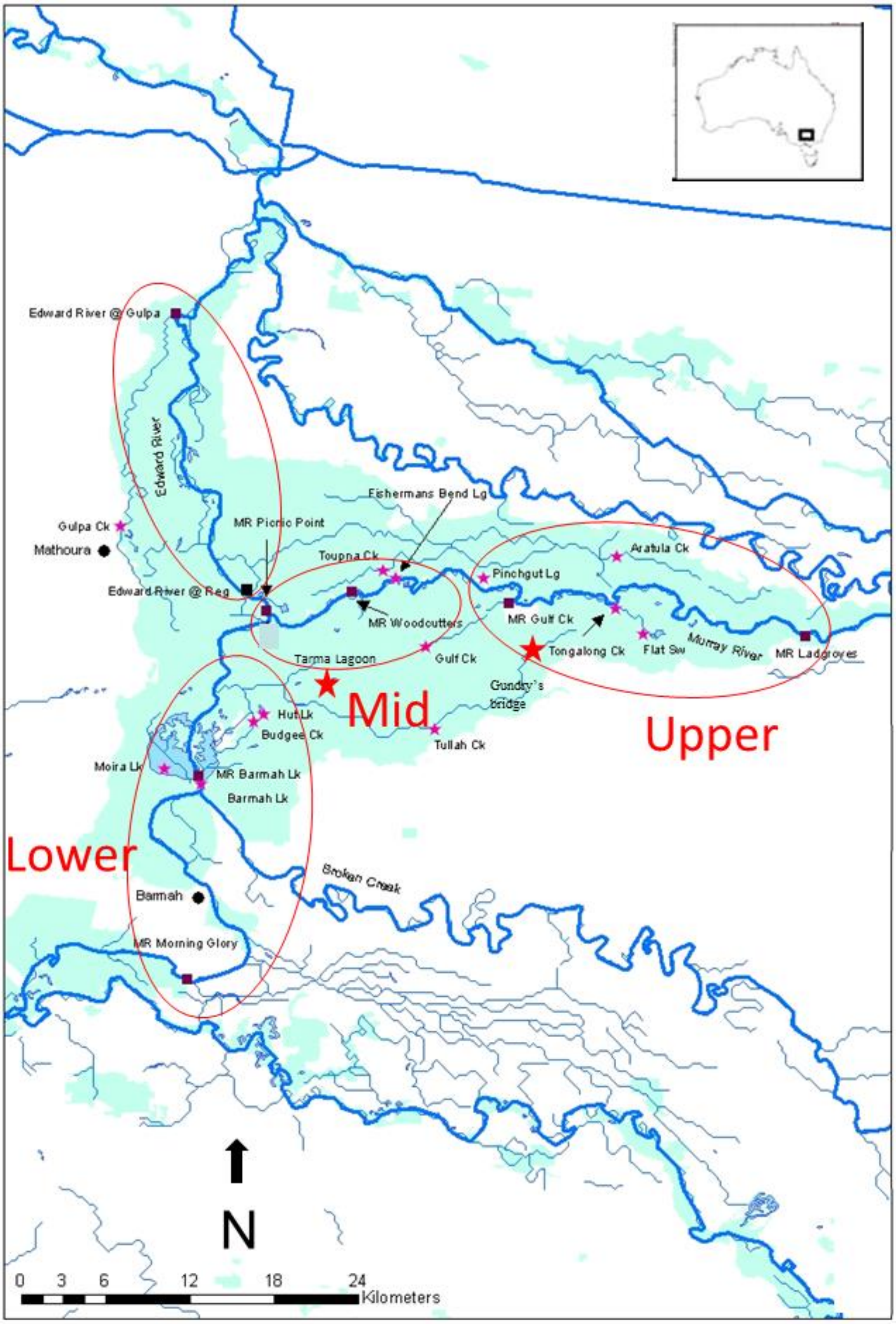

Figure 2. Barmah-Millewa Forest (green shading) illustrating locations of permanent (black squares) and semi-permanent flowing (pink stars) fish monitoring sites and river regions (red ovals). Additional sites monitored in 2016 are represented with red stars.

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

River region 1	Site	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Murray River											
Downstream Region	MR Morning Glory	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
	MR Barmah Lake area	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
Mid Forest Region	MR Picnic Point	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
	MR Woodcutters	✓	✓	✓	✓	#	✓	✓	✓	×	✓
Upstream region	MR Ladgroves Beach	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
	MR Gulf Creek	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
Edward River											
	Edward River @ regulator	✓	✓	✓	✓	✓	✓	✓	×	×	✓
	Edward River @ Gulpa	✓	✓	✓	✓	✓	✓	✓	×	×	✓

✓ Site successfully sampled

Site inaccessible due to floodwaters

× Site not sampled

Murray cray sampling

Ten Munyana crab traps, 75 cm in diameter and baited with liver, were set prior to the commencement of electrofishing with a minimum two-hour soak time (Figure 3). All Murray crays captured were measured for occipital carapace length (OCL) and sex determined where possible. Females were assessed for maturation (setae surrounding the gonopores present in mature females and absent in immature females), and for the presence of eggs (Figure 4).

Figure 3. Munyana crab trap used for sampling Murray cray (a) mature female Murray cray in berry, (b) immature female Murray cray as indicated by lack of setae surrounding gonopores and (c) male Murray cray. Gonopores of Murray cray outlined within red rectangles.

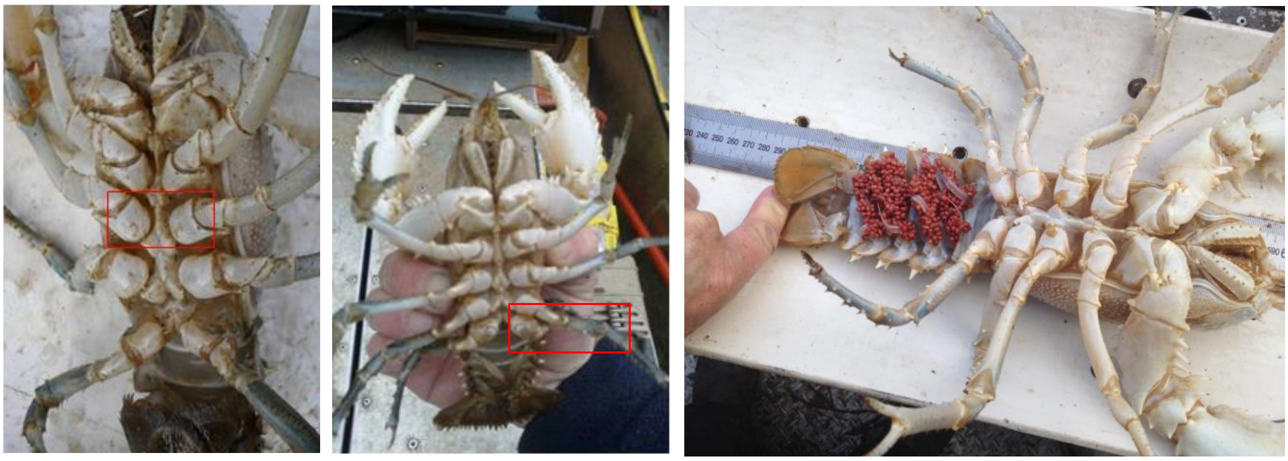

Figure 4. Immature female Murray cray as indicated by lack of setae surrounding gonopores (a) male Murray cray (b) and mature female Murray cray in berry, (c). Gonopores of Murray cray outlined within red rectangles.

2.1.2 Semi-permanent sites

The B-MF contains a diversity of creek systems and wetlands with a wide variety of fish species, some of which only occur in these off-channel habitats (King et al. 2007). Twelve sites (off the Murray River main channel) were therefore selected for inclusion in annual sampling; six creek and six wetland/lake sites that were spatially stratified to include six within the Barmah Forest and six within the Millewa Forest (Table 2). It is important to note that Gulpa Creek and Tongalong Creek, whilst sampled during this period due to flow conditions, are analysed in the permanent flowing habitat due to their having very similar fish communities to the Murray main channel (see Multi-Dimensional Scaling analysis in Raymond et al 2014). An additional site on Gulf Creek (Gulf Creek @ 4-mile) was included in 2010 after surveys in 2009 revealed it to be an important refuge area for a large number of species (see Tonkin and Rourke 2008). Semi-permanent sites were sampled in February/March when water levels were high enough to allow effective sampling.

Sites within the B-MF experience a range of flows over any given year, and this can greatly affect accessibility and the area available to be sampled. Therefore, where necessary, sampling effort was reduced from SRA standards to ensure all sites could be completed in most years. Sampling involved 5—12 replicates of 90 second boat electrofishing shots at each site, with a five shot minimum during low water conditions. If the minimum of five boat electrofishing shots could not be completed due to reduced wetland area or depth, eight replicates of 150 seconds were undertaken with a backpack electrofishing unit (Smithroot Model LR20B, 600v, 120 pulses/second, 40 Hertz) at each site. In addition, 10 unbaited bait-traps were set for a minimum two hour soak time to capture fish not effectively targeted 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. Fish species recorded from B-MF over the course of the study (2007—2016) are listed in Table 3.

Table 2. Semi-permanent flowing sites in the B-MF successfully sampled in each year of the study

Forest	Site	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Barmah	**Tongalong Creek**	✓	✓	✓✠	✓	✓	✓	✓	✓	*	✓
	Budgee Creek	✓	✓	✓	✓	#	✓	✓	✓	*	✓
	Tullah Creek	✓	✖	✖	✖	✓	✓	✖	✓	*	✖
	Gulf Creek @ 4-mile	*	*	✓	✓	✓	✓	✶	✓	*	✓
	Barmah Lake	✓	✓	✓	✓	✓	✓	✓	✓	*	✓
	Hut Lake	✖	✖	✖	✖	✓	✓	✖	✓	*	✓
	Flat Swamp	✓	✖	✖	✖	✓	✓	✖	✓	*	✓
	Gundry's old bridge	*	*	*	*	*	*	*	*	*	✓
	Tarma Lagoon	*	*	*	*	*	*	*	*	*	✓
Millewa	Toupna Creek	✓	✓	✖	✓	✓	✓	✓	✶	*	✓
	Gulpa Creek	✓	✓	✓	✓	✓	✓	✓	✶	*	✓
	Aratula Creek	✓	✓	✓	✓	✓	✓	✓	✶	*	✓
	Moira Lake	✓	✖	✖	✓	✓	✓	✓	✶	*	✓
	Pinchgut Lagoon	✓	✖	✓	✖	✓	✓	✓	✶	*	✓
	Fisherman's bend Billabong	✓	✖	✓	✓	✓	✓	✓	✶	*	✓

✓ Site contained water and successfully sampled, *Site not 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. Sites in bold were included in the permanent flowing strata.

Table 3. Fish species captured from B-MF, 2007—2016.

Common name	Scientific name
Native species	
Australian smelt	*Retropinna semoni*
Bony Herring	*Nematalosa erebi*
Dwarf Flat-headed Gudgeon	*Philypnodon macrostoma*
Flat-headed Gudgeon	*Philypnodon grandiceps*
Golden perch	*Macquaria ambigua ambigua*
Murray cod	*Maccullochella peelii*
Murray cray	*Euastacus armatus*
Murray-Darling Rainbowfish	*Melanotaenia fluviatilis*
Silver perch	*Bidyanus bidyanus*
Southern Pygmy Perch	*Nannoperca australis*
Trout cod	*Maccullochella macquariensis*
Carp gudgeon	*Hypseleotris* spp.
Unidentified cod	*Maccullochella* sp.
Un-specked Hardyhead	*Craterocephalus stercusmuscarum fulvus*
Alien species	
Common carp	*Cyprinus carpio*
Gambusia	*Gambusia holbrooki*
Goldfish	*Carassius auratus*
Oriental Weatherloach	*Misgurnus anguillicaudatus*
Redfin Perch	*Perca fluviatilis*

2.2 Data analysis

Reporting on Icon Site condition included an assessment of community and population indices and their respective sub-indices across years. All of the indices evaluated ranged between 0 (poorest condition) to 1 (best condition), and those that are calculated at each sampling site then averaged to return a strata score performed better. These indices all had similar effect sizes (more power to detect change in condition) and included:

- Community Index 1. The number of sites with recruits
- Community Index 2. The number of species with recruits
- Community Index 3. The number of recruits as a proportion of population
- Community Index 4. The expected number of historic native species collected
- Community Index 5. The number of large-bodied native fish above or below length at maturity
- Community Index 6. Extent, the number of sites each native species is detected in
- Population Index 1. The proportion of fish abundance that is native
- Population Index 2. The proportion of fish biomass that is native (average of site scores)
- Population Index 3. The proportion of fish species that is native
- Community Index 7. Catch per Unit Effort (CPUE) diagnostic only
- Rare species index (diagnostic only).

Analyses of capture data was based on SRA methodology (MDBC 2004) as this was the basis for the sampling strategies. The indices are used to report against TLM icon site objectives for fish and include: native fish community (six indices) and native fish populations (two indices) (Robinson 2012; 2015. CPUE of native fish and rare fish indices weres also included for diagnostic purposes).

Each index was allocated a score (A to E) divided into 20 percentile increments, eg. A is equivalent to 80-100%), with a change in the score from the previous survey reflected as increasing (+) or decreasing (-) (Robinson 2015) (Figure 5). A list of fish for assessing the historical expectedness of native species (Community index 4) is provided in Appendix 1.

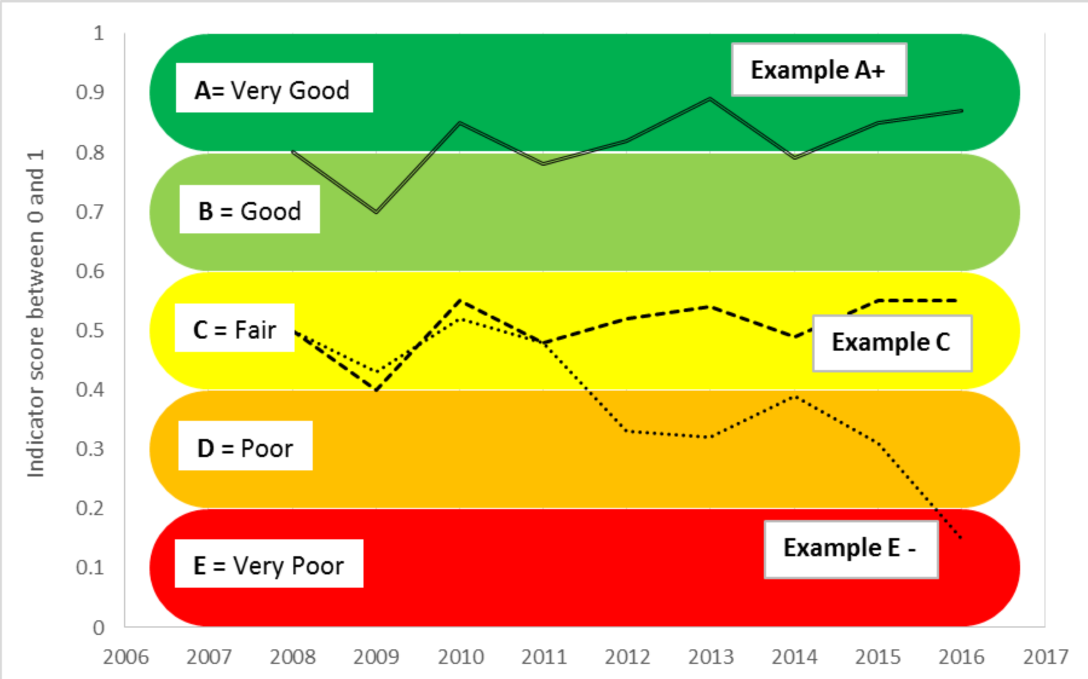

Figure 5. An example of the B-MF indice report scoring system.

2.3 Riverine larval drift sampling

Larval drift sampling targeted drifting eggs and larvae of four native (Murray cod, trout cod, silver perch and golden perch) and one exotic large-bodied species (carp). All are known to have drifting egg and/or larval life stages. Sampling was conducted fortnightly during the spawning period for these species (October to December) (Humphries 2005; Koehn and Harrington 2006; King et al. 2007). Nets were set at three sites on the Murray River (MR) to collect drifting fish eggs and larvae: MR @ Morning Glory, MR @ Barmah Choke and MR @ Ladgroves Beach, which were located downstream, mid and upstream of the B-MF floodplain respectively (see Figure 2 for site locations).

At each site, three 1.5 m long passive drift nets were deployed just below the water surface, one net placed within each third of the river channel to account for possible spatial variability in drifting densities. The nets were constructed of 500 µm mesh with a 0.5 m diameter opening, tapering to a removable collection jar (Figure 6). Each net was anchored to a tree within the river channel. Within each net, a flow meter (General Oceanics Inc. Florida, USA) was fixed to determine the volume of water filtered, thus enabling raw catch data to be standardised to the number of eggs and/or larvae per 1000 m^{-3} of water filtered. All nets were set at dusk and retrieved the following morning. The contents of each collection jar was preserved in 95% ethanol in the field and returned to the laboratory for processing. Samples were sorted using a dissecting microscope and any larvae and eggs identified using Serafini and Humphries (2004), and by comparison with a reference collection of successive larval stages held at the Arthur Rylah Institute (ARI), Melbourne. B-MF larval drift data (2016) was compared with drift data obtained during previous annual fish condition monitoring programs (2008 to 2014) and with data collected from corresponding sites (2003-2007) sampled during a larval fish program undertaken by the ARI.

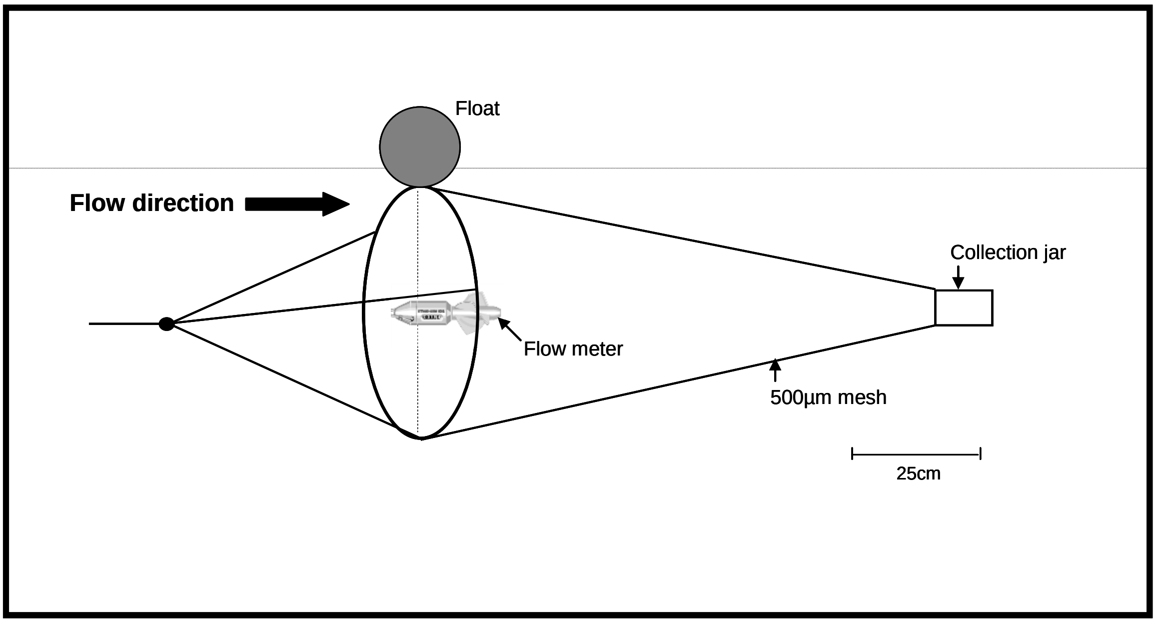

Figure 6. Side view of the standard passive drift net used in the study.

3 Results

3.1 Hydrology

A single, medium duration flood occurred from August to mid-October 2015, sufficient to inundate the B-MF floodplain from August to early November 2015, followed by six months of drying (Figure 7). Several small pulses were delivered by raising and lowering flows during the spawning period of native fish. Larval drift sampling was undertaken from mid-October to early-December 2015 while semi-permanent and permanently flowing habitats were sampled four and eight months following the recession of water from the Barmah-Millewa floodplain, respectively. Water temperature in the mid-Murray River rose through the spring and summer months, covering the core spawning period of all target large-bodied native fish and carp, and declined in the autumn and winter months.

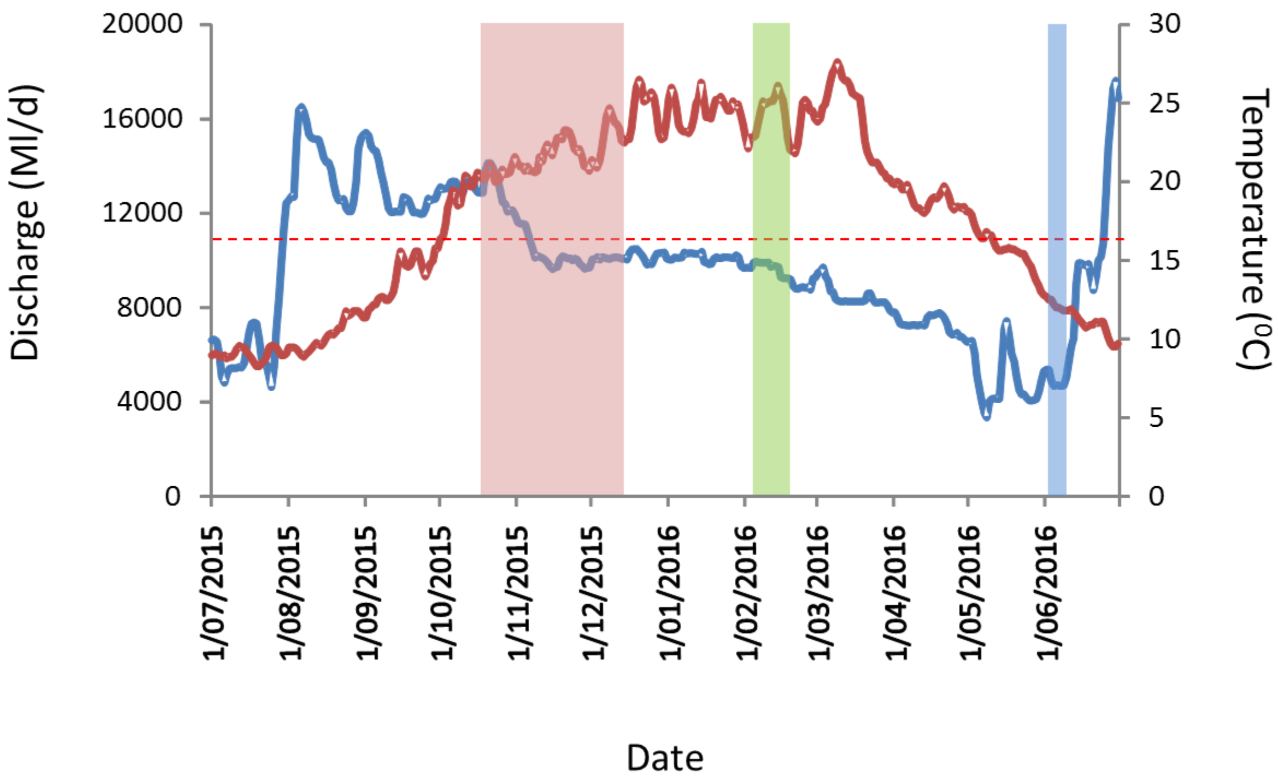

Figure 7. Mean daily discharge of the Murray River downstream of Yarrawonga Weir from June 2015 to July 2016.The dashed red line indicates flow at which B-MF floodplain is inundated (11,000 ML/d). The pink shaded portion of the graph depicts the time of egg and larval sampling, green shading represents Semi-permanent flowing habitat sampling, and the blue shade indicates time of river sampling (Source: MDBA, Gauge # 409025).

3.2 Fish surveys

All 21 B-MF survey sites were sampled in 2016, following 2015 where no sampling was conducted. Sampling of Murray River (permanently flowing) sites was undertaken from 6-9th June 2016 and semi-permanent creek, lake and wetland sites were sampled from 16th of February-16th of March 2016.

3.2.1 Total catch and community composition

A total of 8,022 fish were either captured (n=4,341) or observed (n= 3,681) in 2016, representing 11 native and five alien species (Table 5). Whilst total numbers of fish were similar to 2014, a decline in alien fish abundance and an increase in native fish raw numbers were recorded in 2016. Carp gudgeon and Australian smelt and gambusia and carp were the most abundant native and alien fish species, respectively. The numbers of Murray cod, trout cod and golden perch captured was almost three times higher than the numbers recorded since 2014. Murray crayfish were in their highest abundance since 2009, while silver perch numbers remained low.

3.2.2 Permanently flowing habitat (rivers)

A total of 2,077 fish were captured (n=1,111) or observed (n=966) comprising nine native and two alien species sampled from river sites in 2016 (Table 6). Most common in the 2016 catch were Australian smelt (823) and carp (653), with the highest abundance of carp recorded from MR @ Barmah Lake (143) and MR @ Gulf creek (57) sites. All of the large-bodied native species previously captured at river sites, such as Murray cod, trout cod, golden perch and silver perch, were detected. The general trend in abundances of native fish (captured) was higher pre-2010/11 floods and lower post-floods (Table 6, Figure 8). In contrast, carp abundances were higher in post-flood years (Table 6). Low numbers of goldfish (17) and gambusia (1) were sampled from river sites in 2016, consistent with 2012 onwards.

Of the 74 Murray cod sampled in 2016 (not including those observed), 29 (39%) were over the recreational angling limit of ≥ 550 mm and 16% of fish fell within the angling slot limit of 550-750 mm. Murray cod have maintained a breadth of size classes (cohorts) from 2007 to 2016, but with comparably fewer juvenile fish post 2010/11 floods (Figure 9). Mature (>600 mm) Murray cod were more frequently sampled in 2016 compared with previous sample years.

No YOY silver perch or golden perch were collected in 2016. However, three YOY Murray cod, 13 YOY trout cod and 21 YOY carp were sampled (Figures 9 to 11). This is the first year that YOY Murray cod (<150 mm TL) have been collected from B-MF sites since 2012. A number of cohorts representing juvenile to adult fish were evident for Murray cod (Figure 9). In contrast, golden and silver perch captured across all years were predominantly adults with the exception of a single YOY golden perch sampled in 2010, and a sub-adult (200mm) captured in 2014. The carp population was dominated by YOY individuals from 2008 to 2011 (with high numbers in 2016) and by adults from 2012 onwards (Figure 11).

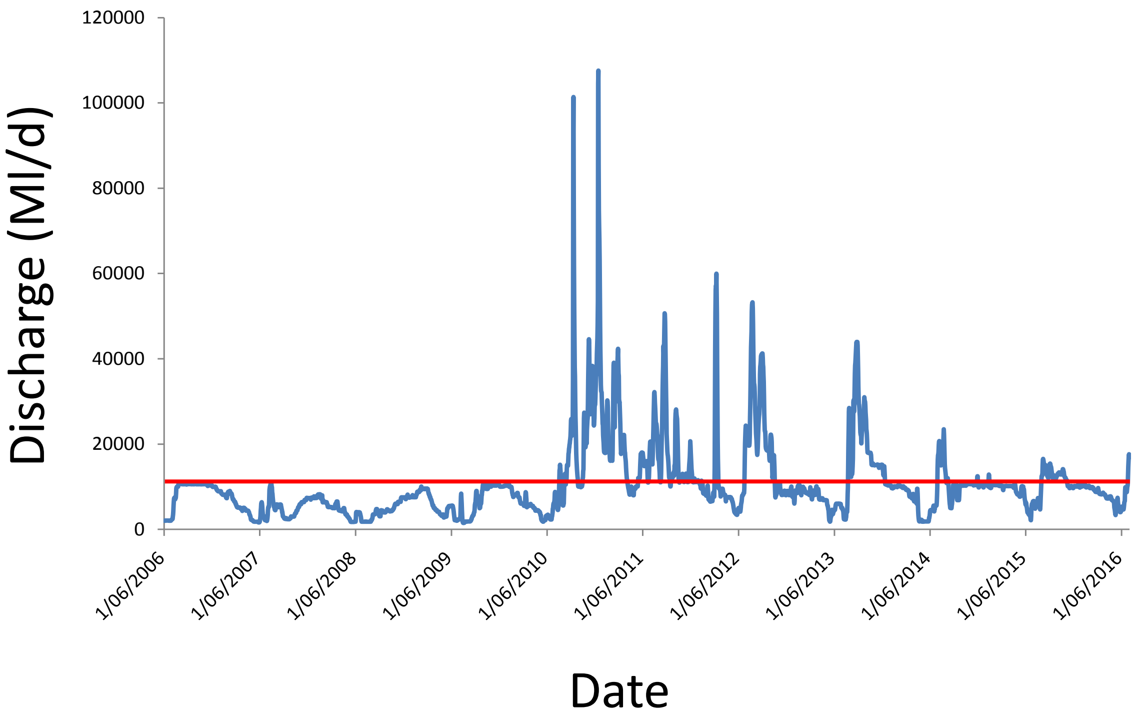

Figure 8. Average daily flows (ML/Day) downstream of Yarrawonga Weir from 2006 to 2016 (Source: MDBA, Gauge # 409025). The red line indicates flow at which B-MF floodplain is inundated.

The abundance of carp at the most downstream site, MR @ Morning Glory, was similar to other river sites from 2007 to 2010. This changed in 2011 when MR @ Morning Glory was heavily impacted by flooding (Figure 7) and a significant blackwater event prior to sampling (Beesley et al 2012). The abundance of carp at MR @ Morning Glory increased from nine individuals in 2010 to 591 individuals in 2011. Since 2011, the abundance of carp captured from MR @ Morning Glory declined to 23 individuals in 2012, 26 individuals in 2014 and 18 individuals in 2016. This represents the smallest abundance of carp sampled from the six river sites this year. The 2016 total catch for all river sites are presented in Appendix 2.

3.2.3 Semi-permanently flowing habitat (non-river)

A total of 5,945 fish were captured (n=3,219) or observed (n=2,726) comprising eight native and five alien species sampled from semi-permanent flowing habitats (Table 7). Most common in the 2016 catch were native carp gudgeon (1,829) and alien gambusia (2,251), representing the highest number of carp gudgeon sampled since 2007 and the maintenance of high numbers of gambusia post-2010.

The general trend, indicated by abundance of native fish and native species richness, was higher numbers and greater richness of small-bodied fish pre-2010 followed by a rapid decline to 2014 and an increase thereafter (Table 7). Whilst total abundance was driven by carp gudgeons and Australian smelt, the increase in species richness was driven by the inclusion of dwarf flat-headed gudgeon, golden perch and trout cod, all of which had not been sampled from semi-permanent flowing habitats for at least the previous four years.

In contrast with native fish, gambusia, goldfish and carp numbers increased in 2011 and showed marked differences in population structure thereafter. Carp abundance sharply declined to 2012 and remained in moderate numbers to 2014 and rose again in 2016, with the increase driven by higher numbers of recruits and adults. After an initial decline in gambusia and goldfish numbers in 2011, both populations rebounded to high numbers in 2014 with goldfish decling in 2016 whilst gambusia remain high.

Table 4. Total number of native and alien fish collected and observed at all sampling sites 2007 — 2016.

Common name	2007	2008	2009	2010	2011	2012	2013	2014	**2015**	**2016**
Native										
Australian Smelt	949	1,547	1,790	4,297	2,017	645	190	1,903		1,052
Bony Herring				59						
Dwarf Flat-headed Gudgeon	2									39
Flat-headed Gudgeon	61	18	9	36		39	1			84
Golden Perch	26	22	25	20	36	73	45	21		62
Murray Cod	29	90	45	85	39	18	17	30		88
Murray Crayfish	9	28	52	24	5	13	30	14		44
Murray-Darling Rainbowfish	210	89	935	607	149	6		2		57
Silver Perch	5	24	12	10	21	21	9	2		4
Southern Pygmy Perch	46									
Trout Cod	16	47	25	34	2	8	9	19		69
Carp Gudgeon	2854	1,570	2,142	1,951	169	334	338	278		1,833
Unidentified cod		2	1							
Un-specked Hardyhead	349	1,945	1,532	3,505	65	5	80	6		260
Total natives	**4,556**	**5,382**	**6,568**	**10,628**	**2,503**	**1,162**	**719**	**2,275**		**3,588**
Alien										
Common Carp	377	648	392	632	2,885	1,152	994	1,345		1,308
Gambusia	467	326	617	1,899	3,309	1,212	281	3,583		2,252
Goldfish	167	190	146	409	883	123	33	2,883		706
Oriental Weatherloach	225	26	61	24	64	58	2	121		145
Redfin Perch	53			2		1		1		23
Total aliens	**1,289**	**1,190**	**1,216**	**2,966**	**7,141**	**2,546**	**1,310**	**7,933**		**4,434**
Total fish count	**5,845**	**6,572**	**7,784**	**13,594**	**9,644**	**3,708**	**2,029**	**10,208**		**8,022**

Table 5. Total number of native and alien fish collected and observed at Permanent flowing strata during 2007 — 2016.

Common name	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Native										
Australian Smelt	615	1,350	1,455	4,254	1,015	507	132	1,793		823
Bony Herring				59						
Flat-headed Gudgeon		9	1							
Golden Perch	24	20	25	19	31	73	45	21		62
Murray Cod	28	87	41	82	28	18	12	20		87
Murray Crayfish	9	28	52	24	5	13	30	14		40
Murray-Darling Rainbowfish	208	88	925	577	37			1		56
Silver Perch	4	24	11	9	13	18	9	1		4
Trout Cod	16	47	25	34	2	8	9	19		68
Carp Gudgeon	392	692	376	96	4	3	8	3		6
Unidentified *Maccullochella*		2	1							
Un-specked Hardyhead	245	1,943	1,450	3,498			77	3		258
Total natives	**1,541**	**4,290**	**4,362**	**8,652**	**1,135**	**640**	**322**	**1,875**		**1337**
Alien										
Common Carp	217	453	232	381	902	945	783	1,155		653
Gambusia	1	7	20	35	53		1			1
Goldfish	21	45	51	139	275	7	1	3		17
Oriental Weatherloach		1	2			5				
Redfin Perch	1			2						1
Total aliens	**240**	**506**	**305**	**557**	**1,230**	**957**	**785**	**1,158**		**644**
Total fish count	**1,781**	**4,797**	**4,667**	**9,209**	**2,365**	**1,597**	**1,107**	**3,033**		**2,077**

Table 6. Total number of native and alien fish collected and observed at semi-permanent flowing strata during 2007 — 2016.

Common name	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Native										
Australian Smelt	334	197	335	43	1,002	138	58	110		229
Flat-headed gudgeon	61	9	8	36		39	1			84
Dwarf Flat-headed gudgeon										39
Golden Perch	2	2		1	5					
Trout cod										1
Murray Cod	1	3	4	3	11		5	10		1
Murray-Darling Rainbowfish	2	1	10	30	112	6		1		1
Silver Perch	1		1	1	8	3				0
Southern Pygmy Perch	46									
Carp Gudgeon	2,462	878	1,766	1,855	165	331	330	275		1,829
Un-specked Hardyhead	104	2	82	7	65	5	3	3		2
Total natives	**3,013**	**1,092**	**2,206**	**1,976**	**1,368**	**522**	**397**	**399**		**2251**
Alien										
Common Carp	160	195	160	251	1,983	207	211	190		654
Gambusia	466	319	597	1,864	3,256	1,212	280	3583		2,251
Goldfish	145	145	95	270	608	116	32	2880		689
Redfin Perch	52					1		1		22
Oriental Weatherloach	225	25	59	24	64	53	2	121		145
Total aliens	**1,048**	**684**	**911**	**2,409**	**5,911**	**1,589**	**525**	**6,775**		**3790**
Total fish count	**4,061**	**1,776**	**3,117**	**4,385**	**7,279**	**2,111**	**922**	**7174**		**5,945**

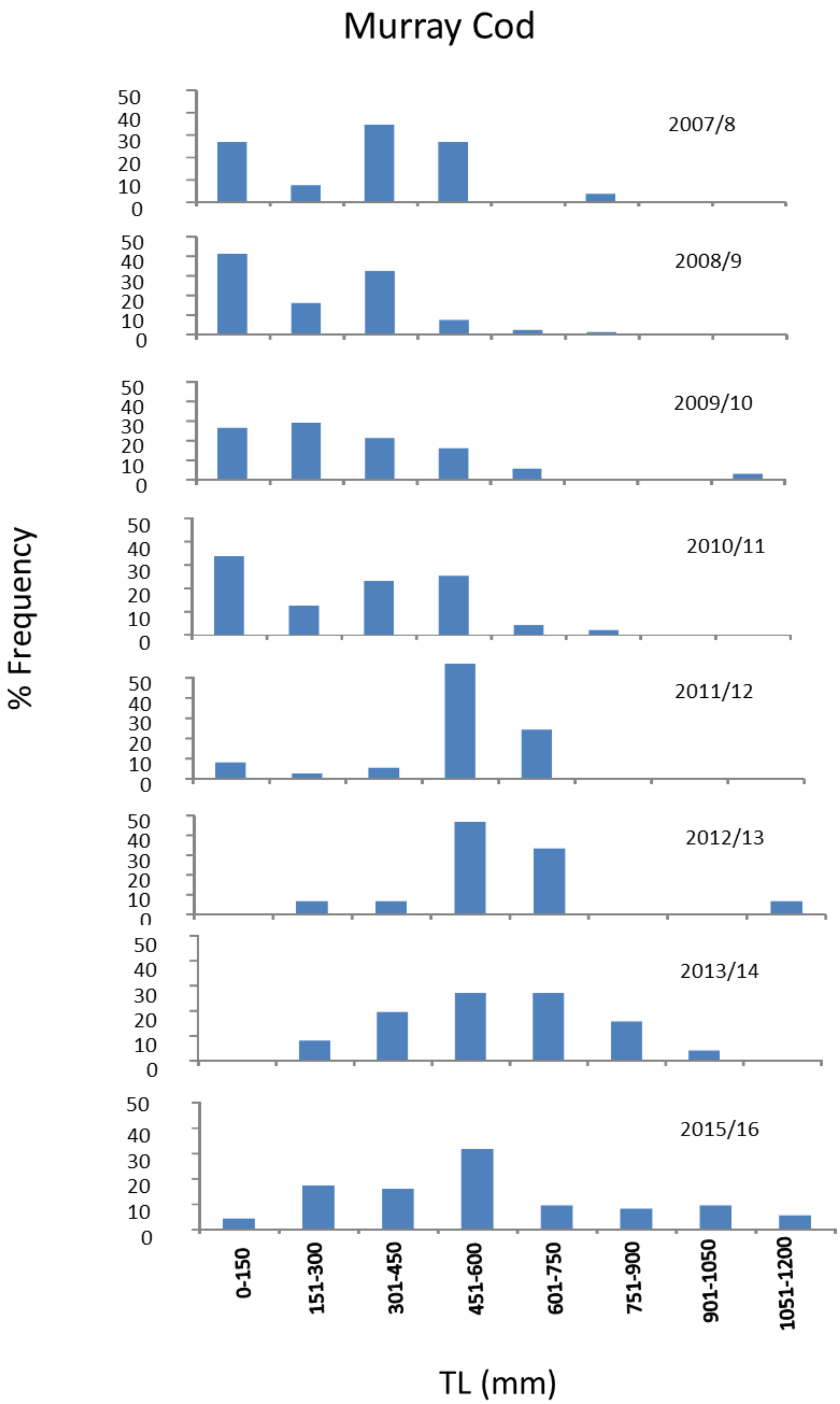

Figure 9. Murray cod length frequency for each of the study years

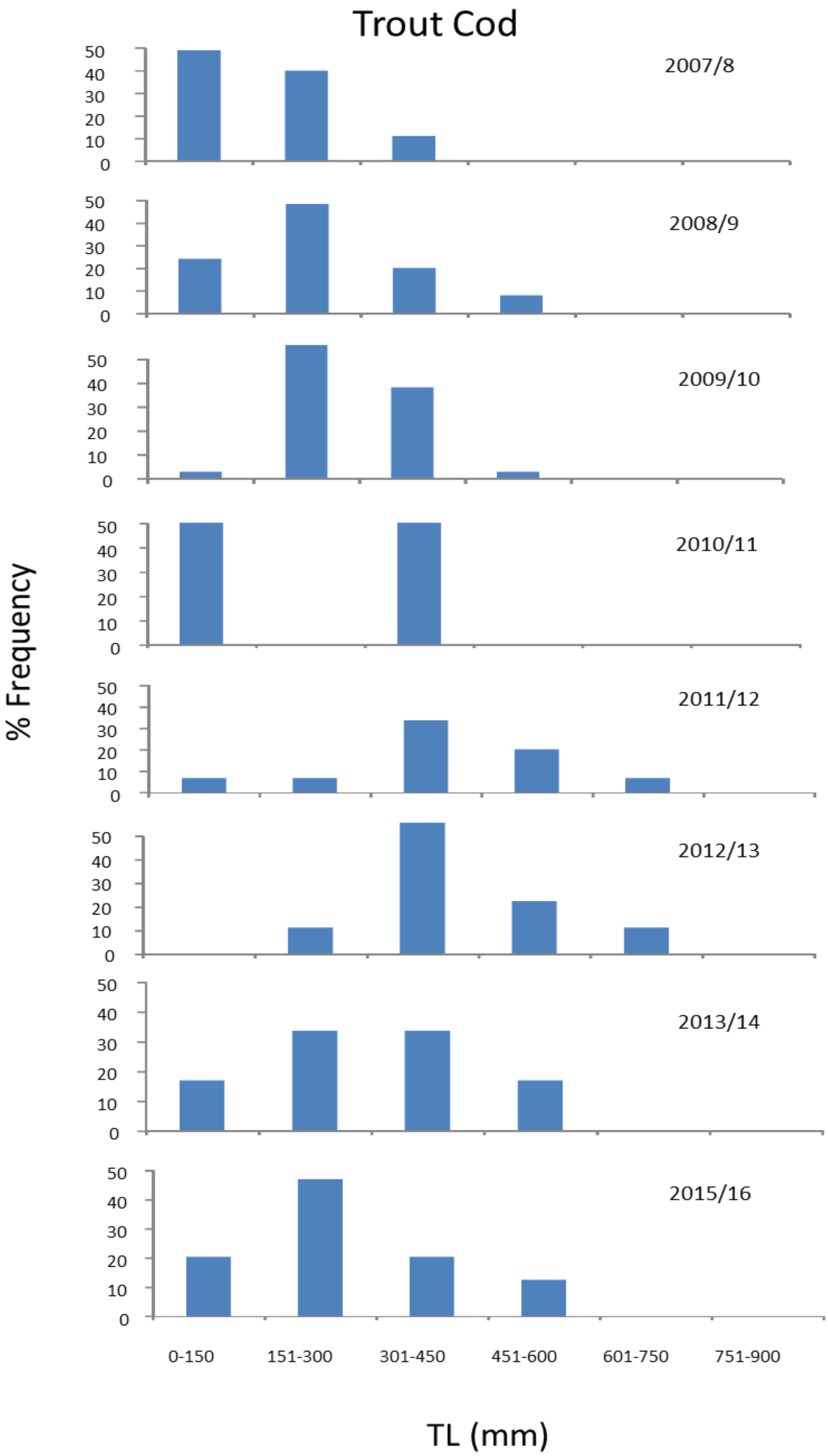

Figure 10. Trout cod length frequency for each of the study years

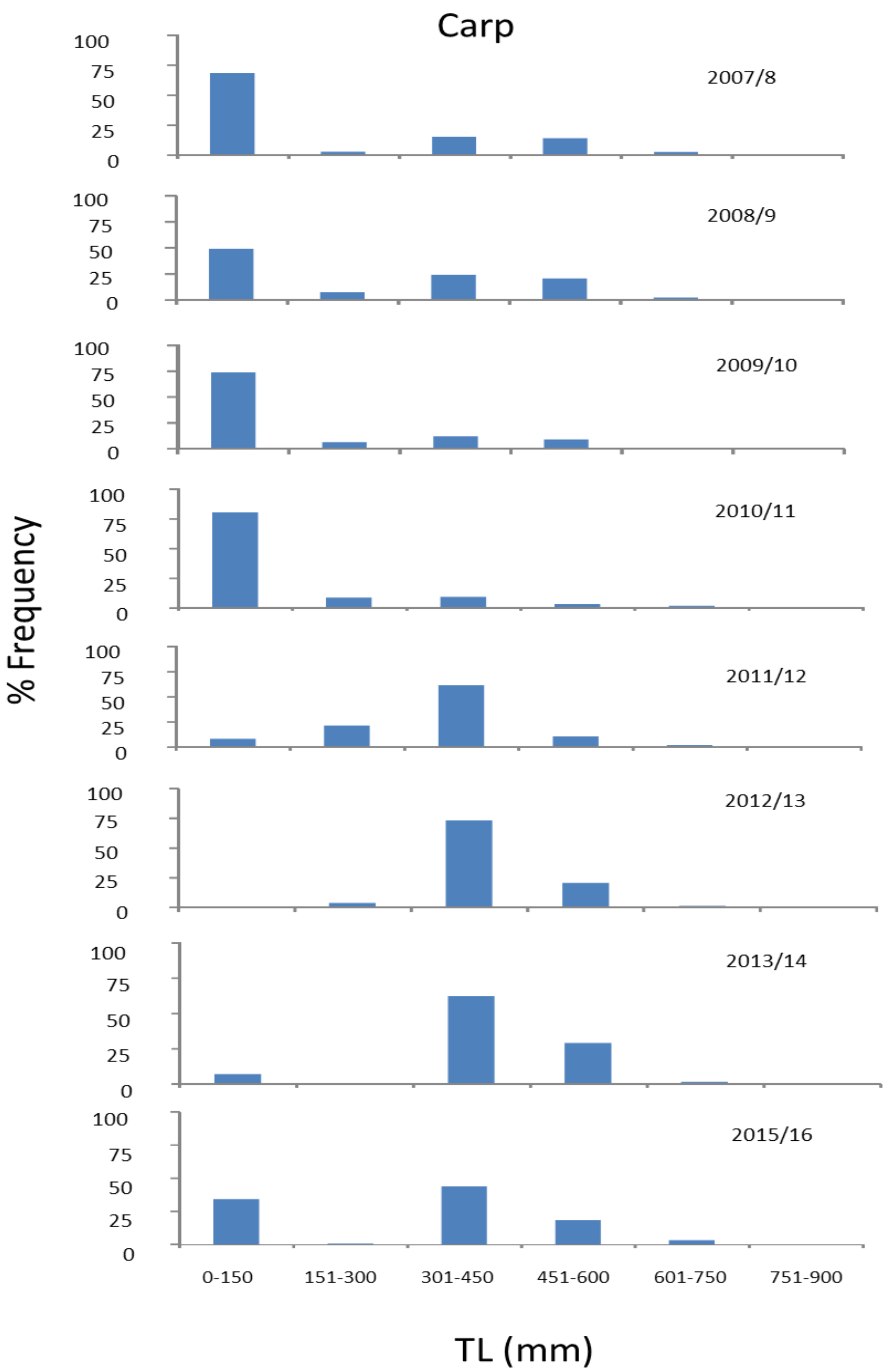

Figure 11. Carp length frequency for each of the study years

3.3 Icon site indicators

3.3.1 Fish community indices

Number of sites with recruits

All flowing sites and all but one semi-permanent sites had recruits detected in 2016, and scored an A and an A-, respectively (Figure 12). BMF fish sampling sites have consistently scored well on this index since 2007. The number of semi-permanent sites with recruits was more variable across years than permanently flowing sites.

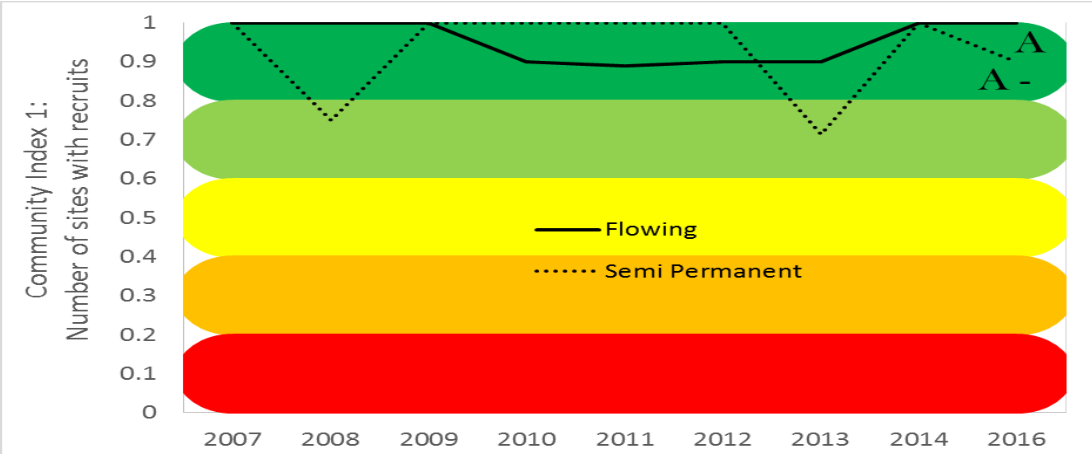

Figure 12. Community Index 1, (proportion of) sites with recruits in BMF during fish condition monitoring, 2007 – 2016. Data were not collected in 2015.

Number of species with recruits

Sixty percent of native fish species in both flowing and semi-permanent habitats had recruits in 2016, and scored a C and a C+, respectively. This is the first time since 2007 that both habitats have had more than half of the species recruiting. Flowing sites have historically had more recruiting species present than 2016, but 2014 and 2016 are seen as an improvement from the low scores of 2012 and 2013 (Figure 13).

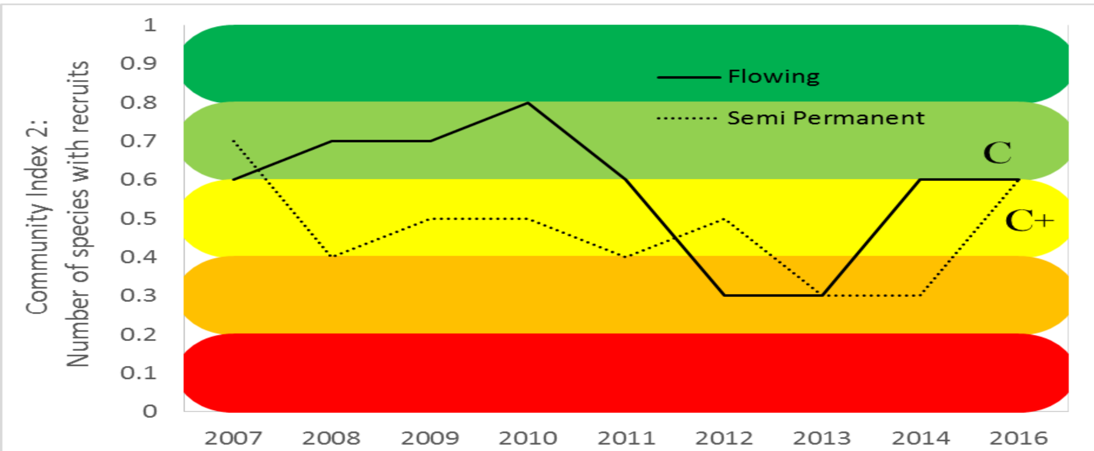

Figure 13. Community Index 2, (proportion of) species with recruits in BMF during fish condition monitoring, 2007 – 2016. Data were not collected in 2015.

Number of recruits as a proportion of population

On average, more than 99% of fish collected per species in the semi-permanent habitat were recruits, a common theme over time and is represented by a score of A+ (Figure 14). In flowing habitats, recruits have averaged less than half the species populations since 2011, and whilst 2016 is showing a slight increase again, the proportions are still about 20% lower than 2008 levels, and scored a C+.

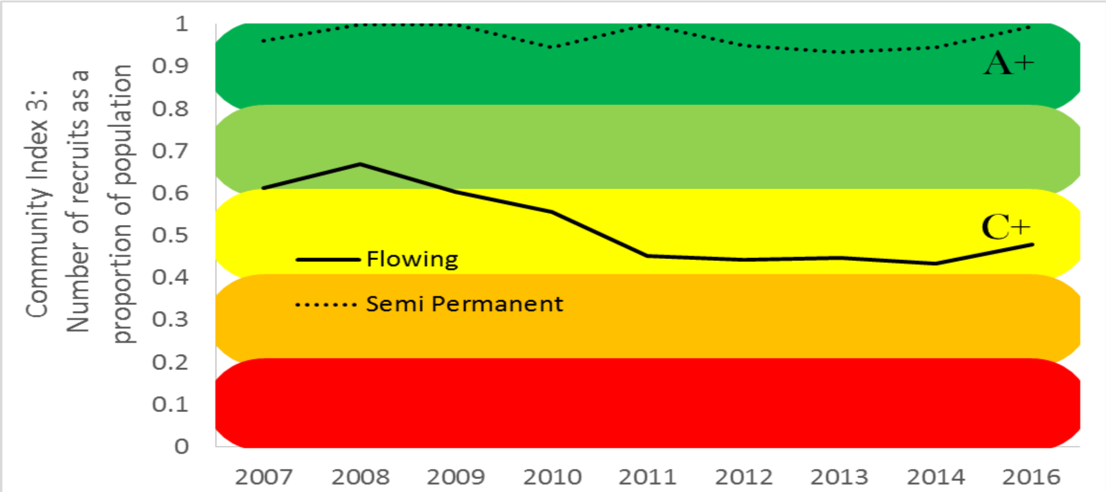

Figure 14. Community Index 3, Average proportion of recruits in the population in BMF during fish condition monitoring, 2007 – 2016. Data were not collected in 2015.

Expected (historic native species) collected (within sites)

The 2016 results showed a slightly better than average site indigenous species richness than the past couple of years, with the sites in the flowing strata (C+) generally having better species lists compared with historical than the semi-permanent sites (D+) (Figure 15). Still, sites generally only average 50% or less of the indigenous species they should be carrying.

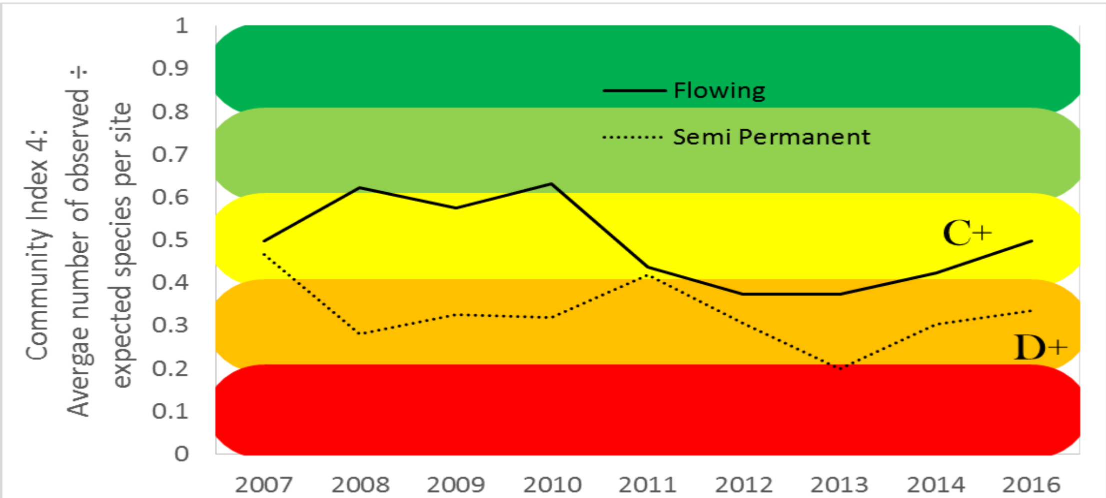

Figure 15.Community Index 4, Average number of historical species ÷ number of expected historical species per site in BMF during fish condition monitoring, 2007 – 2016. Data were not collected in 2015.

Expected (historic native species) collected (across the strata)

The historical species collected across the two strata have remained fairly constant through time with about 8 to 10 species collected. The flowing strata have always returned between 6 and 9 of the historical species, with 8 in 2016 (D+) (Figure 16). The semi-permanent strata returned 6 of the 18 historical species in 2016 (D+), an improvement from the previous three years, but lower than 2007 when 9 species were collected.

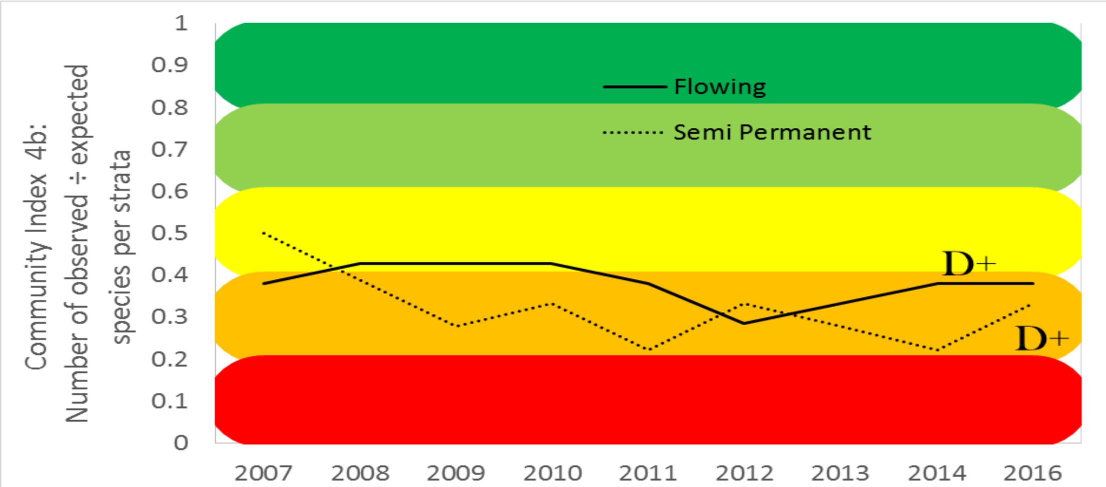

Figure 16. Community Index 4OP, Number of historical species ÷ number of expected historical species per strata in BMF during fish condition monitoring, 2007 – 2016. Data were not collected in 2015.

Number of large bodied native fish above or below length at maturity

The distribution of age cohorts of large-bodied fish in the flowing sites in 2016 showed a marked improvement from 2011- 2014 levels and were the best since monitoring began (Figure 17). Approximately 60% of targeted age cohorts (YOY, Juvenile or Mature) for Murray cod, trout cod, silver perch and golden perch were recorded in every flowing site and allocated a score of C+.

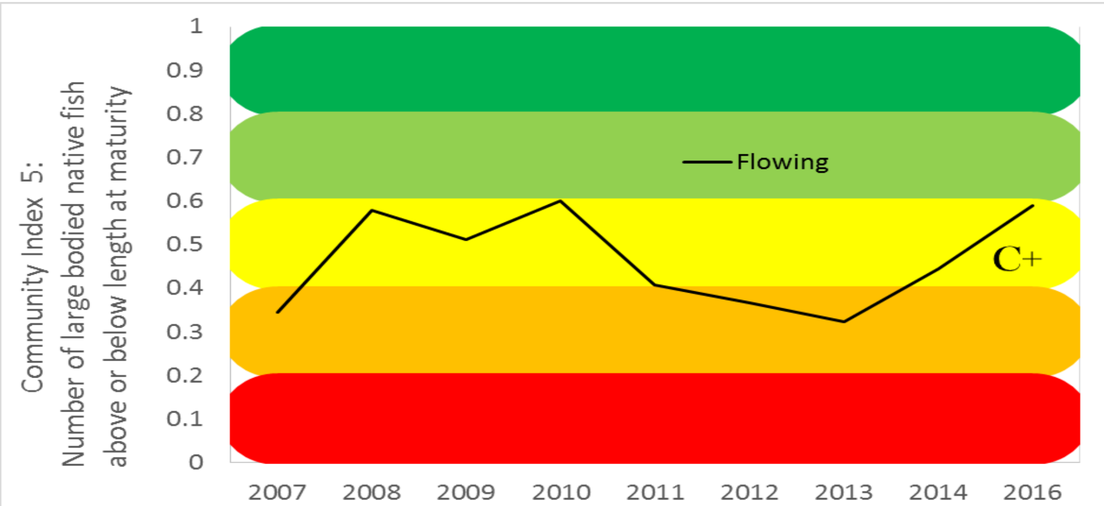

Figure 17. Community Index 5, distribution of age cohorts of large-bodied fish in BMF during fish condition monitoring, 2007 – 2016. Data were not collected in 2015.

Extent, the number of sites each native species is detected in

Approximately three quarters of native fish species that occurred in permanently flowing strata were collected across multiple sites (B+) and in expectation with their historical abundances (Figure 18). Native species collected in semi-permanent habitats were more sparsely distributed than expected and less than 50% of species were as common as they should be (C-). The 2016 results were generally similar to the previous few years.

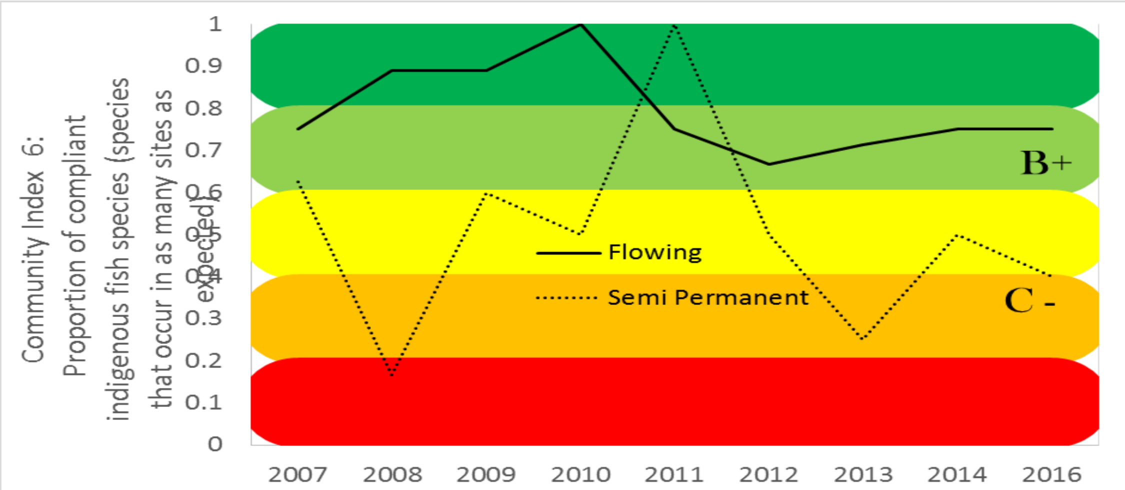

Figure 18. Community Index 6, Extent. The proportion of indigenous fish species that were collected in at least as many sites as expected during BMF fish condition monitoring, 2007 – 2016. Data were not collected in 2015.

3.3.2 Native fish population indices

The proportion of fish abundance that is native

Generally, the proportion of the total catch that is native was greater in permanently flowing habitats (a score of B) than Semi-permanent habitats (a score of C+); however, both strata exhibit high variability across years (Figure 19).

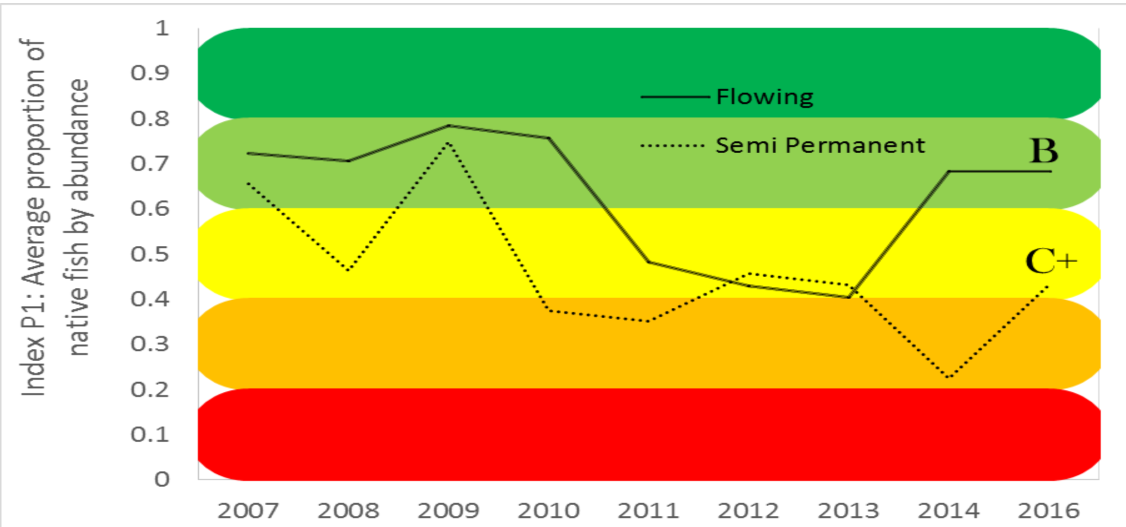

Figure 19. Proportion of fish abundance that is native.

The proportion of fish biomass that is native (average of site scores)

The biomass of fish caught in permanently flowing and semi-permanently flowing strata in BMF in 2016 was dominated by alien fish species and scored a D+ and an E+, respectively (Figure 20). However, the scores were a marked improvement for both strata, and for the flowing sites, these relative biomass scores were the best since monitoring began in 2007.

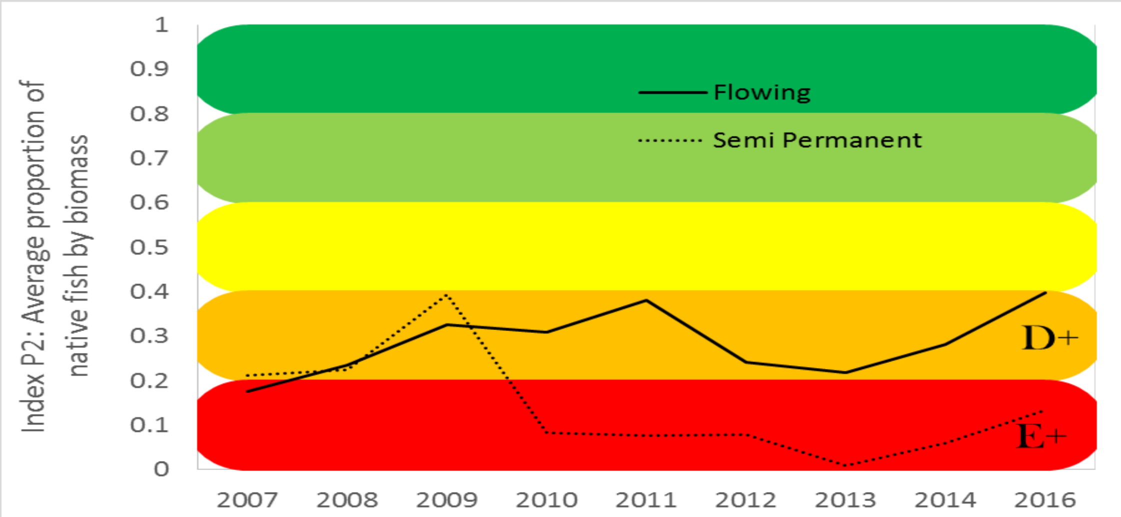

Figure 20. Proportion of fish biomass that is native

The proportion of fish that are native

About 75% of the fish species collected in river sites in BMF in 2016 (B-) were native and this has been a relatively stable score through time (Figure 21). The semi-permanent strata have less than 40% native species per site (scoring a D+), but the trend has improvement since the lows of 2013.

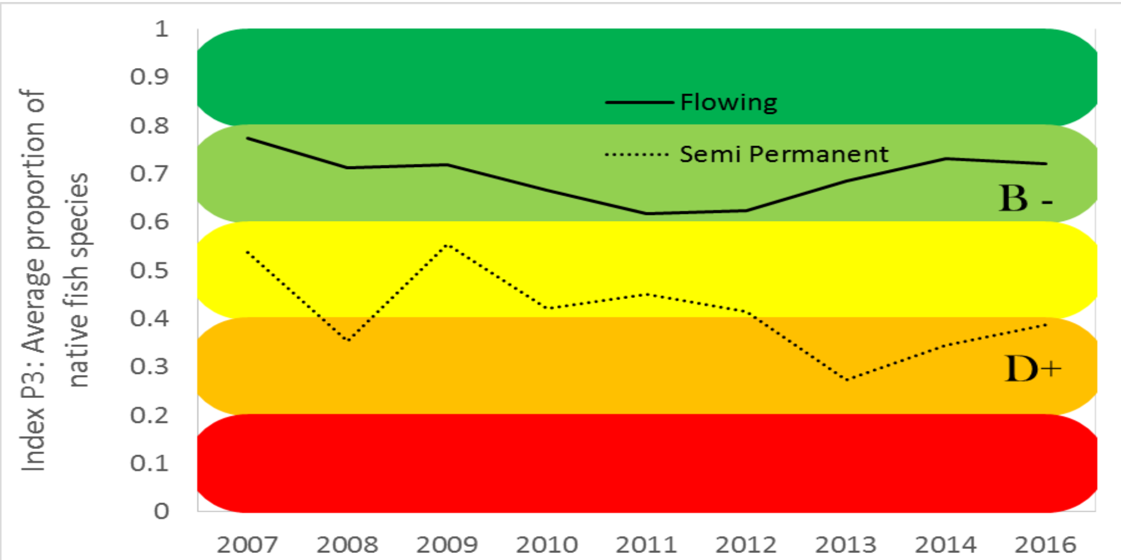

Figure 21. Proportion of fish species that are native

Scores for permanently and semi=permanent flowing strata were similar for fish community indices, whilst permanently flowing strata generally scored higher than semi-permanent strata for fish population indices (Tables 8 and 9). All indices representing the condition of native fish within permanently flowing habitats in 2016, increased or remained stable. Throughout the study, indices showed a marked decline post 2010, followed by an increase to previous levels. Recruitment scores for native fish within permanently flowing strata of the B-MF varied from 1.0 (all sites having recruits) to 0.5 (recruits accounting for half of the population), with the latter score significantly below the target score of 0.75. The number of species with recruits was also lower (0.6) than target expectations, with recent improvement.

Table 7. Scores determined for B-MF fish community indices.

Fish Community Indices							
	1	2	3	4a	4b	5	6
Flowing sites	**A**	**C**	**C+**	**C+**	**D+**	**C+**	**B+**
Semi-permanent	**A -**	**C+**	**A+**	**D+**	**D+**		**C-**

Table 8. Scores determined for B-MF fish population indices.

Fish Population Nativeness			
	1	2	3
Flowing sites	**B**	**D+**	**B-**
Semi-permanent	**C+**	**E+**	**D+**

3.4 Murray cray

Forty four Murray cray were sampled in 2016, all from the four most upstream Murray River sites (Table 10), representing the highest catch since 2009. The majority (n=22) of Murray cray were sampled from MR @ Gulf Creek, the second most upstream site, consistent with 2014 findings. Murray crayfish were not detected in the Edwards River, in 2016. No Murray cray were sampled from MR @ Barmah Lake or MR @ morning glory sites, for the fifth consecutive year. Sixteen Murray cray sampled were male, and 10 of the 28 females were in berry (with eggs) (Appendix 2). Nine female and nine male Murray cray were over the legal size limit of 110 mm. In addition, seven juvenile (< 2 mm occipital carapace length) Murray Cray were captured in larval drift nets set at MR @ Morning Glory (n=3) and MR @ Barmah Choke (n=4) (Table 11).

Table 9. Number of Murray crayfish captured from Murray River monitoring sites, 2007 - 2016.

Site name	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ladgroves Beach	1	4	0	5	0	3	11	2	—	6
Murray River @ Gulf Creek	2	1	5	3	0	6	4	8	—	22
Woodcutters	1	9	7	2	ns	4	3	2	—	6
Picnic Point	1	0	1	8	5	1	9	2	—	10
Barmah - Moira Lake area	1	4	0	1	0	0	1	0	—	
Morning Glory	3	10	39	5	0	0	0	0	—	
Edwards River (d/s regulator)	0	0	0	0	0	0	2	ns	—	
Total	**9**	**28**	**52**	**24**	**5**	**14**	**30**	**14**	**—**	**44**

3.5 Riverine larval drift

One hundred and eighty two eggs and 104 larvae from five native and one alien fish species were collected in drift net sampling in 2015 (2015/16 study; Table 11). Larvae were predominantly carp (86) and Murray cod (50) while eggs were largely silver perch (160) and golden perch (22). Two trout cod larvae were sampled (Table 11). Peak and average densities of target fish are provided in Appendix 4.

A total of 22 golden perch eggs were collected from drift samples undertaken in the River Murray within B-MF from mid to late-October 2015 and coincided with rising water levels (Figure 22). Eggs were collected from MR @ Barmah choke (n=12, middle site) and MR @ Ladgroves Beach (n=10, uppermost site) (Table 11). Peak (137) and average (33) densities of drifting golden perch eggs in 2015 are comparable with 2013 and greater than previous years since 2008. The highest densities of drifting golden perch eggs were in 2005 with peak (>500) and average (>100) densities recorded.

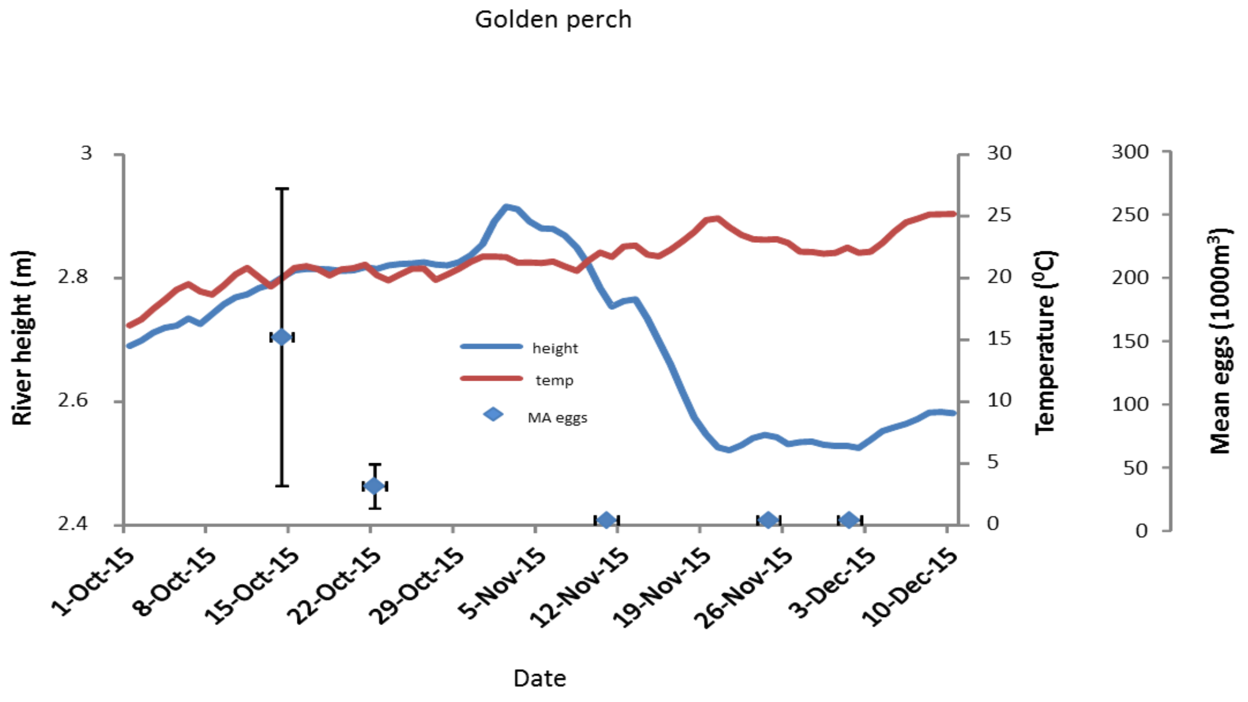

Figure 22. . Mean abundance (+/- s.e.) of drifting Golden perch eggs per sample trip (◆) with river level (blue line) and temperature (red line).

The average density of Murray cod larvae per sampling trip recorded in 2016 was 14.8/m^3, higher than all other sample years since 2003 (Appendix 3). The highest density of drifting Murray cod larvae was recorded at the end of October in five (2004, 05, 06, 08, 09) of the 11 sample years (Figure 24). In 2015, drifting Murray cod larvae peaked in mid-November, which coincided with rising water temperatures (Figure 23). Greater numbers of drifting Murray cod larvae were captured from the mid and upper River Murray drift sites of MR @ Barmah Choke (n=34) and MR @ Ladgroves Beach (n=14) in 2014, with smaller numbers from the lower site of MR @ Morning Glory (n=4) (Table 11).

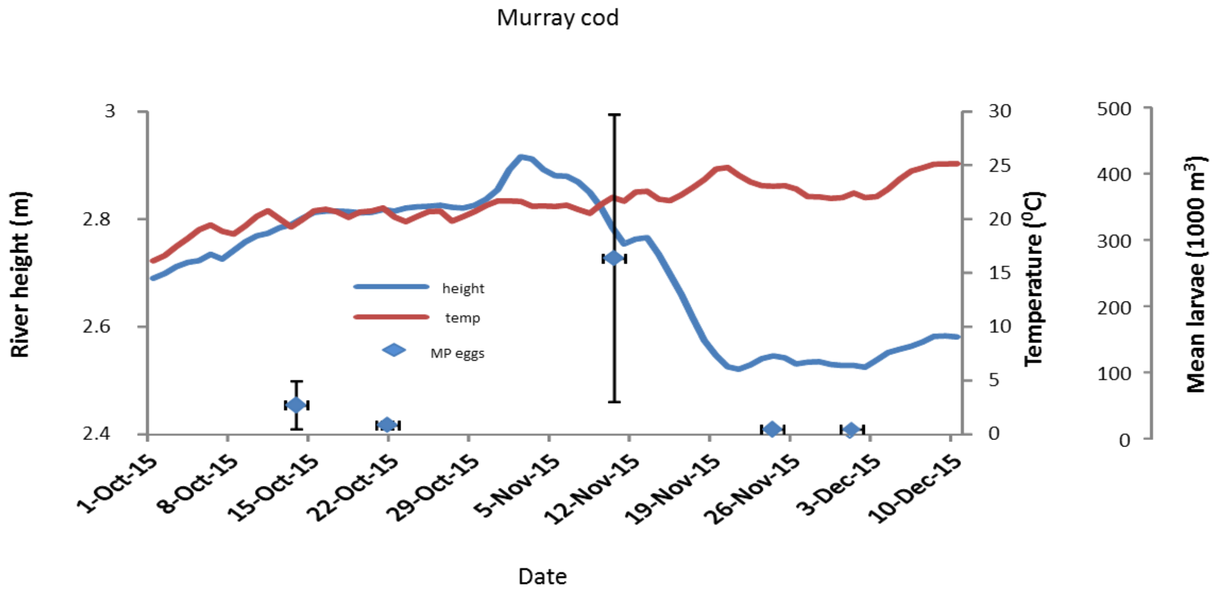

Figure 23. Mean abundance (+/- s.e.) of drifting Murray cod larvae per sample trip (◆) with river level (blue line) and temperature (red line).

Drifting trout cod larvae were captured in 2010 (4), 2013 (1), 2014 (1) and 2015, in low numbers with an average density ≤ 1 larvae m^3 per trip (Appendix 4, Table 11). Drifting trout cod larvae were captured from MR @ Barmah Choke in 2010, from MR @ Morning Glory in 2013, from MR @ Ladgroves beach in 2014 and from Barmah choke and Morning glory in 2015.

One hundred and sixty silver perch eggs were collected from drift samples undertaken in the River Murray within B-MF from October to December 2015 (2015/16 study) with eggs only collected from MR @ Ladgroves Beach (n=160, uppermost site; Table 11). This is in contrast with previous years where silver perch eggs were collected from all three sample sites, with the exception of 2010 where no silver perch eggs were collected. Eggs were collected from late October through to the start of December, with sampling in mid and late November accounting for 40% and 44% of total silver perch eggs, respectively (Figure 24). Egg collection in mid-November coincided with the falling limb of the highest flow event whilst the end of November was characterised by low and variable water levels (Figure24). This is consistent with 2014, where an increase in silver perch eggs was recorded on the falling limb of an environmental flow (e-flow) in mid/late November.

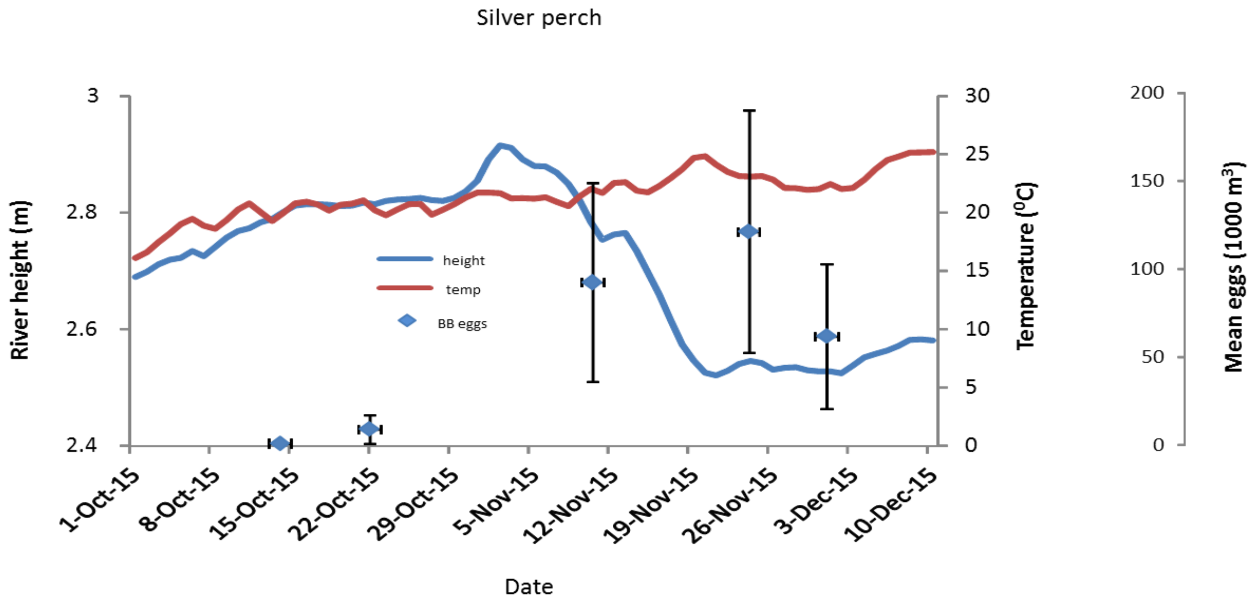

Figure 24. Mean abundance (+/- s.e.) of drifting Silver perch eggs per sample trip (◆) with river level (blue line) and temperature (red line).

Peak and average densities of drifting silver perch eggs per sampling trip (2015) was 117 and 59/m^{-3}, respectively (Appendix 4). These densities were at the lower end of the scale compared with previous years (2003-2014). The highest density of drifting silver perch eggs was 8,275 m^3 in December 2005 with remaining densities < 2,100 m^3. Through the study, silver perch eggs were most abundant at MR @ Ladgroves Beach, followed by MR @ Morning Glory, and least abundant at MR @ Barmah Choke (Table 11). Silver perch eggs were recorded in high abundance (>100) in each year from 2009 to 2015 (Table 11).

The majority (74%) of drifting carp larvae were captured from MR @ Morning Glory in 2015, consistent with previous years (Table 11). An average density per trip of 64 m^{-3} drifting carp larvae was recorded in 2015, similar to 2008 (66 m^3) and 2012 (65 m^3) and greater than 2009 to 2011 (average densities < 18 m^3) (Appendix 4). Drifting carp larvae were generally captured in October throughout the study years (Figure 25). No observed relationship was evident between flow and/or temperature with abundances of drifting carp larvae in 2015/16 (Figure 25).

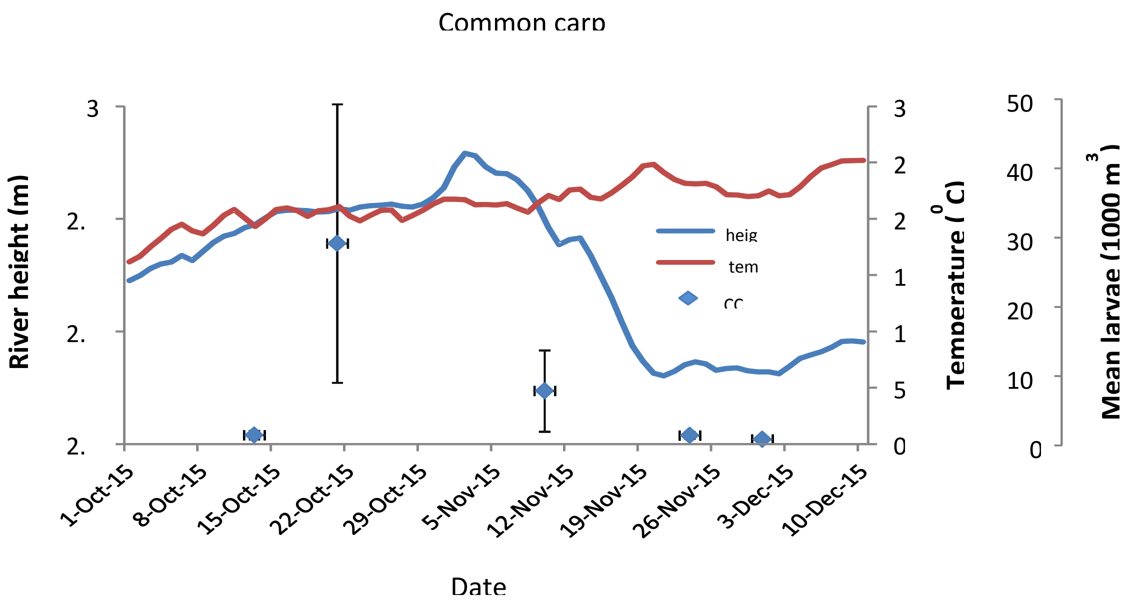

Figure 25. Mean abundance (+/- s.e.) of drifting Common carp larvae per sample trip (◆) with river level (blue line) and temperature (red line).

Table 10. Raw abundances of drifting eggs (in parentheses) and larvae collected from the Murray River, 2008 — 2015. Drift sampling preceded fish sampling and the sample year shown represents the year drift samples were collected (eg. 2008 refers to the 2007/8 sample season).

Larval drift site	Common name	2008	2009	2010	2011	2012	2013	2014	2015
Morning Glory	*Native*								
	Murray cod	16	10	0	2	5	10	2	14
	Trout cod	0	0	0	0	1	0	0	1
	Silver perch	(15)	(234)	0	(106)	(39)	(45)	(8)	0
	Golden perch	0	3	(1)	0	0	(3)	0	0
	Murray crayfish	0	0	0	0	3	9	0	3
	Alien								
	Goldfish	2	0	2	0	0	0	0	0
	Common carp	42	14	8	92	109	515	2	64
	sub-total (eggs and larvae)	***211***	***292***	***47***	***221***	***198***	***586***	***12***	***82***
Barmah Choke	*Native*								
	Murray cod	22	26	10	0	204	11	84	34
	Trout cod	0	4	0	0	0	0	2	1
	Silver perch	2 (15)	2 (154)	0	(7)	(72)	(23)	(16)	1 (0)
	Golden perch	1	3	(7)	0	0	(40)	0	(12)
	Murray crayfish	0	0	0	0	2	4	0	4
	Alien								
	Goldfish	0	0	3	0	1	0	0	0
	Common carp	0	6	0	0	9	1	0	21
	sub-total (eggs and larvae)	***402***	***226***	***46***	***14***	***303***	***86***	***102***	***73***
	Native								
Ladgroves Beach	Murray cod	4	0	38	5	13	14	4	3
	Trout cod	0	0	0	0	0	1	0	0
	Silver perch	(231)	(426)	0	(139)	(559)	(427)	(175)	(160)
	Golden perch	0	0	(22)	1	0	(78)	0	(10)
	Murray crayfish	0	0	0	0	0	0	0	0
	Alien								
	Goldfish	1	0	1	0	0	0	0	0
	Common carp	12	2	0	1	1	0	0	1
	sub-total (eggs and larvae)	***277***	***497***	***121***	***151***	***574***	***556***	***179***	***174***
	Total (eggs and larvae)	**890**	**1015**	**214**	**386**	**1075**	**1228**	**293**	**329**

4 Discussion

4.1. Permanently flowing habitats

The sampling of recruits from all river sites in 2016 indicates that recent conditions within the river were suitable for spawning and survival of recruits and consistent with previous study years. The broad distribution and recent increase in small-bodied native fish from flowing habitats indicates that connectivity between habitats has improved and facilitated the dispersal of these species throughout the waterways of the B-MF. While greater numbers of small-bodied fish within the river strata contributed to improved recruitment by virtue of their automatic inclusion as recruits, increasing proportions of large-bodied native fish recruits suggests improved river conditions in recent years. A lag in productivity following the 2010/11 flood event, coupled with a return to natural flow conditions within and through the forest, likely enhanced adult 'condition' and improved habitat and food for new recruits. While the number of sites with recruits was high, the number of species with recruits and the number of recruits as a proportion of the population scored 0.6 and 0.5, respectively, and may be likely linked with the preference of large-bodied fish for these habitats and detectability. Over the ten year study, a single YOY silver perch (2008, 2015) and two YOY golden perch (2009, 2010) were collected from the Murray River. Lyon et al. (2008) and King et al. (2009) found it difficult to collect YOY golden and silver perch, even following flood events. While this could be related to equipment inefficiencies for collecting this life stage (Dolan and Miranda 2003; Erős et al. 2009), it is possible that recruits for these species are in low abundance or juvenile recruitment is occurring in areas not sampled. Management targets have not been finalised relative to the SRA indicators in this ecosystem. Achieving 75% nativeness (0.75) would place B-MF fish community approximately 20% above the Central Murray River scores in SRA 1 (2008) and SRA 2 (2012) (Davies et al. 2012). It is acknowledged that the recruit abundance sub-indicator should have a lower reference than the others because large-bodied fish need adults to recruit and these could take several years to appear. Nevertheless 75% is deemed a reasonable target for B-MF given that most expected taxa are small-bodied and short-lived (Appendix 1), hence most fish collected should be recruits.

The expectedness score of rivers in 2016 was 0.5, considerably below the target of 0.75. Expectedness declined steeply following the 2010/11 floods, largely due to the absence of small-bodied native fish such as Murray-Darling Rainbowfish (2012 and 2013), un-specked hardyhead (2011 and 2012), flat-headed gudgeon and bony herring (2011 onwards). The decline in native fish species post 2010/11 may be related to flooding/blackwater induced death or recruitment success, changes in connectivity between strata, and/or altered sampling efficiency due to differing water height and flow among years. Competition with and predation by alien fish species may also negatively impact native fish within the riverine habitat.

There are many species that were historically present in B-MF that are now considered locally extinct including; freshwater catfish (*Tandanus tandanus*), river blackfish (*Gadopsis marmoratus*), short-headed lamprey (*Mordacia mordax*), Macquarie perch (*Macquaria australasica*), bony bream (*Nematalosa erebi*), Murray hardyhead (*Craterocephalus fluviatilis*), southern pygmy perch (*Nannoperca australis*), purple spotted gudgeon (*Mogurnda adspersa*), flathead galaxias (*Galaxias rostratus*), mountain galaxias (*Galaxius olidus*) and olive perchlet (*Ambassis agassizii*). For many of these species, particularly the small-bodied wetland specialists, recovery is highly dependent on reintroduction coupled with regular wetland watering to provide conditions required for spawning and recruitment.

While most of these species have been absent for many years, southern pygmy perch have not been sampled since 2008 (Tonkin and Rourke 2008). This species is a wetland specialist and it is likely that the prolonged absence of conditions required for successful recruitment, combined with a short life-span (Tonkin et al. 2008), has directly contributed to its disappearance from the B-MF. Theoretically, higher water levels over the past four years could allow this species to recolonise from sites upstream of the B-MF, though the species' largely sedentary behaviour, and the presence of intervening barriers and large distance to a source population in the Ovens and Goulburn-Broken river systems River, makes this unlikely (MacDonald et al. 2013). If the species fails to naturally re-establish populations in B-MF, a stocking program may be considered. Ideally, this would occur in an area that can be readily provided with environmental water over the spawning season (Tonkin et al. 2008), to maximise the chance of successful spawning and recruitment.

The four large-bodied native fish species known to inhabit the B-MF region were recorded from the Murray River in all sample years. Whilst accurate assessments of true changes in population size are difficult (hence the absence of this metric in the reporting), several species including Murray cod, trout cod and golden perch were recorded in greater abundances. Increasing recruitment and distribution of cohort indices show that Murray cod and trout cod populations are increasingly robust (Peoples and Frimpong 2012). The length frequency data support the assertion that B-MF cod populations are self-sustaining and robust. Our findings also indicate that recent conditions within the river, (e.g. productivity and flows) were more favourable in recent years compared with conditions immediately following the 2010 floods and that these improved conditions are likely to have contributed to enhanced survival of juvenile and adult cod. Whilst the abundance of adults within the golden perch population dramatically increased in the last few years, juvenile abundance has remained consistently low across years, indicating that juvenile fish are likely to be in limited numbers, or that sampling methods were not suited to the collection of this life-history stage.

River sites have supported high numbers of carp throughout the condition monitoring program, and likely influenced population indices in permanent flowing habitats such as overall native abundance. The dramatic decline in native fish abundance (index 1) from 2010 (0.76) to 2011 (0.45) coincided with a rapid increase in the carp population, driven by YOY (>150 mm fork length) carp which accounted for 95% of the

2011 carp population. Similarly, the subsequent decline in carp from 2014 onwards was linked with an increase (from 0.4 to 0.7) in native fish abundance, particularly large-bodied natives. The absence of prolonged and protracted flooding of B-MF will likely restrict suitable conditions for carp spawning and recruitment in the future.

4.1.1 Murray cray

This project has now amassed nine years of catch data on Murray cray, a species restricted to riverine habitats. Raw catch of this species ranged from a low of five individuals in 2011 to a high of 52 in 2009. In the five sample years following flooding, fewer total numbers of this species were caught compared with the four year period pre-flood, however, numbers of Murray cray increased to pre-flood levels in 2016. While sampling variation may be responsible for fluctuations in numbers, it is of concern that this species was not captured from the two most downstream sites in 2011, 2012, and 2016 which were impacted by blackwater, with only a single individual caught in 2013. This is consistent with a recent investigation where an 81% decline in Murray cray abundance was recorded following the 2010/11 blackwater event in the Murray River (McCarthy et al. 2014).

The blackwater event resulted in large numbers of Murray cray leaving the water due to low dissolved oxygen levels (King et al. 2012, McCarthy et al. 2014). While they are exposed on the banks they are at increased risk of predation and poachers. Thus, it is reasonable to suggest that the Murray cray population in blackwater affected areas was substantially reduced and that the species is yet to recover in these areas. Recovery is likely to be slow given Murray cray have a small home range and limited dispersal (Ryan 2005, Gilligan et al. 2007), and take between six to 10 years to mature (Gilligan et al. 2007). The increase in total number of Murray cray caught this year upstream of blackwater affected areas is more likely related to sampling variation than population change. A distribution-wide study is currently underway to benchmark distribution and abundance (mark-recapture methodology), assess reproductive condition, and to determine whether new fishing regulations assist in the recovery of populations. The capture of five (2012), 13 (2013) and seven (2015) drifting larval Murray cray from sites previously impacted by blackwater indicates that these sites and those directly upstream are suitable spawning grounds for this species and that we may expect to sample adults from these sites in coming years.

4.2. Semi-permanent flowing habitats

In general, community and population indices for native fish in semi-permanent habitats scored below 0.5, well below the target level of 0.75, and declined over the study, with recent improvement noted in the last sample year. The sharp decline in scores coincided with the 2010 floods and blackwater event which likely impacted native fish within semi-permanent flowing habitats through increasing displacement due to high water velocities coupled with a loss of preferred habitat and post-flood conditions being more favourable to alien species. Conditions within semi-permanent flowing habitats (including non-flowing reaches of creeks) may benefit alien fish species such as carp, gambusia and goldfish due to more favourable habitat conditions post-flood, their higher tolerance to low dissolved oxygen concentrations and the comparatively higher fecundity of alien fish species.

The dramatic decline across all native fish indices (with the exception of Entent [index 6]) within B-MF semi-permanent habitats in 2011 and 2014, coincided with marked increases in goldfish and gambusia, with subsequent reversal of indices closely linked with declining small-bodied alien fish numbers. This suggests that conditions, such as increasing availability of shallow, warm water preferred by gambusia (Humphries et al. 1999, Lintermans 2007) in the semi-permanent flowing habitats were favourable to gambusia in these sample years). The marked variation in gambusia numbers across years highlights the high fecundity and rapid recolonisation of habitats by this species (Tonkin et al. 2011a) and other alien fish species which may be responsible, in part, for the competitive exclusion of small-bodied natives from these habitats, as indicated by comparatively lower numbers post-flood.

Changes in water level within the B-MF provided periods of connectivity between permanent and semi-permanent flowing habitats and also periods of isolation. Whilst periods of connectivity facilitated access to off-channel habitats for breeding in small-bodied species such as Australian smelt, Murray-Darling Rainbowfish and gudgeons, improved connectivity likely provided carp (spawned after the 2010/11 flood) with access to semi-permanent flowing habitats in 2015, that may have contributed to declines in nativeness and expectedness indices within this strata.

The dominance of alien fish species in off-channel habitats following the 2010/11 floods and subsequent blackwater event demonstrates that the recolonisation capacity of these species following flooding is greater than natives. While small-bodied species tend to have relatively broad spawning periods, optimal conditions for recruitment are not well understood (Humphries et al. 2002). It is possible that the dramatic increase in alien fish species within semi-permanent flowing habitats has restricted the ability of small-bodied natives to re-colonise and/or maintain their populations within these habitats.

4.3. Riverine spawning assessment

The eighth year of egg/larval drift sampling has shown that the main channel of the Murray River remains a spawning habitat for eight species of native fish, including all four targeted large-bodied native species (golden perch, silver perch, Murray cod and trout cod). Twenty two golden perch and 160 silver perch eggs along with 51 Murray cod and two trout cod larvae were collected during the 2015/16 B-MF drift sampling, representing a continued recent increase in golden perch numbers, lower silver perch abundance and maintenance of Murray and trout cod numbers over the study.

In the River Murray at Barmah, golden perch eggs were first collected in mid-October 2015 on a steady rise in river height (volume at first capture was 13,370 ML/d) at a water temperature of 20.3 °C. Whilst the timing was similar to 2013, eggs were captured as water levels dropped following a managed overbank (volume at first capture = 17950 ML/D) supporting previous research indicating that spawning magnitude is associated with high flows in both flood and within channel flow pulse years (King et al. 2007, 2008 and 2009. With the exception of 2013, higher numbers of golden perch eggs were collected in 2015 (total = 22, average density = 32.6 individuals per 1000 m^3) compared with surveys of eggs conducted from 2008 - 2012 in the Murray River at B-MF, where eggs were only sampled in 2010 (i.e. 2010/11: total = 3, average density = 6.7 individuals per 1000 m^3). The low levels or failure of golden perch spawning in the Murray River at Barmah between 2008 - 2012 was thought to be a result of either low or stable flows during the core spring spawning window (see King et al. 2009) or disruption of spawning the year of and year following the 2010/11 blackwater event (Raymond et al. 2013). Thus the return of more variable overbank flows in 2013 and within channel pulses in 2015 did result in an increase in golden perch spawning intensity, with densities of drifting eggs declining or not detected at all during relatively stable flows beyond early November when water temperatures are hypothesised to further enhance spawning of the species (e.g. Zampatti and Leigh 2013).

An additional sampling trip was conducted to investigate the spawning response to a minor flow pulse in mid November 2015. We sampled during the falling limb of the flow pulse, and recorded no golden perch eggs, then sampled the rising limb three days later and recorded golden perch and silver perch eggs. Whilst the densities of drifting perch eggs were low and not at the levels recorded two weeks previous, it does highlight the potential of this kind of delivery. Further flow manipulation and monitoring to test the flow and spawning relationship would benefit the development of water delivery strategies for improved environmental outcomes, particularly the potential for delivering water without delving into the environmental water parcel, or during times when such water cannot be accessed.

Silver perch eggs were first collected in late October 2015 under stable flows (volume at first capture was 13,958 ML/d) at a temperature of 20°C. However, peak densities of drifting silver perch eggs were sampled throughout November under a range of flows including the receding limb and low variable flows. No silver perch eggs were sampled in 2011, indicating that silver perch either did not spawn in that year (2010/11) or that condition for the collection of their eggs was unsuitable.

The presence of Murray cod larvae at Morning Glory in 2011, 2012, 2014 and again in 2016 indicates that Murray cod spawned within or directly upstream of this site, and that the absence of Murray cod larvae in 2010 was possibly due to hypoxic blackwater conditions. The low number of Murray cod larvae at Morning glory following the 2010 flood/blackwater event indicates that either adults have been slow to recolonise affected sites, or that the fitness and consequent fecundity of resident adults has decreased. In either case, the change in larval abundance of Murray cod highlights the potential impact of hypoxic blackwater on the spawning of large-bodied native fish as noted by the reduction in drifting larvae/eggs of the four large-bodied native fish species post 2010.

A total of 51 drifting Murray cod larvae were sampled from B-MF in 2016, at an average drift density of 14.6 individuals per 1000 m^3, the highest recorded in the last eight years. This increase in drifting Murray cod larvae is likely linked with the highest recorded abundance of Murray cod captured during permanently flowing site surveys along with the highest proportion of adult fish within the population over the past eight years of sampling. The importance of considering the status of adults when interpreting spawning and recruitment outcomes are often ignored in the literature and is highlighted in Tonkin et al. (2015).

Murray cod larvae were collected from mid October to mid November, similar to previous years and consistent with numerous other studies (Humphries 2005; Koehn and Harrington 2006; King 2009). Average densities have changed relatively little over the eight year study, supporting findings of previous studies which indicate that flow conditions have little influence on the presence and densities of Murray cod larvae (Humphries 2005, Koehn and Harrington 2006, King et al. 2008) and that Murray cod spawning is closely related to the time of year and/or temperature (King et al. 2016).

We suggest two modifications to the 2016/17 sampling to enhance our understanding of the impact of flow regime on large-bodied native fish species within the B-MF Icon site. Firstly, that larval drift sampling is conducted weekly and under differing pulsed flow deliveries to provide a more detailed understanding of the relationship between fish spawning with flows, temperature and flow/temperature interactions. Secondly, that larval drift sampling commence at the beginning of October as peak densities of golden perch eggs and drifting carp larvae are often recorded in mid-October.

Conclusion

The overall condition of the fish community in B-MF in 2016 was good, with indices showing stable or improved scores since 2014, yet below the target of 0.75. Recruitment, expectedness and nativeness indices for native fish across years and strata were fair to good and showed recent improvement. Native fish recruitment in river habitats was high and stable across sample years. Approximately 60% of native species within flowing habitats successfully recruited individuals into their respective populations in 2016, following a decline in the two years post 2010/11 flooding and associated blackwater event. Expectedness was stable and low while the number of sites each native species was detected in remained stable post-2010 flooding. In general, community and population indices indicate native fish stability within the riverine strata across years and were more variable in non-river habitats.

Whist the program will continue to provide valuable information about the overall condition of its fish populations, identifying the specific mechanisms driving these trends, particularly aspects of the icon sites watering regime, remain uncertain (excluding the riverine spawning component). Therefore, whilst this long term monitoring program will continue to provide overarching trends in the condition of fish populations in BM, targeted intervention monitoring is best placed to identify cause and effect of these dynamics. Continued condition monitoring in B-MF will enable long-term changes in the fish community to be documented. The current program has provided valuable data that can be used to assist in developing a more robust sampling program to address new more clearly defined objectives.

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Appendix 1. B-MF native fish historical catch

Native fish expected to occur within B-MF. Reference Condition for Fish (RCF) score is from the MDB SRA Central Murray River, Middle Section. Life guilds (life cycles) are short-lived (SL <3 years), intermediate-lived (IL ≥ 3 years to 6 years) and long-lived (LL > 6 years).

Common Name	Scientific name	RCF Score	Life Guild
Murray cod	*Maccullochella peelii*	5	LL
Trout cod	*Maccullochella macquariensis*	(5)	LL
Golden perch	*Macquaria ambigua ambigua*	5	LL
Silver perch	*Bidyanus bidyanus*	5	LL
Freshwater Catfish	*Tandanus tandanus*	3	LL
Bony Bream	*Nematalosa erebi*	3	IL
River Blackfish	*Gadopsis marmoratus*	3	IL
Short-headed Lamprey	*Mordacia mordax*	(3)	*
Macquarie Perch	*Macquaria australasica*	(3)	LL
Murray Darling	*Melanotenia fluviatilis*	3	SL
Murray Hardyhead	*Craterocephalus fluviatilis*	1	SL
Unspecked Hardyhead	*Craterocephalus stercusmuscarum fulvus*	3	SL
Australian smelt	*Retropinna semoni*	5	SL
Carp gudgeon	*Hypseleotris spp.*	5	SL
Flathead Gudgeon	*Philypnodon grandiceps*	3	IL
Southern Pygmy Perch	*Nannoperca australis*	3	SL
Purple Spotted Gudgeon	*Mogurnda adspersa*	1	IL
Flathead Galaxias	*Galaxias rostratus*	3	IL
Mountain Galaxias	*Galaxius olidus*	1	IL
Olive Perchlet	*Ambassis agassizii*	3	SL
Dwarf flathead Gudgeon	*Philypnodon macrostomus*	1	SL

* Short-Headed Lampreys were not included in the recruitment calculations because of insufficient knowledge of their biology.
Riverine only species are shown in parentheses.
Source: Muschal et al. (2010)

Appendix 2. B-MF Catch data

Sitename	Fullcode	_2007	_2008	_2009	_2010	_2011	_2012	2013	2014	2016
Aratula Creek	CARAUR	1	15	3	3	66				
Aratula Creek	CRASTE				2	5				
Aratula Creek	CYPCAR	13	25	3	3	3	3	1		11
Aratula Creek	GAMHOL	89	21		434	14	13	31		414
Aratula Creek	HYPSPP	2	47	23	806	15	36	5		139
Aratula Creek	MELFLU				11	1				
Aratula Creek	MISANG		17		2	24	1			
Aratula Creek	PHIGRA	4			15		3			40
Aratula Creek	PHIMAC									34
Aratula Creek	RETSEM	13				139	1			2
Barmah - Moira Lake area	BIDBID	1	5	1	1	6	1	1		
Barmah - Moira Lake area	CARAUR				4	1			1	
Barmah - Moira Lake area	CRASTE	1	10		31					1
Barmah - Moira Lake area	CYPCAR	58	46	32	9	6	5	349	627	187
Barmah - Moira Lake area	EUAARM	1	4		1			1		
Barmah - Moira Lake area	GAMHOL		3		7					
Barmah - Moira Lake area	HYPSPP		17		1					
Barmah - Moira Lake area	MACAMB	4		3		22	2	6	3	13
Barmah - Moira Lake area	MACMAC	4	6	4	6			1		17
Barmah - Moira Lake area	MACPEE	1	4	1	6	8		4	3	19
Barmah - Moira Lake area	MELFLU		6		41					6
Barmah - Moira Lake area	RETSEM	43	375	47	566	77	8		488	159
Barmah Lake	BIDBID						3			
Barmah Lake	CARAUR	29	20	3	149	1	35	7	56	27
Barmah Lake	CRASTE			11		1				
Barmah Lake	CYPCAR	15	60	44	2	327	13	118	10	5
Barmah Lake	GAMHOL			2		116			8	166
Barmah Lake	HYPSPP				5	3				
Barmah Lake	MELFLU			2		2				
Barmah Lake	MISANG	2					1	1		1
Barmah Lake	RETSEM	6		102	3	54	1	4		6
Budgee Creek	BIDBID				1					
Budgee Creek	CARAUR		16	11	1		8	1	26	16
Budgee Creek	CRASTE			14						
Budgee Creek	CYPCAR	26	38	4	39		10	48	83	25
Budgee Creek	GAMHOL	1	1	26	2		13	2	2	47
Budgee Creek	HYPSPP	1	6	39	24		3	7	7	
Budgee Creek	MACAMB	1								
Budgee Creek	MACPEE		1					1	1	
Budgee Creek	MELFLU		1	2						
Budgee Creek	MISANG						13	2	8	2
Budgee Creek	PERFLU								1	
Budgee Creek	RETSEM	99	98	66	25		20	33	6	17
Edward River 5km DS regulator	BIDBID			1		1	1			1

Edward River 5km DS regulator	CARAUR	9	3	9	9	32	1			
Edward River 5km DS regulator	CRASTE	82	436	7	512			9		155
Edward River 5km DS regulator	CYPCAR	8	15	36	42	217	23	98		77
Edward River 5km DS regulator	GAMHOL			15	1	50				
Edward River 5km DS regulator	HYPSPP	1	19	152	5	1	1	1		2
Edward River 5km DS regulator	MACAMB	1	3	4	3	1	2	3		1
Edward River 5km DS regulator	EUAARM							2		
Edward River 5km DS regulator	MACMAC	8			1		1			1
Edward River 5km DS regulator	MACPEE	9	2	5	6		1			2
Edward River 5km DS regulator	MELFLU	207	2	33	1	35				
Edward River 5km DS regulator	PERFLU				1					
Edward River 5km DS regulator	PHIGRA			1						
Edward River 5km DS regulator	RETSEM	33	9	7	50	1	1	22		136
Edward River DS Gulpa Creek	BIDBID		2						1	
Edward River DS Gulpa Creek	CARAUR	12	2	4	2	149			2	
Edward River DS Gulpa Creek	CRASPP			1				78		
Edward River DS Gulpa Creek	CRASTE	23	7	5	8					
Edward River DS Gulpa Creek	CYPCAR	15	27	17	27	53	15	25		11
Edward River DS Gulpa Creek	GAMHOL			5	1	2		1		
Edward River DS Gulpa Creek	HYPSPP	1	2	21	14			7		
Edward River DS Gulpa Creek	MACAMB	5		5	3	2	1	5		
Edward River DS Gulpa Creek	MACMAC			3	1					
Edward River DS Gulpa Creek	MACPEE	2	1	8	6	5		2	2	
Edward River DS Gulpa Creek	MACSPP			1						
Edward River DS Gulpa Creek	MELFLU	1	3	12	5					
Edward River DS Gulpa Creek	MISANG						2			
Edward River DS Gulpa Creek	RETSEM	105	10	11	18	98	6	13		166
Fishermans Bend Lagoon	CRASTE	91	1		2					
Fishermans Bend Lagoon	CYPCAR	9			2	1	3	6		14
Fishermans Bend Lagoon	GAMHOL	8	14	23	450	9	6			57
Fishermans Bend Lagoon	HYPSPP	6	346	101	428	20	48	28		413
Fishermans Bend Lagoon	MELFLU						1			
Fishermans Bend Lagoon	MISANG	1		1		1		1		
Fishermans Bend Lagoon	NANAUS	1								
Fishermans Bend Lagoon	PERFLU	47								
Fishermans Bend Lagoon	PHIGRA	3	9	4	19		34	1		42
Fishermans Bend Lagoon	PHIMAC								4	
Fishermans Bend Lagoon	RETSEM	101								
Flat Swamp	CARAUR	17				12	1	ns	2	33
Flat Swamp	CRASTE					6		ns		
Flat Swamp	CYPCAR	12				16	10	ns	9	14
Flat Swamp	GAMHOL	80				73	4	ns	15	30
Flat Swamp	HYPSPP	660				1	5	ns	21	100
Flat Swamp	MELFLU					21		ns		1
Flat Swamp	MISANG	155				1	2	ns	1	7
Flat Swamp	NANAUS	4						ns		
Flat Swamp	PERFLU	4						ns		
Flat Swamp	PHIGRA									1

Flat Swamp	PHIMAC	2						ns		
Flat Swamp	RETSEM	2				150		ns	20	13
Gulf Creek @ Four Mile	CARAUR	3		42	68		49	ns	2312	153
Gulf Creek @ Four Mile	CRASTE			1		1		ns		2
Gulf Creek @ Four Mile	CYPCAR	13		73	26	1	19	ns	37	167
Gulf Creek @ Four Mile	GAMHOL	2		401	283	3	62	ns	3082	236
Gulf Creek @ Four Mile	HYPSPP	42		246	120	1	3	ns	161	61
Gulf Creek @ Four Mile	MISANG	10		57	22	3	18	ns	17	6
Gulf Creek @ Four Mile	NANAUS	7						ns		
Gulf Creek @ Four Mile	PERFLU	1						ns		
Gulf Creek @ Four Mile	RETSEM	2		8		30	29	ns	2	22
Gulpa Creek	CARAUR	1	6	10	1	218	3	18		16
Gulpa Creek	CRASTE	2				2				
Gulpa Creek	CYPCAR	7	7	2	4	176	38	12		30
Gulpa Creek	GAMHOL					160				
Gulpa Creek	HYPSPP		1	7		32	9	1		2
Gulpa Creek	MACAMB		1							
Gulpa Creek	MACPEE	1	1	1	3			1		1
Gulpa Creek	MELFLU	1		1		2				
Gulpa Creek	MISANG					2				
Gulpa Creek	PERFLU									1
Gulpa Creek	RETSEM	6	54	1		25	4	3		71
Hut Lake	CARAUR					2	12	ns	1	1
Hut Lake	CRASTE					4	5	ns	1	
Hut Lake	CYPCAR					3	3	ns		4
Hut Lake	GAMHOL					5	170	ns	2	90
Hut Lake	HYPSPP						7	ns	4	184
Hut Lake	MELFLU					4	1	ns		
Hut Lake	MISANG								38	40
Hut Lake	RETSEM					1	11	ns	5	11
Gundry’s Old Bridge	CARAUR									26
Gundry’s Old Bridge	CYPCAR									91
Gundry’s Old Bridge	GAMHOL									25
Gundry’s Old Bridge	HYPSPP									546
Gundry’s Old Bridge	MISANG									1
Gundry’s Old Bridge	RETSEM									132
Ladgroves Beach	BIDBID		1		2		1			
Ladgroves Beach	CARAUR		2		12	2				
Ladgroves Beach	CRASTE	33	508	164	474					2
Ladgroves Beach	CYPCAR	33	64	15	58	9	1	13	68	63
Ladgroves Beach	EUAARM	1	4		5		1	11	2	6
Ladgroves Beach	GAMHOL				1					
Ladgroves Beach	HYPSPP	7			1		1		3	
Ladgroves Beach	MACAMB	4		1		1	1	6	6	4
Ladgroves Beach	MACMAC	1	15	6	10	1	2	2	8	20
Ladgroves Beach	MACPEE	7	24	5	14	6	1		6	14
Ladgroves Beach	MELFLU		4		30	2				2
Ladgroves Beach	RETSEM	264	254	121	811	257	4	45	363	50

Moira Lake	BIDBID	1								
Moira Lake	CARAUR	6			10	7				10
Moira Lake	CYPCAR	21			80	5		2		32
Moira Lake	GAMHOL				8		20	12		3
Moira Lake	HYPSPP	24			2	1	5			2
Moira Lake	MISANG						1			
Moira Lake	RETSEM	27				187	2			1
Morning Glory	BIDBID	1	2	2	2	2	1	7	1	1
Morning Glory	CARAUR		17	26	84	85	1			1
Morning Glory	CRASTE		19	22	163					
Morning Glory	CYPCAR	26	29	10	35	591	1	27	45	40
Morning Glory	EUAARM	3	10	39	5					
Morning Glory	GAMHOL		1			1				
Morning Glory	HYPSPP	3	2		2	1				
Morning Glory	MACAMB		3	3	1	2	1	5	6	5
Morning Glory	MACMAC		3	1	2			1		5
Morning Glory	MACPEE	1	9	3	7		1		1	7
Morning Glory	MELFLU		13							
Morning Glory	MISANG		1							
Morning Glory	NEMERE				5					
Morning Glory	PERFLU	1			1					
Morning Glory	RETSEM	26	171	6	209	13	1	38	178	68
Murray River @ Gulf Creek	BIDBID		11	7	3	2	1		1	1
Murray River @ Gulf Creek	CARAUR		14		20	6	1			
Murray River @ Gulf Creek	CRASTE	90	442	92	1941					35
Murray River @ Gulf Creek	CYPCAR	43	117	78	153	14	13	74	75	86
Murray River @ Gulf Creek	EUAARM	2	1	5	3		1	4	8	22
Murray River @ Gulf Creek	HYPSPP	2	4		1					
Murray River @ Gulf Creek	GAMHOL									1
Murray River @ Gulf Creek	MACAMB	4	14	8	9	2	1	9		24
Murray River @ Gulf Creek	MACMAC		4	6	2	1			5	5
Murray River @ Gulf Creek	MACPEE	8	14	13	15	3	2	3	6	18
Murray River @ Gulf Creek	MELFLU		38	5	240				1	19
Murray River @ Gulf Creek	MISANG			2						
Murray River @ Gulf Creek	NEMERE				53					
Murray River @ Gulf Creek	RETSEM	52	177	933	424	79	3	6	28	35
Picnic Point	BIDBID		1			2	1			
Picnic Point	CARAUR		1	11	8		0		2	1
Picnic Point	CRASTE	4	145	58	337				3	65
Picnic Point	CYPCAR	20	25	29	49	12	24	160	303	102
Picnic Point	EUAARM	1		1	8	5	1	9	2	10
Picnic Point	GAMHOL				1					
Picnic Point	HYBRID		1							
Picnic Point	HYPSPP	1	26	36	3					
Picnic Point	MACAMB	2		1	2	1	1	6	3	10
Picnic Point	MACMAC	3	9	4	7		1	4	2	5
Picnic Point	MACPEE		6	2	19	6	1	1	2	12
Picnic Point	MACSPP		1							

Picnic Point	MELFLU		11	7	157					29
Picnic Point	NEMERE				1					
Picnic Point	RETSEM	45	157	300	990	180	1	2	300	102
Pinch Gut Lagoon	CARAUR					1		7		3
Pinch Gut Lagoon	CRASTE					1				
Pinch Gut Lagoon	CYPCAR					15	3	5		14
Pinch Gut Lagoon	GAMHOL	67				423	2	226		19
Pinch Gut Lagoon	HYPSPP	309		2		16	8	248		127
Pinch Gut Lagoon	MELFLU					1				
Pinch Gut Lagoon	MISANG					5	7			
Pinch Gut Lagoon	NANAUS	1								
Pinch Gut Lagoon	PERFLU									20
Pinch Gut Lagoon	PHIGRA	1								
Pinch Gut Lagoon	RETSEM	2				26	5			
Tarma Lagoon	CARAUR									380
Tarma Lagoon	CYPCAR									256
Tarma Lagoon	GAMHOL									1112
Tarma Lagoon	HYPSPP									154
Tarma Lagoon	MISANG									84
Tarma Lagoon	PERFLU									1
Tarma Lagoon	RETSEM									1
Tongalong Creek	BIDBID			1		8				
Tongalong Creek	CARAUR	3	79	2	7	41	4	1	6	
Tongalong Creek	CRASTE	11	1	56	3	45		3	2	
Tongalong Creek	CYPCAR	8	59	5	26	294	84	31	16	2
Tongalong Creek	GAMHOL		5	25	1	57	3	8		40
Tongalong Creek	HYPSPP	2	1		10	3	11	29	9	2
Tongalong Creek	MACAMB	1	1		1	5				2
Tongalong Creek	MACMAC									4
Tongalong Creek	MACPEE		1	3		11		3	9	2
Tongalong Creek	MELFLU			2	2	18			1	
Tongalong Creek	MISANG					12		1		4
Tongalong Creek	RETSEM	72	45	100	15	121	44	23	69	9
Toupna Creek	CARAUR	7	2		22	14				37
Toupna Creek	CYPCAR	1			45	5	10	11		4
Toupna Creek	GAMHOL	51	204		147	85	1	1		12
Toupna Creek	HYPSPP	512	40		60	1	1	12		101
Toupna Creek	MELFLU	1			17	1				
Toupna Creek	MISANG	9	8			5				
Toupna Creek	NANAUS	33								
Toupna Creek	PERFLU									1
Toupna Creek	PHIGRA	20								1
Toupna Creek	PHIMAC									1
Toupna Creek	RETSEM					12				
Tullah Creek	CARAUR	79				110	4	ns	477	dry
Tullah Creek	CYPCAR	33				1	11	ns	35	dry
Tullah Creek	GAMHOL	76				143	4	ns	474	dry
Tullah Creek	HYPSPP	159					6	ns	73	dry

Tullah Creek	MELFLU					1		ns		dry
Tullah Creek	MISANG	48					10	ns	56	dry
Tullah Creek	PERFLU						1	ns		dry
Tullah Creek	PHIGRA	5						ns		dry
Tullah Creek	RETSEM	4				257	20	ns	4	dry
Woodcutters	BIDBID	2	2		1		1	1		
Woodcutters	CARAUR		6	1			0	1		
Woodcutters	CRASTE	12	376	76	32					
Woodcutters	CYPCAR	14	130	15	8		22	52	37	73
Woodcutters	EUAARM	1	9	7	2		3	3	2	5
Woodcutters	GAMHOL	1	3		21					
Woodcutters	HYPSPP	344	615	34	7					
Woodcutters	MACAMB	4					3	5	3	3
Woodcutters	MACMAC		10	1	5		1	1	4	12
Woodcutters	MACPEE		27	4	9		1	2	2	11
Woodcutters	MACSPP		1							
Woodcutters	MELFLU		2	1	1					
Woodcutters	PHIGRA		9							
Woodcutters	RETSEM	40	197	30	1186		3	1	436	51

Appendix 3. Murray cray catch data

Length, weight, sex and presence of eggs in Murray crayfish captured from Murray River sample sites in 2016.

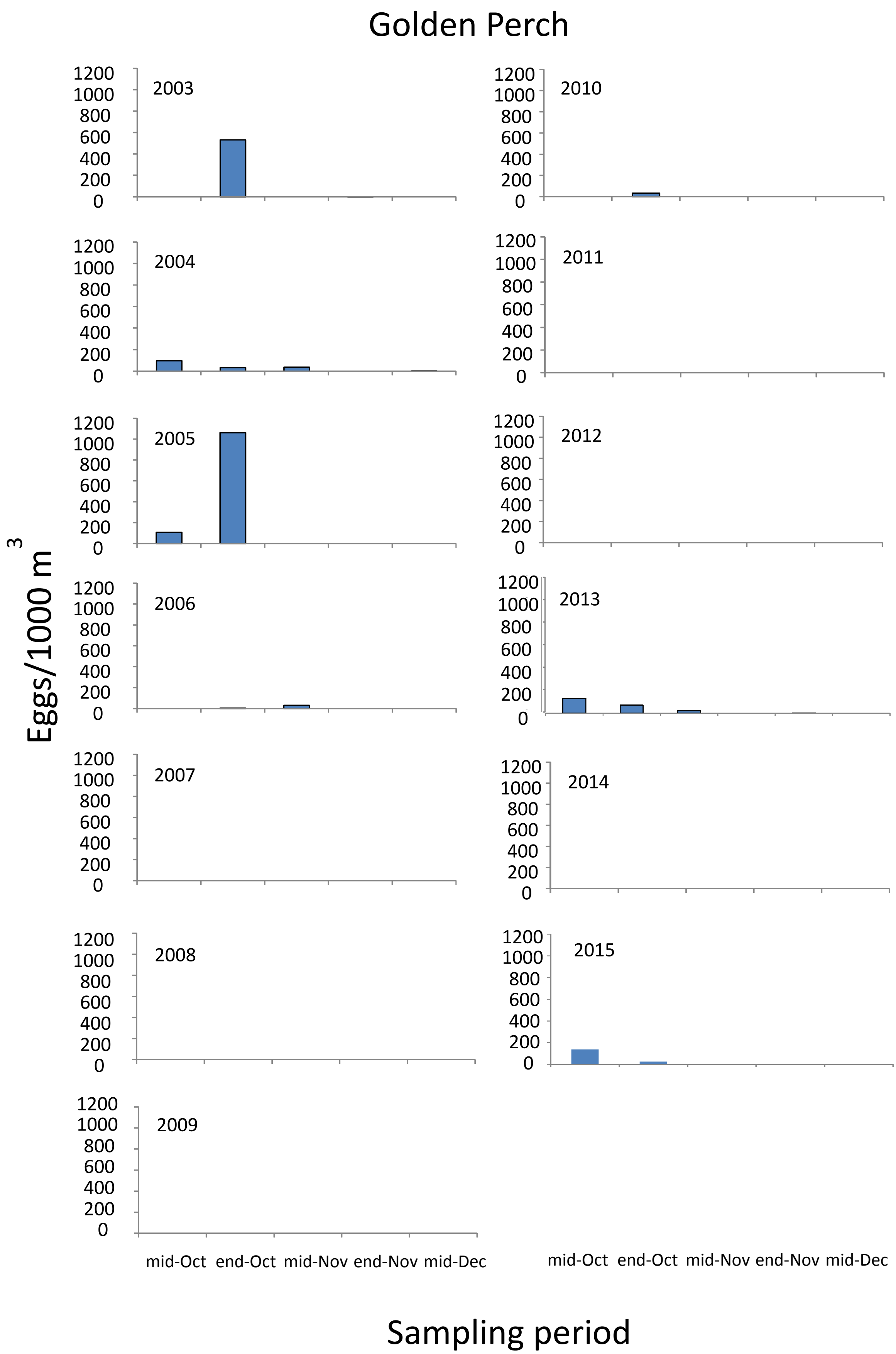
Site name	Length (mm)	Sex	Eggs present
Murray River @ Gulf Creek	67	F	No
Murray River @ Gulf Creek	65	M	
Murray River @ Gulf Creek	105	F	Berried
Murray River @ Gulf Creek	104	F	No
Murray River @ Gulf Creek	102	F	No
Murray River @ Gulf Creek	119	F	No
Murray River @ Gulf Creek	85	M	
Murray River @ Gulf Creek	89	F	No
Murray River @ Gulf Creek	97	F	No
Murray River @ Gulf Creek	124	M	
Murray River @ Gulf Creek	110	F	Berried
Murray River @ Gulf Creek	122	F	No
Murray River @ Gulf Creek	114	M	
Murray River @ Gulf Creek	93	F	No
Murray River @ Gulf Creek	115	M	
Murray River @ Gulf Creek	110	F	No
Murray River @ Gulf Creek	114	M	
Murray River @ Gulf Creek	128	F	No
Murray River @ Gulf Creek	94	F	No
Murray River @ Gulf Creek	98	F	No
Murray River @ Gulf Creek	107	F	No
Murray River @ Gulf Creek	114	M	
Murray River @ Ladgroves Beach	102	M	
Murray River @ Ladgroves Beach	109	F	Berried
Murray River @ Ladgroves Beach	112	F	
Murray River @ Ladgroves Beach	104	M	Berried
Murray River @ Ladgroves Beach	94	F	No
Murray River @ Ladgroves Beach	124	M	
Murray River @ Picnic Point	102	F	Berried
Murray River @ Picnic Point	112	M	
Murray River @ Picnic Point	106	M	
Murray River @ Picnic Point	93	M	
Murray River @ Picnic Point	72	F	Berried
Murray River @ Picnic Point	104	F	Berried
Murray River @ Picnic Point	102	M	
Murray River @ Picnic Point	83	F	Berried
Murray River @ Picnic Point	117	M	
Murray River @ Picnic Point	95	F	Berried
Murray River @ Woodcutters	125	F	Berried

Murray River @ Woodcutters	115	M	
Murray River @ Woodcutters	92	F	No
Murray River @ Woodcutters	114	F	No
Murray River @ Woodcutters	89	F	No
Murray River @ Woodcutters	106	F	No

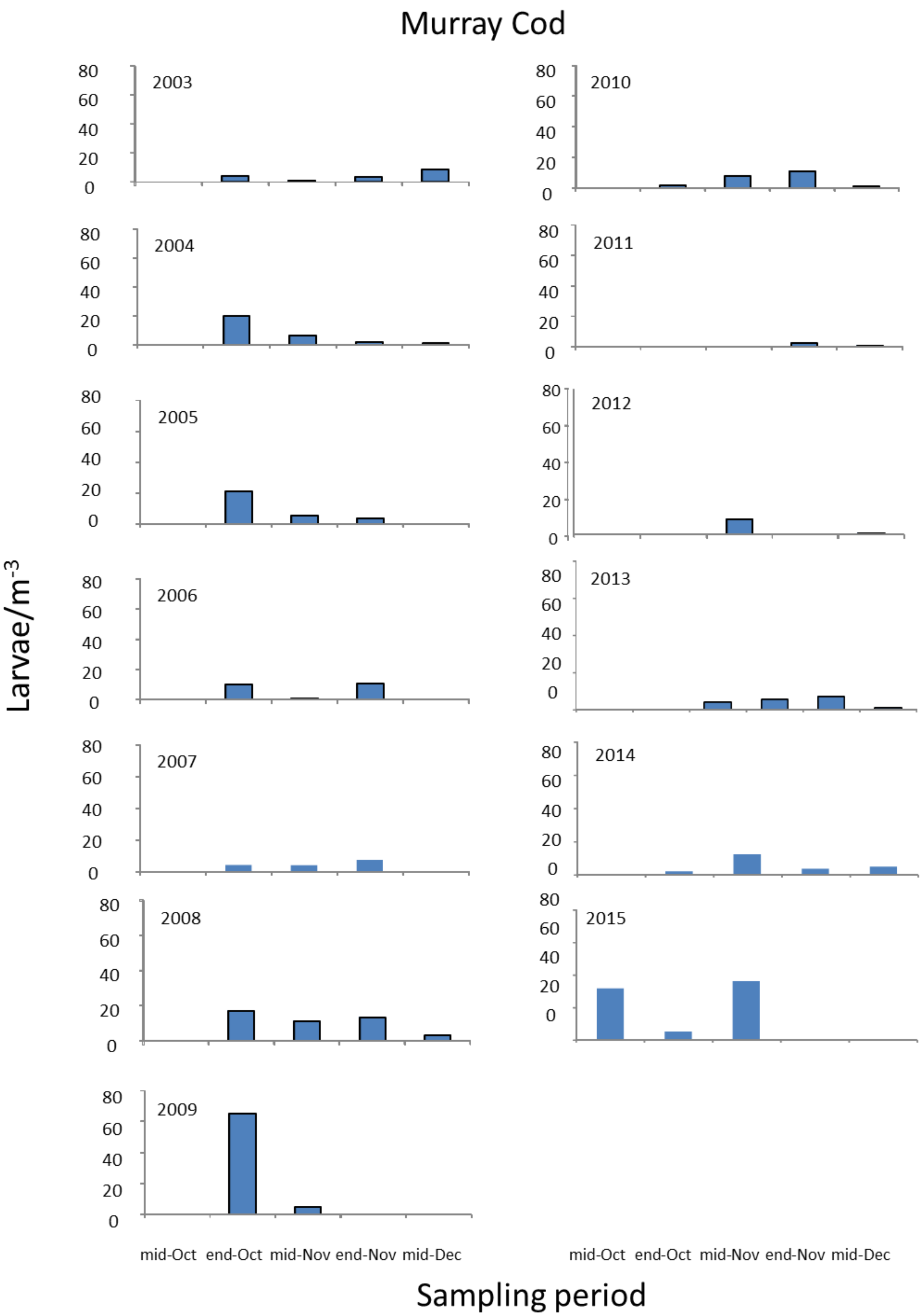
Appendix 4. Drifting eggs and larvae of target fish

Peak and average (mean per trip) densities (per m-3) of drifting larvae/eggs for the four large-bodied native fish and Common carp from the Murray River, 2008-2016.

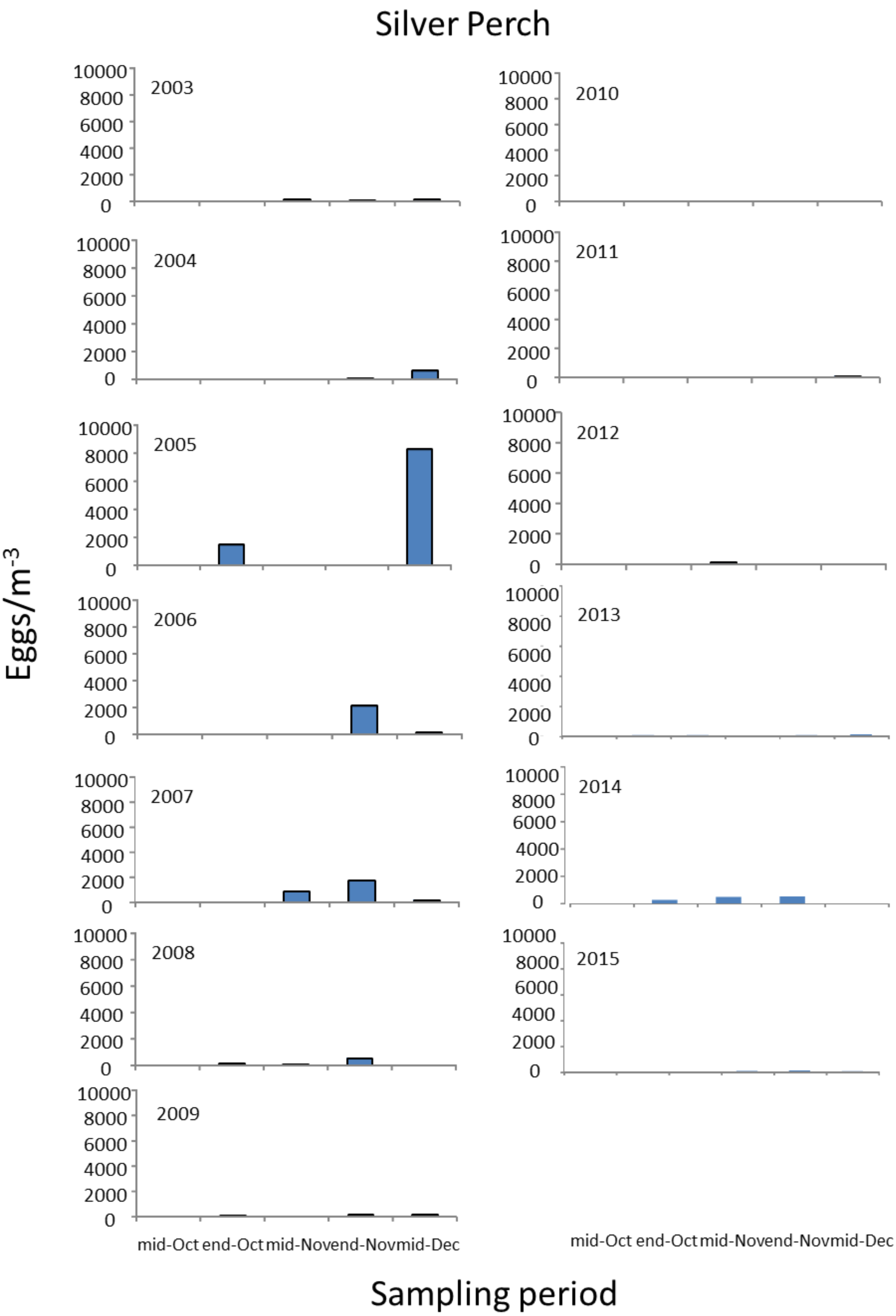
Common name	Egg/larvae	Trip number	2008	2009	2010	2011	2012	2013	2014	2015
Murray cod	larvae	1	0.00	0.00	0.00	0.00	0.00	0.00	2.18	31.79
Murray cod	larvae	2	16.97	65.26	1.77	0.00	0.65	0.00	12.20	5.18
Murray cod	larvae	3	11.17	4.86	8.04	0.00	47.89	3.70	3.64	36.16
Murray cod	larvae	4	13.20	0.00	11.22	2.52	0.00	7.14	4.89	0.00
Murray cod	larvae	5	3.06	0.00	1.44	0.65	6.58	1.06	0.00	0.00
Murray cod (total)			8.88	14.02	4.49	0.65	11.02	2.79	5.73	14.62
Trout cod	larvae	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trout cod	larvae	2	0.00	5.19	0.00	0.00	0.00	0.00	0.20	1.83
Trout cod	larvae	3	0.00	0.00	0.00	0.00	1.92	0.57	0.00	0.00
Trout cod	larvae	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trout cod	larvae	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trout cod (total)			0.00	1.04	0.00	0.00	0.38	0.11	0.05	0.37
Golden perch	egg	1	0.00	0.00	0.00	0.00	0.00	197.25	0.00	137.48
Golden perch	egg	2	0.00	0.00	33.45	0.00	0.00	72.27	0.00	25.42
Golden perch	egg	3	0.00	0.00	0.00	0.00	0.00	23.57	0.00	0.00
Golden perch	egg	4	0.00	0.00	0.00	0.00	0.00	1.64	0.00	0.00
Golden perch	egg	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Golden perch (total)			0.00	0.00	6.69	0.00	0.00	45.80	0.00	32.58
Silver perch	egg	1	0.00	524.82	0.00	0.00	0.00	0.00	269.96	0.00
Silver perch	egg	2	146.92	269.55	0.00	0.00	2.11	12.33	497.16	7.78
Silver perch	egg	3	49.05	129.21	0.00	77.56	1337.93	16.05	519.32	88.90
Silver perch	egg	4	537.50	475.52	0.00	55.20	216.47	18.27	7.82	116.80
Silver perch	egg	5	0.00	591.87	0.00	99.75	10.31	64.14	0.00	59.08
Silver perch (total)			146.69	398.20	0.00	45.80	313.36	22.16	323.57	54.51
Common carp	larvae	1	258.58	49.55	16.71	48.48	323.77	391.08	7.70	5.30
Common carp	larvae	2	11.07	33.64	2.54	2.79	2.69	64.76	0.00	247.05
Common carp	larvae	3	0.00	1.13	0.00	4.33	0.32	123.65	0.00	61.06
Common carp	larvae	4	60.66	0.00	0.00	0.00	1.03	1.87	0.00	4.97
Common carp	larvae	5	0.00	0.70	1.04	0.00	0.00	0.00	0.00	0.00
Common carp (total)			66.06	17.01	4.06	11.28	65.56	90.64	1.92	63.68



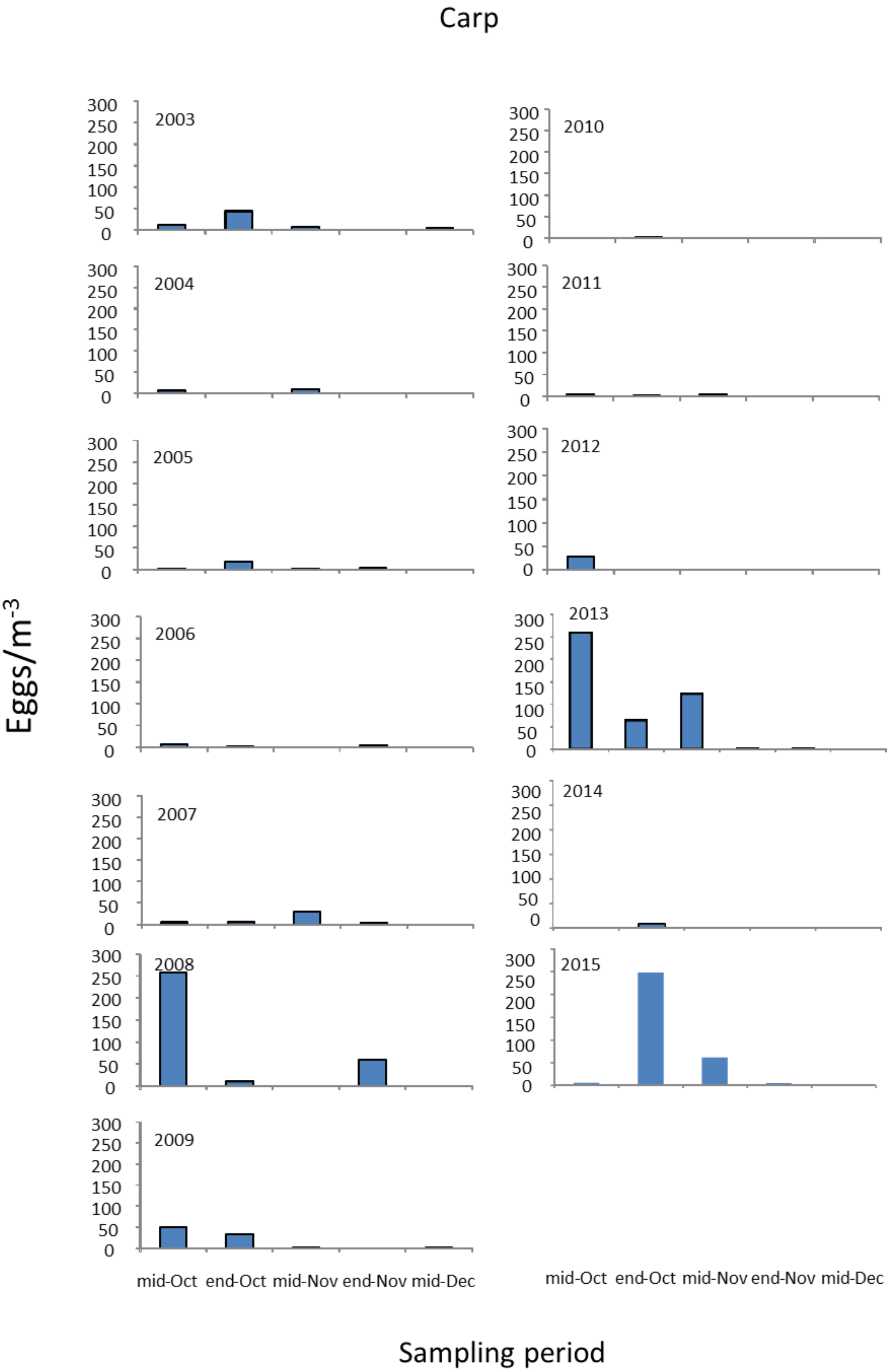
Mean densities (per m-3) of drifting Golden perch larvae/eggs collected from the Murray River, 2003 – 2015. Drift data is presented in year sampling was undertaken.



Mean densities (per m-3) of drifting Murray cod larvae collected from the Murray River, 2003 – 2015. Drift data is presented in year sampling was undertaken.



Mean densities (per m-3) of drifting Silver perch eggs collected from the Murray River, 2003 – 2015. Drift data is presented in year sampling was undertaken.



Mean densities (per m-3) of drifting carp larvae collected from the Murray River, 2003 – 2015. Drift data is presented in year sampling was undertaken.

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