

Barmah-Millewa Fish Condition Monitoring: 2018



Arthur Rylah Institute for Environmental Research, August 2018

Acknowledgements

We would like to thank the Barmah-Millewa Technical Advisory Committee and the Living Murray section of the Murray-Darling Basin Authority for their financial and technical support. The following staff are thanked for their contribution to field and laboratory work for the 2017/18 season: Graeme Hackett, Jason Lieschke and Kim Loeun (Arthur Rylah Institute, DELWP); Kate Martin, Jonathon Doyle, Tom Butterfield, Nick O'Brien and Jarryd McGowan (Department of Primary Industries, NSW). Joanne Kearns (ARI) is thanked for providing comments on the final draft. Kelvin Berry from the Wangaratta Sustainability Network provided valuable field assistance. Sampling in NSW waters was conducted under Industry and Investment NSW Fish Collection Permit P01/0059 (A). Sampling within Victorian waters was covered under Fisheries Victoria Permit RP 827 and National Parks Victoria (Flora and Fauna Guarantee Act 1988) Permit 10002155. Animal Care and Ethics Approval is granted under Department of Primary Industries, NSW general biodiversity project Number ACEC98/14 and the Victorian DEPI ethics permit AEC 10/13. This project was funded by The Living Murray. The Living Murray is a joint initiative funded by the New South Wales, Victorian, South Australian, Australian Capital Territory and Commonwealth Governments, coordinated by the Murray–Darling Basin Authority

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Front cover photo: Hut Lake at Barmah, Murray River rainbowfish (left) and Trout Cod (right). [Photos: Scott Raymond].

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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. Fish condition monitoring has been designed to assess the health and status of the fish community at 21 sampling sites distributed across two strata; permanent flowing (riverine) and semi-permanent flowing (creeks, lakes and wetlands) habitats. 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 (-). This report presents the results from the eleventh year of monitoring. We also present descriptive data for rare native species, Murray crayfish and riverine spawning of large-bodied species based on the objectives of the icon site.

Monitoring of the B-MF fish community has covered periods of drought (2007 to 2010), floods including hypoxic blackwater events (2011 and 2016) and a return to more historical flows. The B-MF fish community has improved from 2017 to 2018, as indicated by both community (all 6 indices show improvement) and population (2 of the 3 indices improved) indices. We propose the increased condition of the B-MF fish community in 2018 was likely the result of more frequent connection between riverine and floodplain habitats over the past 2 years.

In 2018, B-MF fish scored a B+ for overall community indices (up from a B- in 2017) and a D+ (up from a D in 2017) for the population indices. In general, native fish recruitment was high and stable across strata and years; native species expected to be sampled (based on historical species richness) was low (<50%) within and between strata, and the number of large-bodied native fish at maturity was stable across years in permanently flowing strata. Population indices (proportions of abundance, species and biomass that are native) were higher in permanent flowing habitats than semi-permanent habitats.

Monitoring of riverine spawning indicated that Murray Cod, Trout Cod, Golden Perch and Silver Perch all spawned during the spring/summer of 2017. Good numbers (relative to past years) of Murray Cod larvae (380) and eggs of Golden Perch (307) and Silver Perch (302) were sampled in 2017 compared with the previous 10 sample years, and in the case of Golden Perch, likely reflect an increase in flow related spawning cues (e.g. in-channel pulse and flow variability) during peak spawning periods for this species. Murray Cod larvae were detected at all sites in 2017, including the most downstream site, Morning Glory, which was subject to blackwater in 2016.

A sampling protocol specifically developed for B-MF Murray crayfish was established in 2018 and generated baseline data used to compare population parameters between sample events (years) as well as baseline data on population size structure and sex ratios. The new protocol may be used to assess the impact of specific events (eg blackwater, flows) as well as long-term population trends. Murray crayfish were again, not detected from their pre-blackwater stronghold (Murray River at Morning Glory).

The B-MF 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. Whilst 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 B-MF, 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 an initiative of the Australian Federal Government which aims to improve the environmental health of six Icon sites chosen for their significant ecological, cultural, recreational, heritage and economic values' (MDBA 2013). The initiative is multi-jurisdictional (ACT, NSW, SA and VIC), and is coordinated by the Murray-Darling Basin Authority (MDBA).

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 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 therefore essential for reliable interpretation and management of the MDB Icon sites.

The Barmah-Millewa Forest (B-MF) is a 66,000-ha wetland complex on the Murray River floodplain, upstream 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.

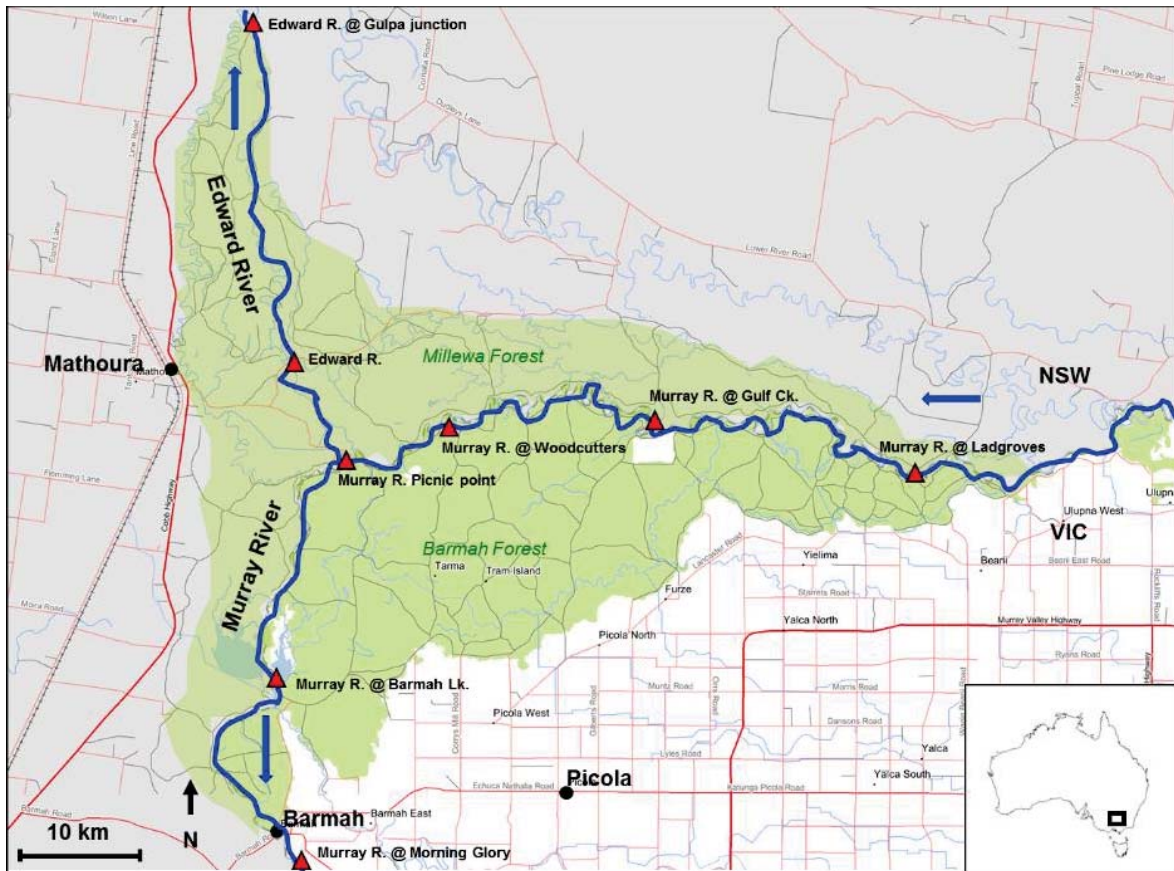


Figure 1. The Barmah-Millewa Forest (shaded green). Red triangles represent riverine sample sites and blue arrows indicate direction of water flow.

In 2007, a condition monitoring program commenced (as part of TLM) 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 program. The overall objectives of the 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 the 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 selected riverine fish species (Murray Cod *Maccullochella peelii*, Trout Cod *Maccullochella macquariensis*, Silver Perch *Bidyanus bidyanus*, Golden Perch *Macquaria ambigua*, and exotic Carp species), 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: with sites which had permanent (river and permanently flowing creeks) and semi-permanent flowing water (wetlands, lakes and ephemeral creeks). Further reporting on community and population indices, and their sub-indices was included in the reporting framework to detail the specific components of fish community and population responsible for changes in fish assemblage structure, and the relative

strength of any change. Recent revision of data collection and analysis has allowed for improved reporting against Icon site monitoring objectives.

This report presents the results of data collected during the eleventh year of fish condition monitoring, which also incorporates an updated sampling protocol for Murray crayfish (*Euastacus armatus*), and spawning assessments of five primarily riverine large-bodied fish species which we compare with previous survey years. Additional sampling of two semi-permanent flowing habitats in 2018 was included to improve capacity to assess change within this stratum.

2 Methods

2.1 Annual fish condition monitoring

To assess the condition of fish communities within the B-MF, methods were developed to maintain compatibility with current Sustainable Rivers Audit (SRA) protocols (MDBC 2004). The program has maintained consistency from 2007 to 2018 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 2017, three additional semi-permanent sites in Barmah Forest; Boals, Punt Paddock and Mary Ada creeks were sampled, based on the outcome of the B-MF refinement report (Robinson 2015). These three sites were replaced by three semi-permanent sites, Tullah Creek at Gundry's Old Bridge, Tarma lagoon and Wild Dog Creek in 2018 (Figure 2). Water flow and temperature (°C) data (Barmah River d/s of Yarrawonga) were collected to determine their relationship with the timing of egg/larval drift and to provide long-term flow patterns covering the duration of the study.

2.1.1 Permanent flowing sites

Permanently flowing river sites (Table 1) were sampled in June/July annually, 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 the four regions, with the exception of 2014, where Edward River sites were not sampled and 2015 where sampling was not undertaken due to financial constraints. 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 5 KVA, Smithroot boat-mounted electrofishing unit (1000v, 120 pulses/second, 40 hertz). Twelve replicates of 90 second electrofishing shots were conducted at each 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 or fork length (Carp and Silver Perch) (to the nearest mm). Once processed, all fish were returned to the site of capture. Large-bodied native fish, in excess of 200 mm in length, had an external T-bar tag inserted in their left shoulder for future recapture.

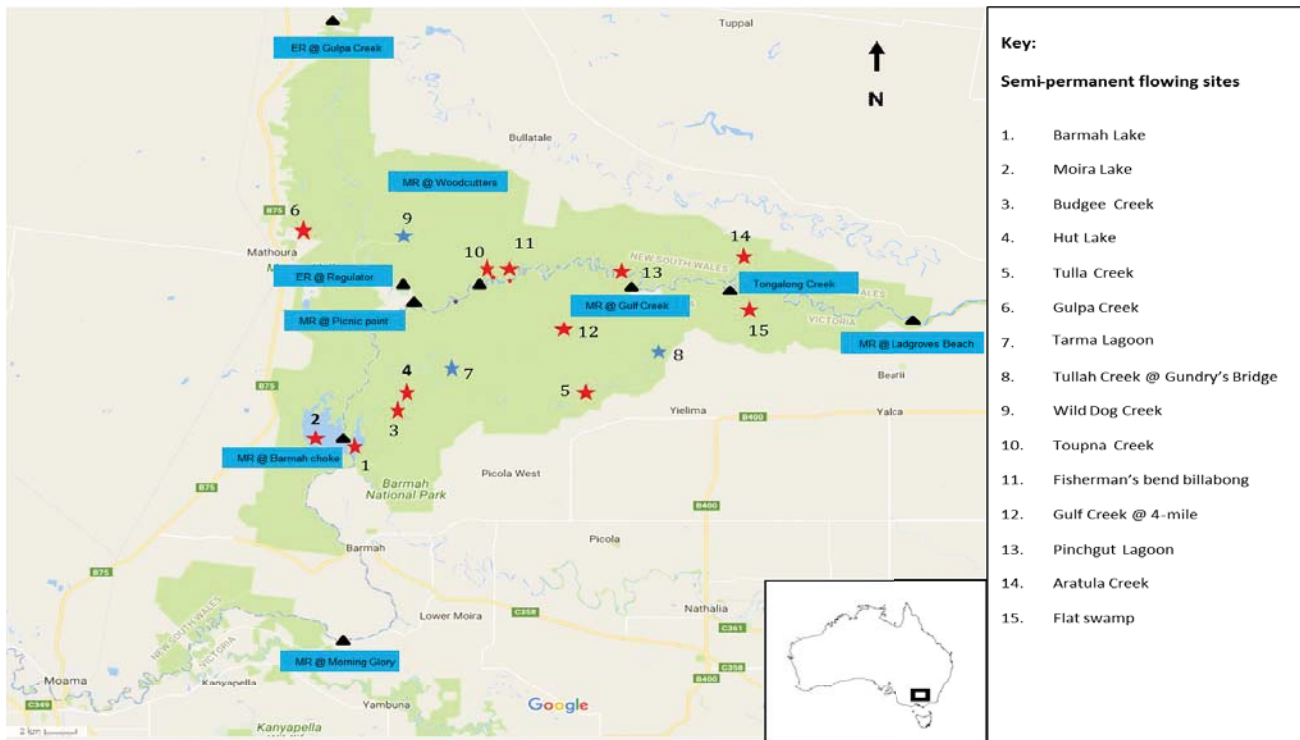


Figure 2. Barmah-Millewa Forest (green shading) illustrating locations of permanent (black triangles, blue labels) and semi-permanent flowing (red stars) fish monitoring sites. Additional sites monitored in 2018 are represented with blue stars.

Table 1. Permanent flowing river sites in the B-MF sampled in each study year

River region	Site	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Murray River													
Downstream Region	MR @ Morning Glory	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓
	MR @ Barmah near Moira 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	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓
Anabranches													
	Tongalong Creek	✓	✓	✓	✓	✓	✓	✓	✓	*	✓	✓	✓
	Gulpa Creek	✓	✓	✓	✓	✓	✓	✓	✗	*	✓	✓	✓

✓ Site successfully sampled

Site inaccessible due to floodwaters

✗ Site not sampled

Anabranche sites were added to the permanent flowing strata in 2016

2.2.1.1 Annual crayfish condition monitoring

A new sampling protocol for Murray crayfish was introduced in 2018 to provide an Index of Abundance and baseline data on sex ratios and size classes for future trend analysis. Ten Munyana crab traps (Figure 3), 75 cm in diameter and baited with liver, were set at 14 sites (Appendix 6) in the afternoon for a minimum 2hr soak time. All Murray crayfish captured were determined as either male or female, measured for occipital carapace length (OCL) (to the nearest mm) on their dorsal side from the lower eye socket margin to the central posterior margin of the cephalothorax (Morgan 1997) and sex determined where possible. The sex of crayfish was determined by the location of gonopores; female crayfish are identified by the presence of gonopores on the inside of the first segment of the second walking legs (Figure 4a) while the gonopores of males are located on the inside of the first segment of the posterior walking legs (Figure 4b). Females were assessed for maturation via determination of the presence of setae surrounding the gonopores present in mature females, [Figure 4c] and absent in immature females), and for the presence of eggs (Figure 4c).



Figure 3. Munyana crab trap used for sampling Murray crayfish

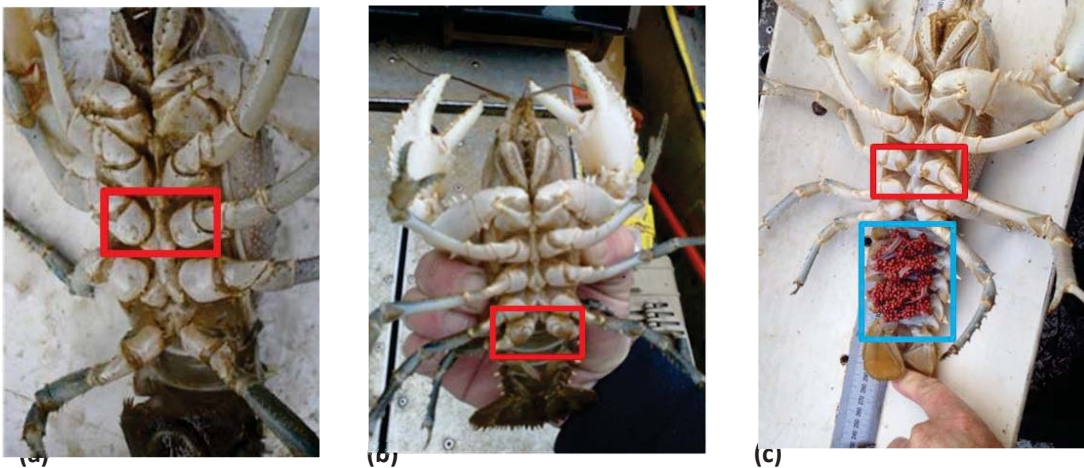


Figure 4. Location of gonopores on an immature female (a) as indicated by lack of setae surrounding gonopores, a male Murray crayfish (b) and a mature female (as indicated by the presence of setae around the gonopores) in berry (with eggs) (c). Gonopores of Murray crayfish are outlined within red rectangles and eggs are outlined in blue.

2.1.2 Semi-permanent sites

The B-MF contains a diversity of creek systems and wetlands with a variety of fish species, some of which only occur in off-channel habitats (King et al. 2007). Twelve sites (off the Murray River main channel) were initially selected for inclusion in annual sampling; six creeks and six wetland/lake sites that were spatially stratified to include six within the Barmah Forest and six within the Millewa Forest (Appendix 1). 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 (Tonkin and Rourke 2008). Semi-permanent sites were sampled in February/March when water levels were high enough to allow access to the site to enable effective sampling.

Sites within the B-MF experience variable 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 2 hr 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.

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 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 (three indices) (Robinson 2012; 2015). CPUE of native fish and rare fish indices were also included for diagnostic purposes.

Each index was allocated a score (A to E) divided into 20 percentile increments, e.g. 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 2.

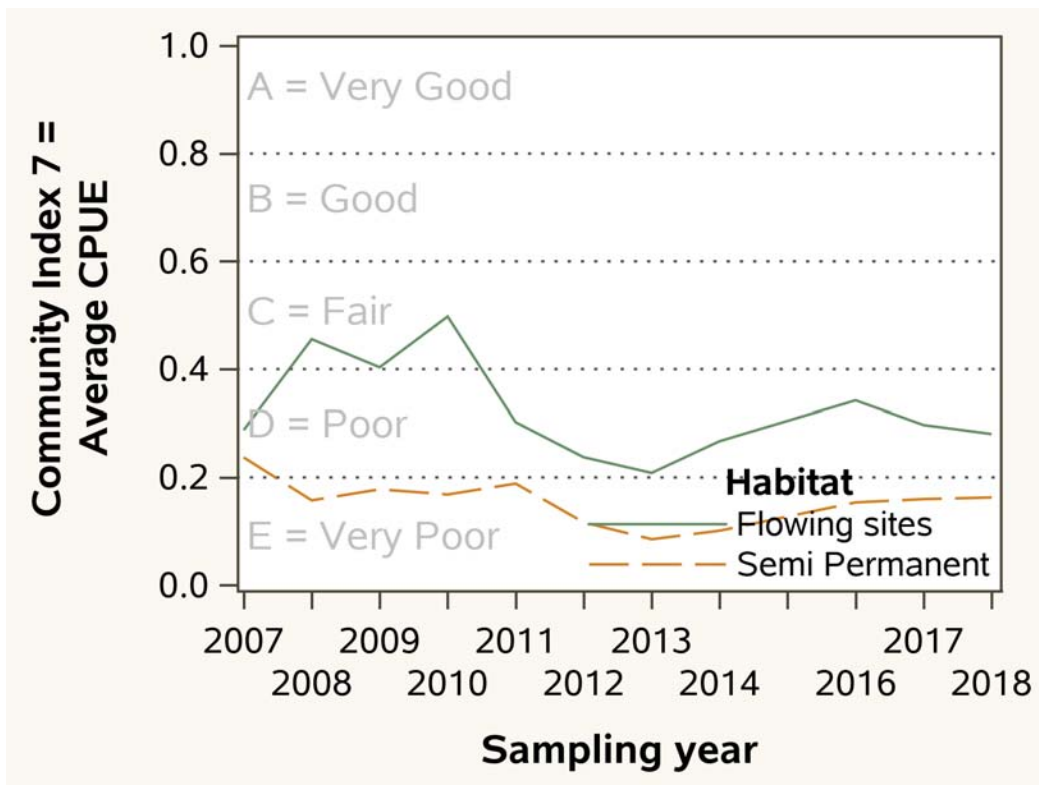


Figure 5. An example of the B-MF indice report scoring system.

2.3 Riverine larval drift sampling

Sampling was conducted fortnightly during the spawning period of targeted 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 are located downstream, mid and upstream of the B-MF floodplain respectively (Figure 2).

At each site, three 1.5 m long 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 log 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 were 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 were identified according to 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 (2017) 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 (King et al. 2009).

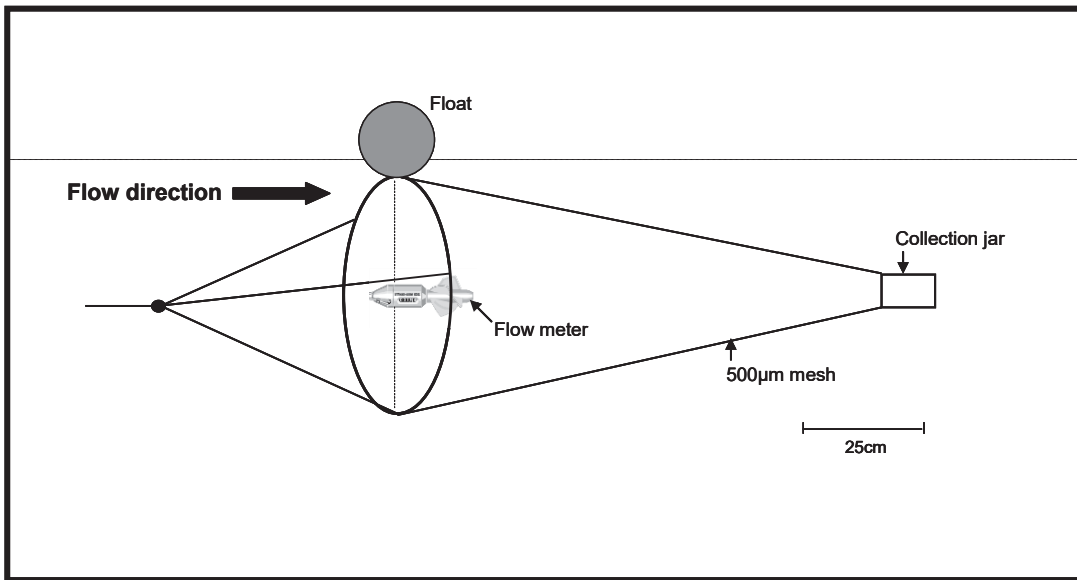


Figure 6. Side view of the standard passive drift net used in the study.

2.4 Murray crayfish condition monitoring refinement study

As in the case of B-MF fish reporting (Robinson 2015), a refinement study was undertaken in 2017 to assess our present sampling methodology of Murray crayfish to develop a standardised robust sampling protocol (Raymond et al. 2017). The specific outcomes of this study enabled researchers to:

- yield an index of abundance
- investigate population sex ratios, and
- examine population size structure

The Index of Abundance (IOA) is a reliable and robust method for assessing relative changes in populations (condition) and along with sex ratios and age structure, provides a baseline for assessing population responses to disturbance (e.g. blackwater) and other potential impacts (e.g. flows). This year (2018) is the first year of reporting on Murray crayfish using the standardised sampling methodology.

3 Results

3.1 Hydrology

A single, short duration flood event (>35,000 ML/d) occurred in late August 2017 and was followed by a minor flood event (20,000 ML/d) in the first week of December 2017. Flooding from late September to mid-December was sufficient to inundate the B-MF floodplain for three months, followed by seven months of drying (Figures 7 & 8). Larval drift sampling was undertaken from mid-October to mid-December 2017 and semi-permanent and permanently flowing habitats were sampled two and six months following the recession of water from the Barmah-Millewa floodplain, respectively. Water temperature in the mid-Murray River rose from 10°C in August 2017, to 16°C at the beginning of October 2017, and peaked at 28.3°C on January 29, 2018, before declining thereafter. The increase in temperature through the spring and summer months covered the core spawning period of all target large-bodied native fish and Carp, and declined in the autumn and winter months (Figure 7).

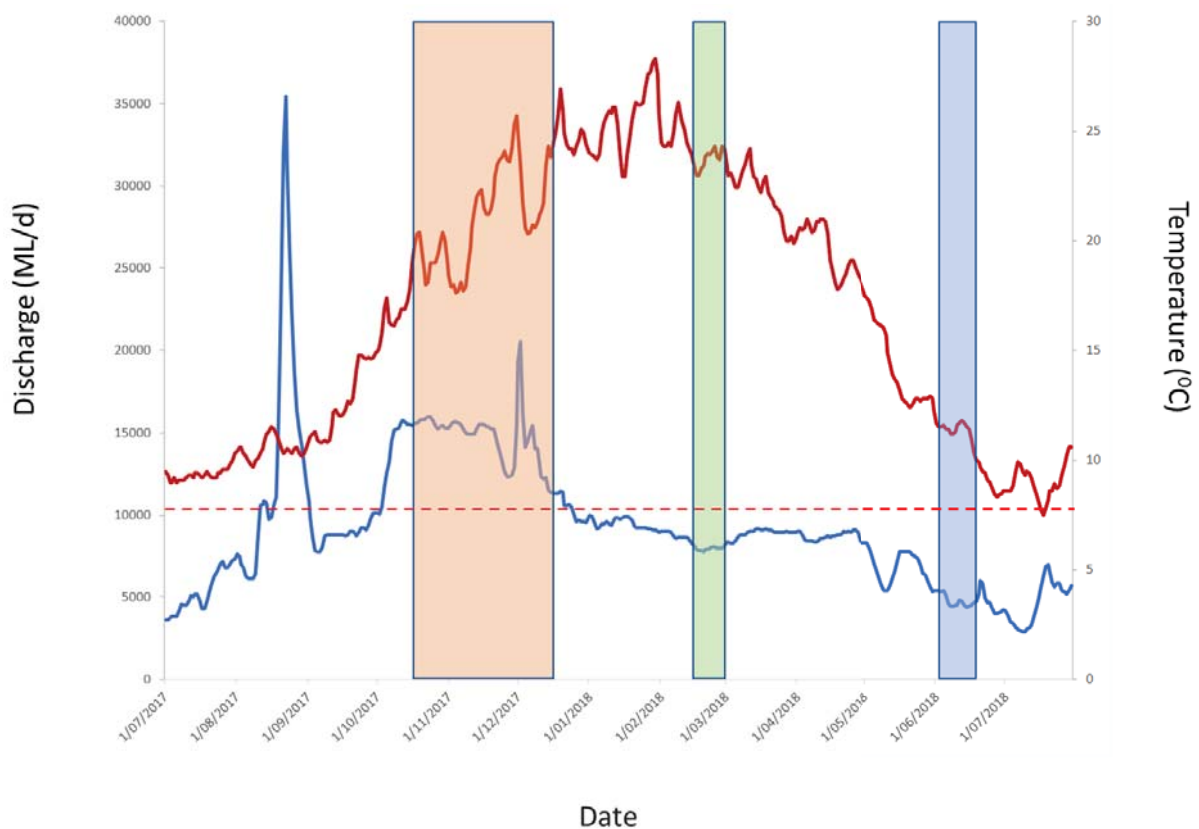


Figure 7. Mean daily discharge (blue line) and surface water temperatures (red line) in the Murray River at Yarrowonga from June 2016 to July 2017. The pink shaded portion of the graph depicts the time of egg and larval sampling, green shading represents Semi-permanent flowing habitat sampling, and the blue shade indicates time of river and crayfish sampling (Source: MDBA, Gauge # 409025).

3.2 Fish surveys

Twenty-four survey sites were sampled in 2018 including three extra sites (Appendices 1, 2 & 3). Sampling of semi-permanent creek, lake and wetland sites was undertaken between the 19th February and the 1st of March 2018. Two Murray River anabranch sites (Tongalong Creek and Gulpa Creek) were also sampled during this period whilst the remainder of the permanently flowing sites were sampled from 4–13th June 2018. Murray crayfish sampling was undertaken from 4–8th June 2018.

3.2.1 Overview of total catch and community composition since 2007

A total of 5,017 fish were collected in 2018, comprising 10 native and 5 alien species (Tables 2 & 3). In permanent river habitats there were 8 native and 4 alien species collected and 8 native and 5 alien species in semi-permanent habitats. The relative abundance estimate (average number of fish per site) was very low for flowing or semi-permanent sites compared to the best years (2008–2011) and comparable with the low numbers also experienced in 2012 (Tables 2 & 3).

Australian Smelt, *Retropinna semoni* and Carp were the most abundant fish collected in river sites in 2018, numerically comprising 84% of all individuals collected (Table 2). These two species were also abundant in the semi-permanent habitats, but Eastern Gambusia, *Gambusia holbrooki*, Australian Smelt, and Goldfish, *Carassius auratus* were also very abundant (Table 3). Of note however, the average number of Eastern gambusia and Goldfish collected per site in semi-permanent habitats were considerably lower than in any of the past three years (Table 3). There were more Carp Gudgeon, *Hypseleotris spp.* collected in river habitats in 2018 than in any year since 2009, but all other species decreased in abundance in 2018 compared to 2017 (Table 2). Fish species recorded from B-MF over the course of the study (2007–2017) are listed in Appendix 4.

3.2.2 Permanently flowing habitat (rivers and creeks)

River sites were dominated by large-bodied fish species with Carp collected at every site, Murray Cod in all but one site whilst Golden Perch were in eight of the ten sites sampled in 2018 (Appendix 2). Silver Perch and Trout Cod were collected in low numbers but were widespread and collected in seven and six sites respectively. Alien Redfin Perch were not collected in 2018 and alien Goldfish, Gambusia and Oriental Weatherloach, *Misgurnus anguillacaudatus* were rare, only occurring in one or two sites each (Appendix 2).

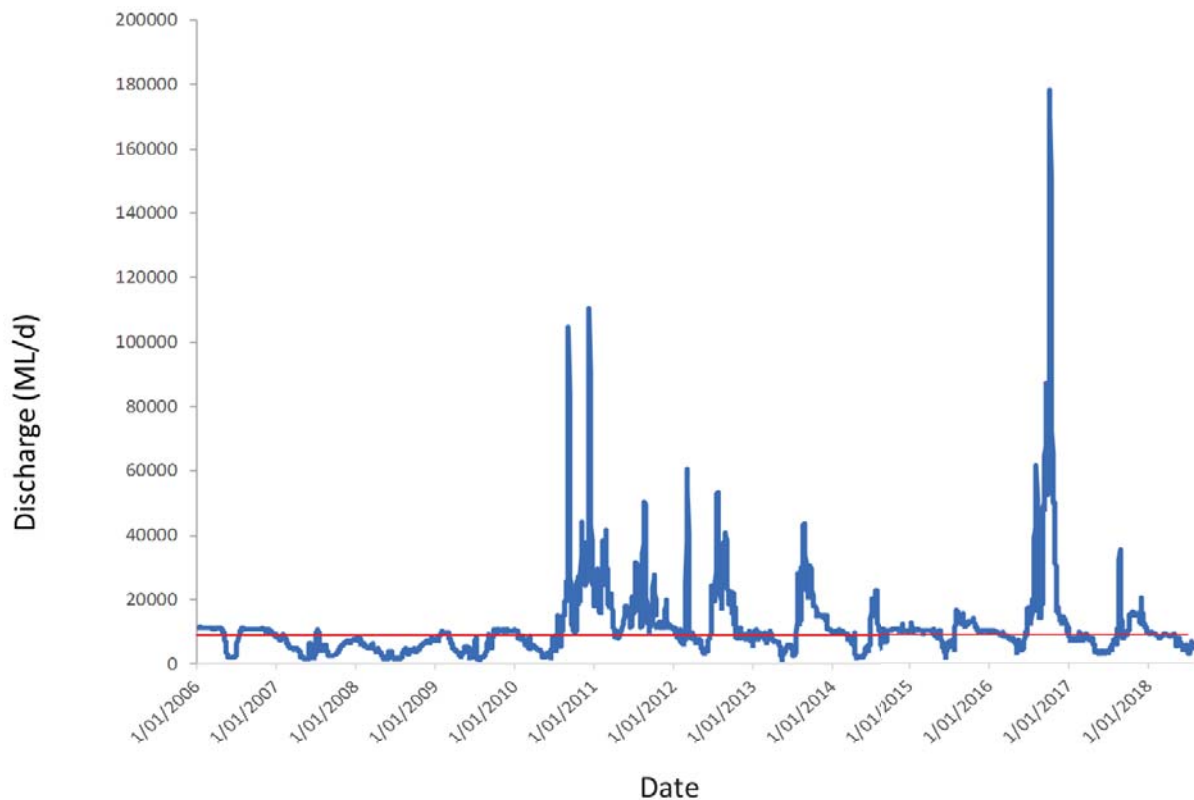


Figure 8. Average daily flows (ML/day) downstream of Yarrowonga Weir from 2006 to 2018 (Source: MDBA). The red line indicates flow at which B-MF floodplain is inundated.

3.2.3 Semi-permanently flowing habitat (non-river)

Carp Gudgeons and Australian Smelt were the most widespread native species, occurring in 13 and 10 of the 14 sites respectively (Appendix 3). The sites were dominated by alien species however, with Goldfish, Carp and Eastern gambusia occurring in 12, 13 and 12 of the 14 sites respectively (Appendix 3). Sites ranged from 10 species at Flat Swamp (6 of which were native) down to just two (both alien) species at Budgee Creek (Appendix 3).

Table 2. Total number of native and alien fish collected and observed in permanently flowing sampling sites 2007 — 2018. Average CPUE is the average number of fish per site.

Year	2007	2008	2009	2010	2011	2012	2013	2014	2016	2017	2018
Number of sites	10	10	10	10	9	10	10	7	10	10	10
Native species											
Carp Gudgeon	50	694	388	108	56	23	38	12	10	21	118
Flat-headed Gudgeon		9	1								
Australian Smelt	693	1449	1614	4269	1161	601	168	1730	791	1306	751
Un-specked Hardyhead	258	1944	1506	3501	47		65	5	256	56	1
Murray-Darling Rainbowfish	209	88	931	579	90			2	46	11	2
Murray Cod	29	89	45	85	39	18	16	25	75	63	66
Golden Perch	25	22	25	20	36	75	45	18	53	49	43
Silver Perch	4	24	12	9	21	18	9	2	4	7	12
Trout Cod	16	47	25	34	2	8	9	18	65	34	18
Unidentified cod		2	1								
Bony Herring				59							
Alien species											
Gambusia		12	63	37	390	6	9		1	1	1
Goldfish	25	130	63	147	534	23	20	9	17	27	9
Common Carp	232	519	239	411	1372	1067	841	1169	637	842	623
Oriental Weatherloach		1	2		14	4	1				1
Redfin Perch	1			2					1		
Average CPUE	154	503	492	926	418	184	122	427	196	242	165

Table 3. Total number of native and alien fish collected and observed in semi-permanently sampling sites 2007 — 2018. Average CPUE is the average number of fish per site.

Year	2007	2008	2009	2010	2011	2012	2013	2014	2016	2017	2018
Number of sites	9	5	6	7	10	11	7	6	12	12	14
Native species											
Carp Gudgeon	2202	876	1754	1843	113	311	300	241	1486	1132	772
Southern Pygmy Perch	39										
Flat-headed Gudgeon	50	9	8	36		39	1		82	9	5
Australian Smelt	254	98	176	28	856	90	32	38	179	347	519
Un-specked Hardyhead	91	1	26	4	18	5		1	2	8	9
Murray-Darling Rainbowfish	1	1	4	28	59	6			1	11	3
Murray Cod		1					1	1			5
Silver Perch	1			1		3					
Dwarf Flat-headed Gudgeon	2								39	1	3
Trout Cod											1
Alien species											
Gambusia	464	314	554	1862	2919	1206	272	3279	1387	1206	577
Goldfish	139	60	83	262	349	109	15	2797	618	1805	453
Common Carp	117	129	153	221	1513	85	190	144	592	564	793
Oriental Weatherloach	214	25	59	24	50	53	3	97	137	90	111
Redfin Perch	51					1		1	22	14	121
Average CPUE	403	303	470	616	588	173	116	1100	379	432	241

3.3 Icon site indicators

3.3.1 Fish community indices

Number of sites with recruits

All flowing and all but one semi-permanent sites had recruits detected in 2018, with flowing sites scoring an A+ and the semi-permanent an A- (Figure 9). B-MF fish sampling sites have consistently scored well on this index since 2007. The number of semi-permanent sites with recruits is generally slightly more variable across years than permanently flowing sites.

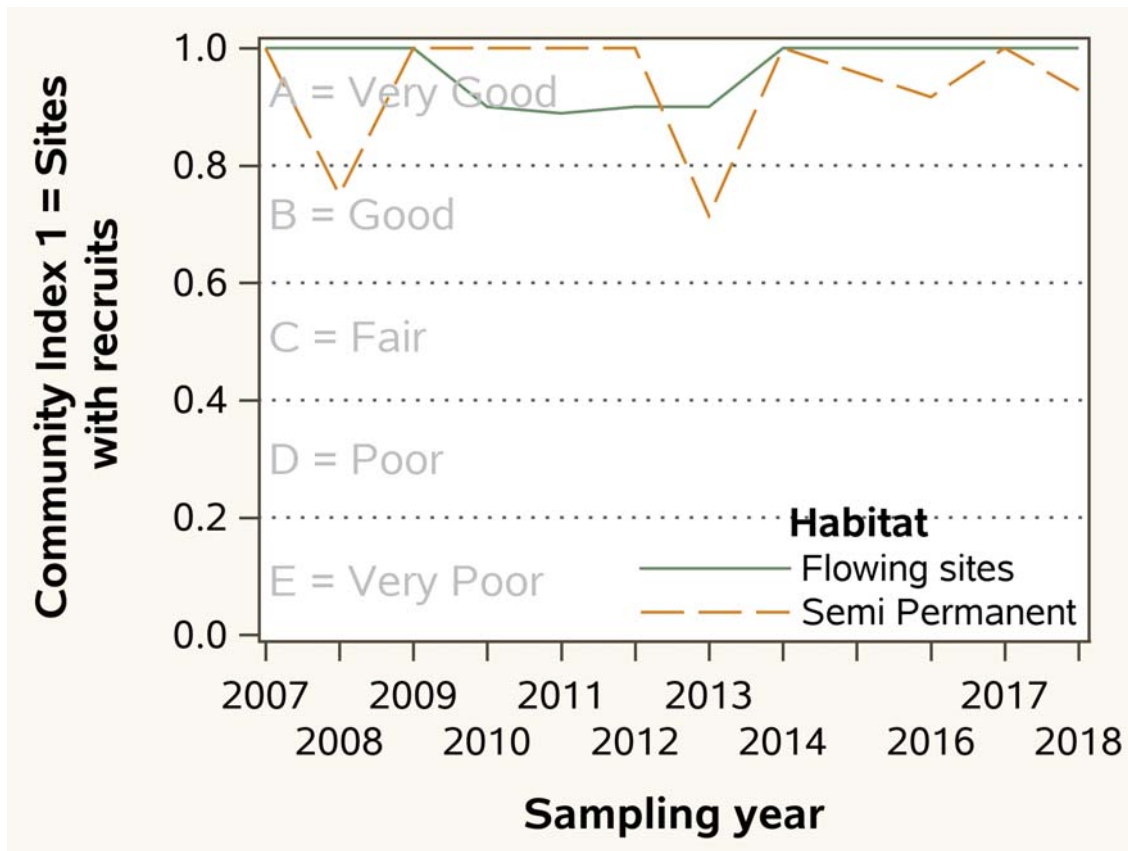


Figure 9. Community Index 1, (proportion of) sites with native recruits in B-MF during fish condition monitoring, 2007 – 2018. Data were not collected in 2015.

Number of species with recruits

Native fish species in permanently flowing and semi-permanent sites had recruits in 2018 and scored a C and B+ respectively. Continued improvement in the scores for the semi-permanent sites has seen them achieve a better score than the flowing sites for the first time since 2007 (Figure 10).

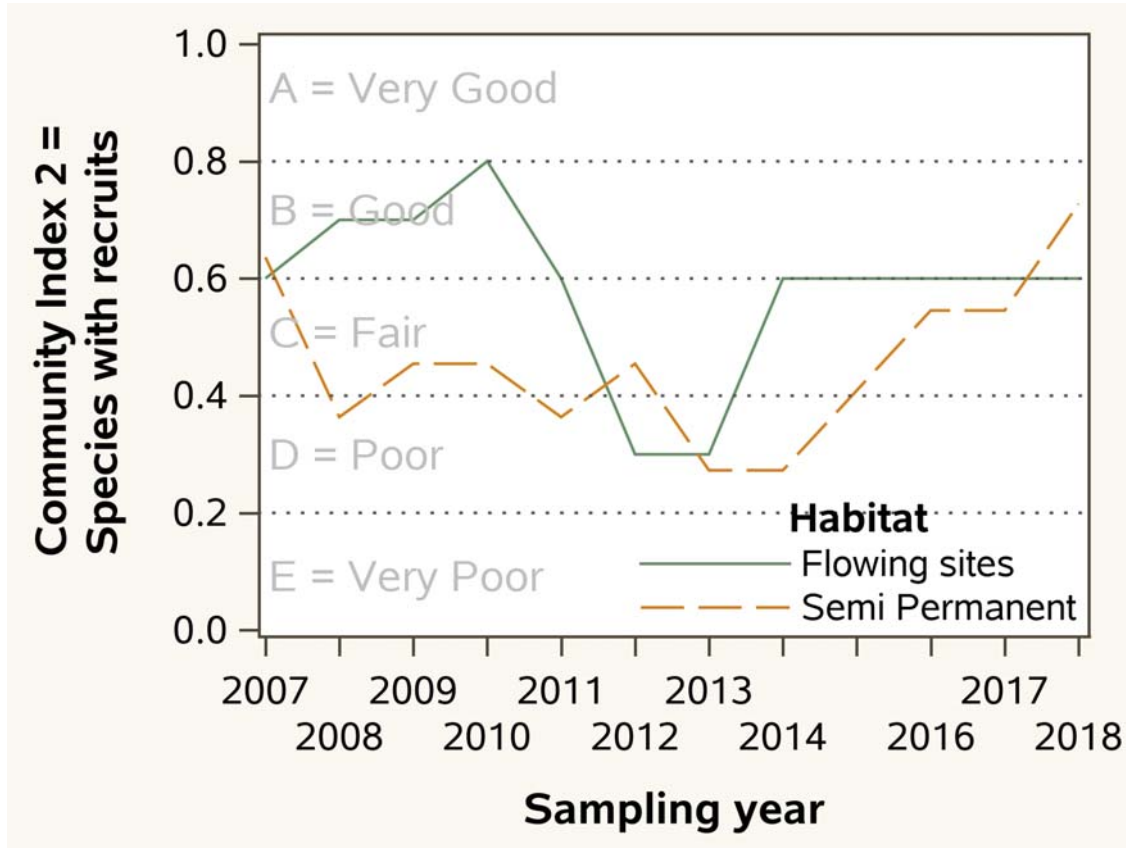


Figure 10. Community Index 2, (proportion of) species with native recruits in B-MF during fish condition monitoring, 2007 – 2018. Data were not collected in 2015.

Number of recruits as a proportion of population

Most fish collected in the semi-permanent sites were recruits in 2018. This habitat has been consistent through time and scores A+ in 2018. The proportion of the population sampled in the permanently flowing sites decreased slightly from 2017 and remains substantially lower than 2008 levels (Figure 11). The permanently flowing sites scored a C- in 2018.

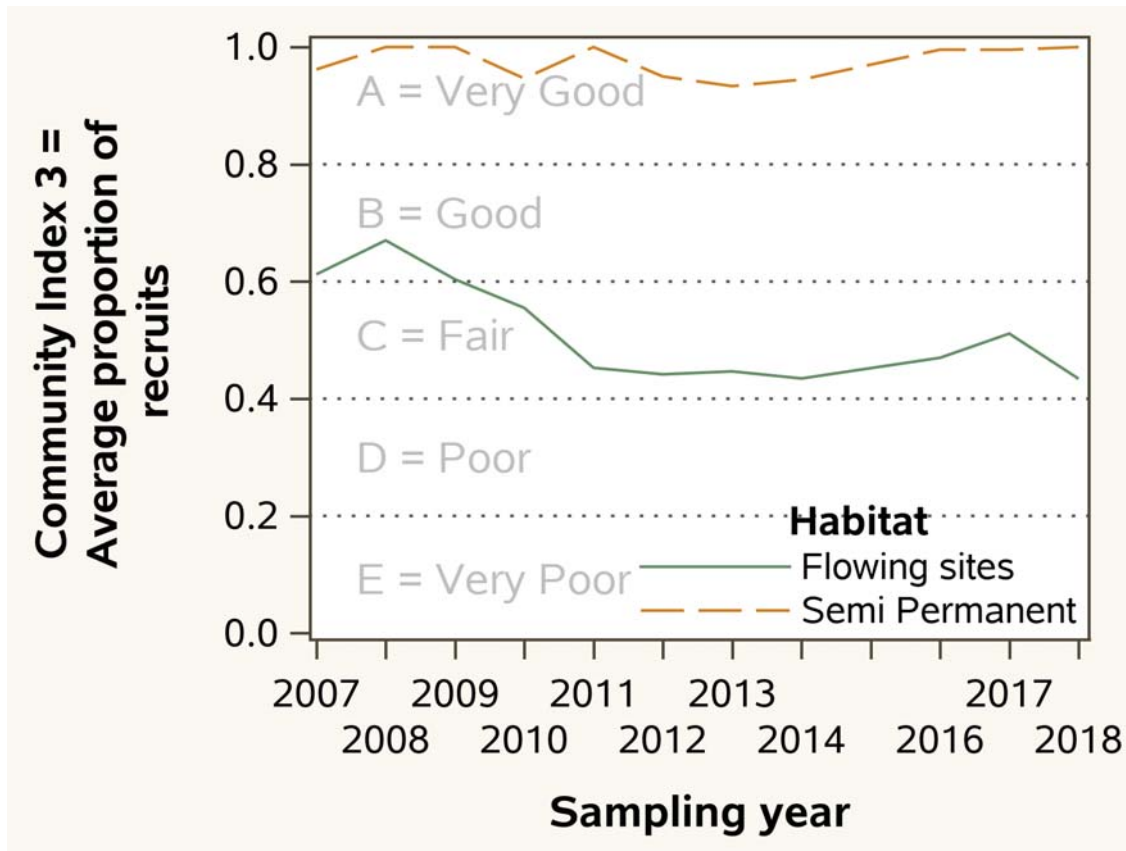


Figure 11. Community Index 3, Average proportion of native recruits in the population in B-MF during fish condition monitoring, 2007 – 2018. Data were not collected in 2015.

Expected (historic native species) collected (within sites)

There was a slight increase in the average number of native species observed to expected in 2018 in permanently flowing sites (C+) and semi-permanent sites (D+) (Figure 12). The number of observed to expected native fish has increased since 2013 but still represents an average of 50% or less of the expected native species being observed.

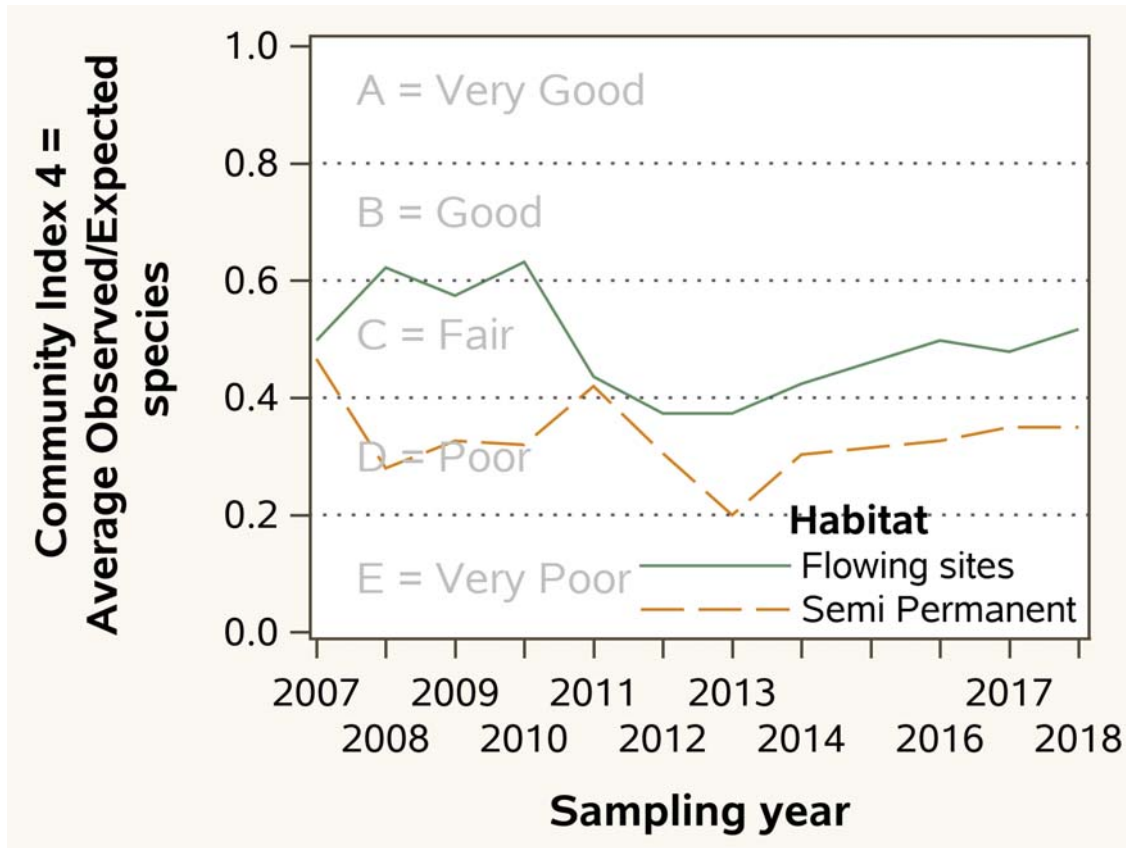


Figure 12. Community Index 4, Average number of observed historical species ÷ number of expected historical species per site in B-MF during fish condition monitoring, 2007 – 2018. Data were not collected in 2015.

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

Expected species collected across the two strata have remained fairly constant through time with about 8 to 10 species collected and index scores of between 0.2 and 0.4. The permanently flowing strata have always returned between 6 and 9 of the historical species, with 8 in 2018 (D-) (Figure 13). The semi-permanent strata returned 9 of the 18—expected species in 2018 (C+), an improvement from the previous year and the highest since monitoring began in 2007 (Figure 13). Expected species were based on Muschal et al. (2010).

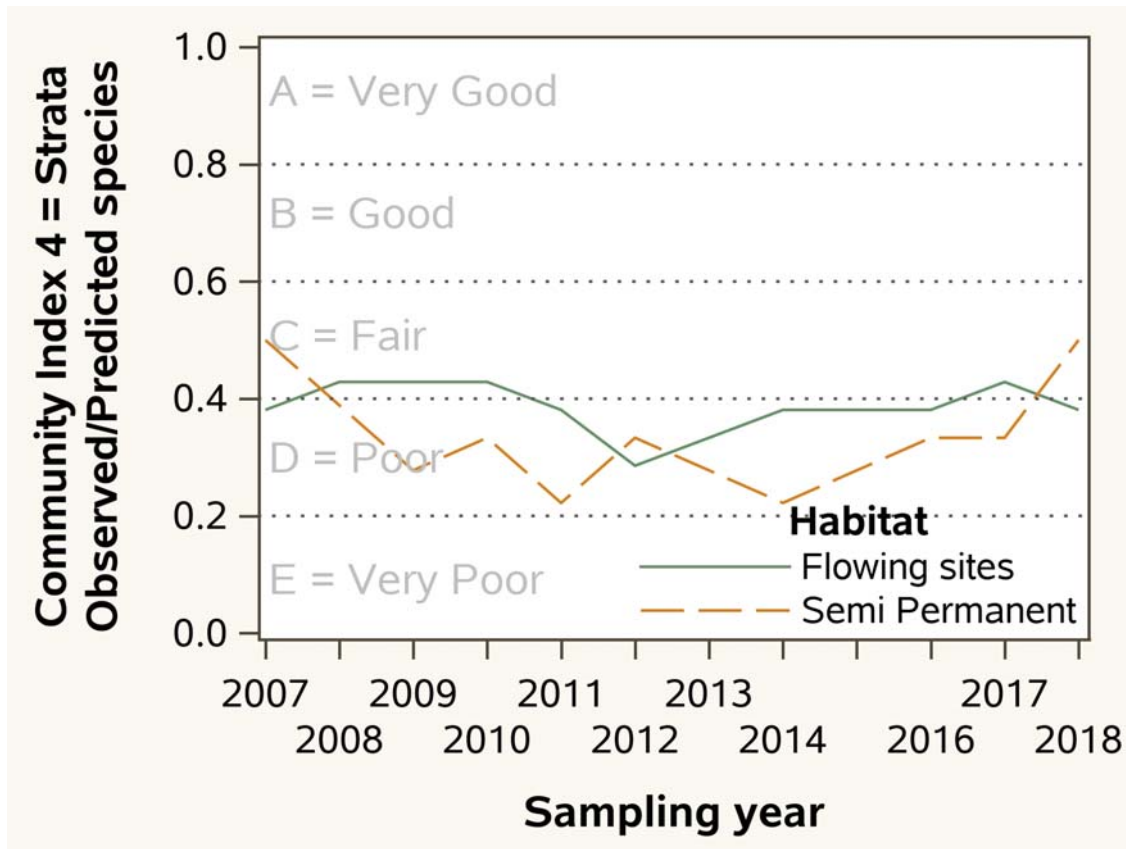


Figure 13. Community Index 4OP, Number of historical species ÷ number of expected historical species per strata in B-MF during fish condition monitoring, 2007 – 2018. Data were not collected in 2015.

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

The distribution of age cohorts of large-bodied fish in the permanently flowing sites in 2018 scored 50% (Figure 14) and the icon site receives a score of C+.

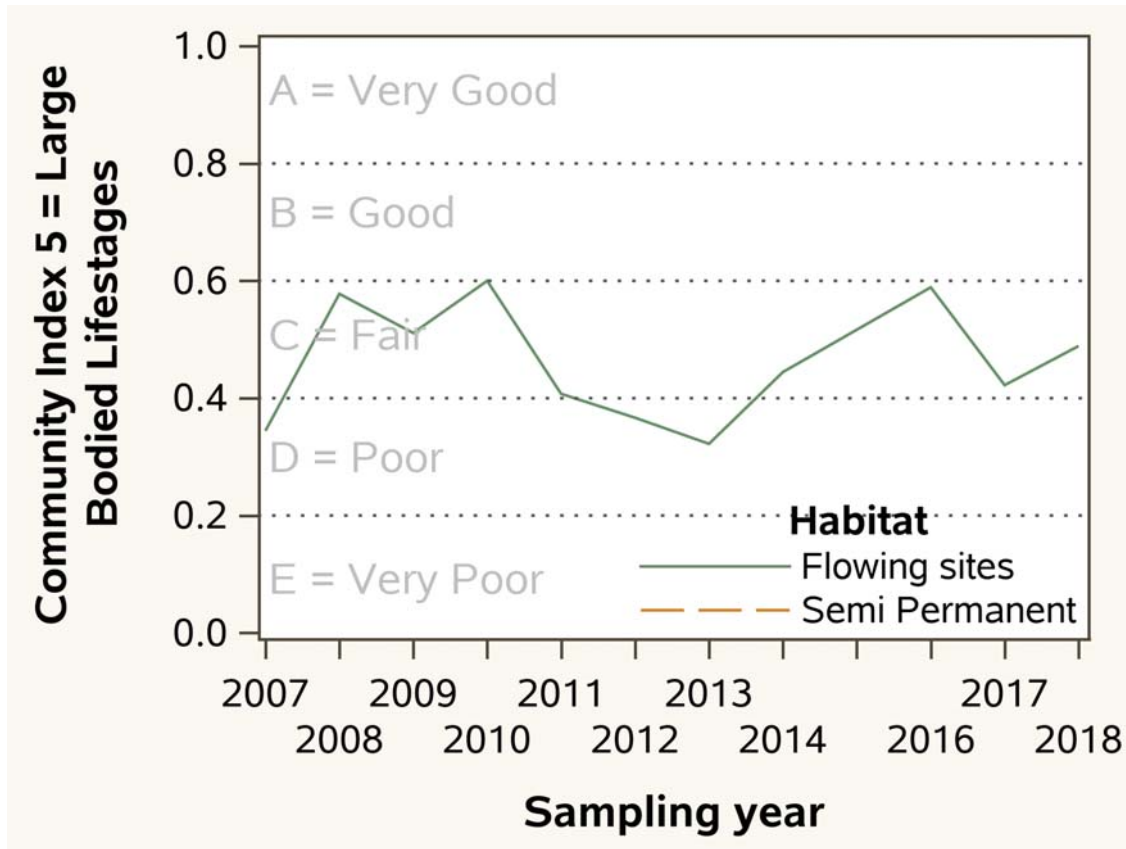


Figure 14. Community Index 5, distribution of age cohorts of large-bodied fish in B-MF during fish condition monitoring, 2007 – 2018. Data were not collected in 2015.

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

There was a decrease in the average number of native fish species present in BMF in 2018 that occurred in as many permanently flowing sites as expected, continuing a long-term downward trend (D-, Figure 15). In 2018, 78% of species occurred in as many semi-permanent sites as expected, close to the best recorded since monitoring began (B+, Figure 15).

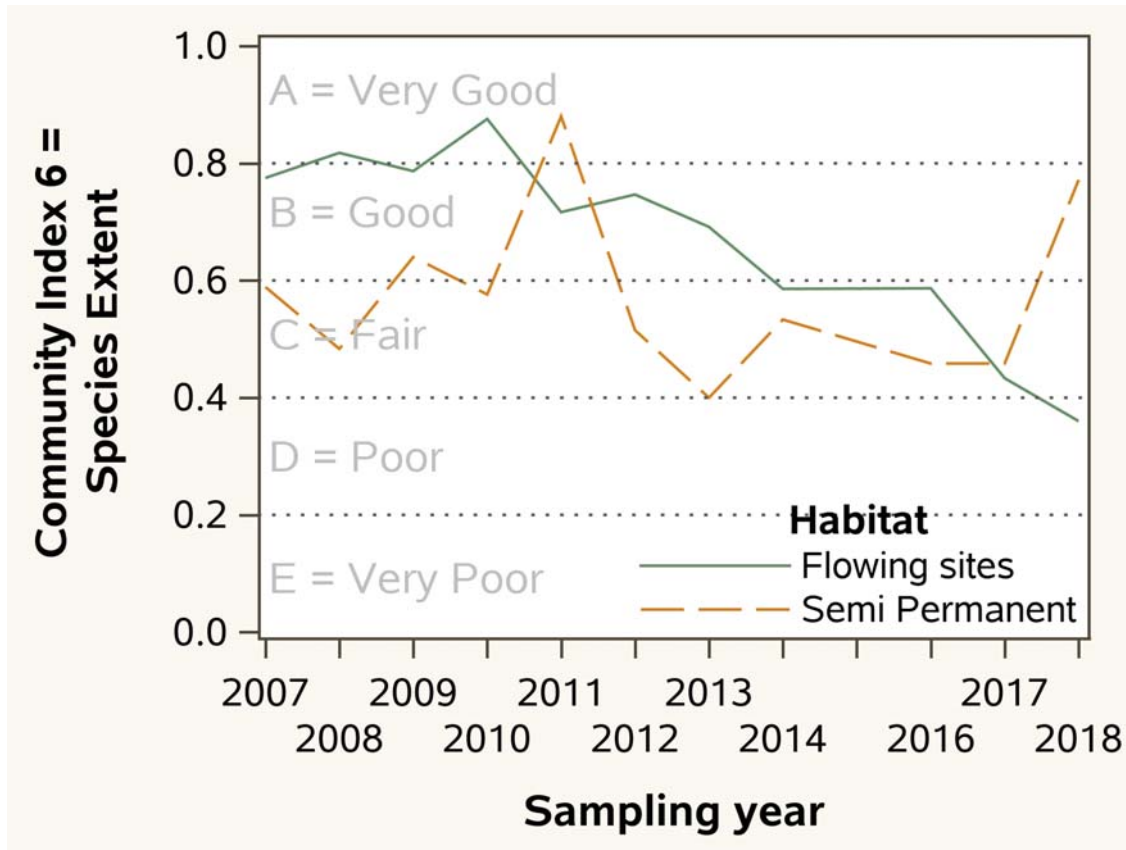


Figure 15. Community Index 6, Extent. The proportion of indigenous fish species that were collected in at least as many sites as expected during B-MF fish condition monitoring, 2007 – 2018. Data were not collected in 2015.

3.3.2 Native fish population indices

The proportion of fish abundance that is native

The average proportion of the total catch that is native is highly variable across years, with permanently flowing sites and semi-permanent sites decreasing since 2017 (Figure 16). Both habitat strata scores represent declines similar to the worst experienced since monitoring began and well below the very good scores achieved in 2009 (Figure 16). Permanently flowing sites score C- and semi-permanent sites score D- in 2018.

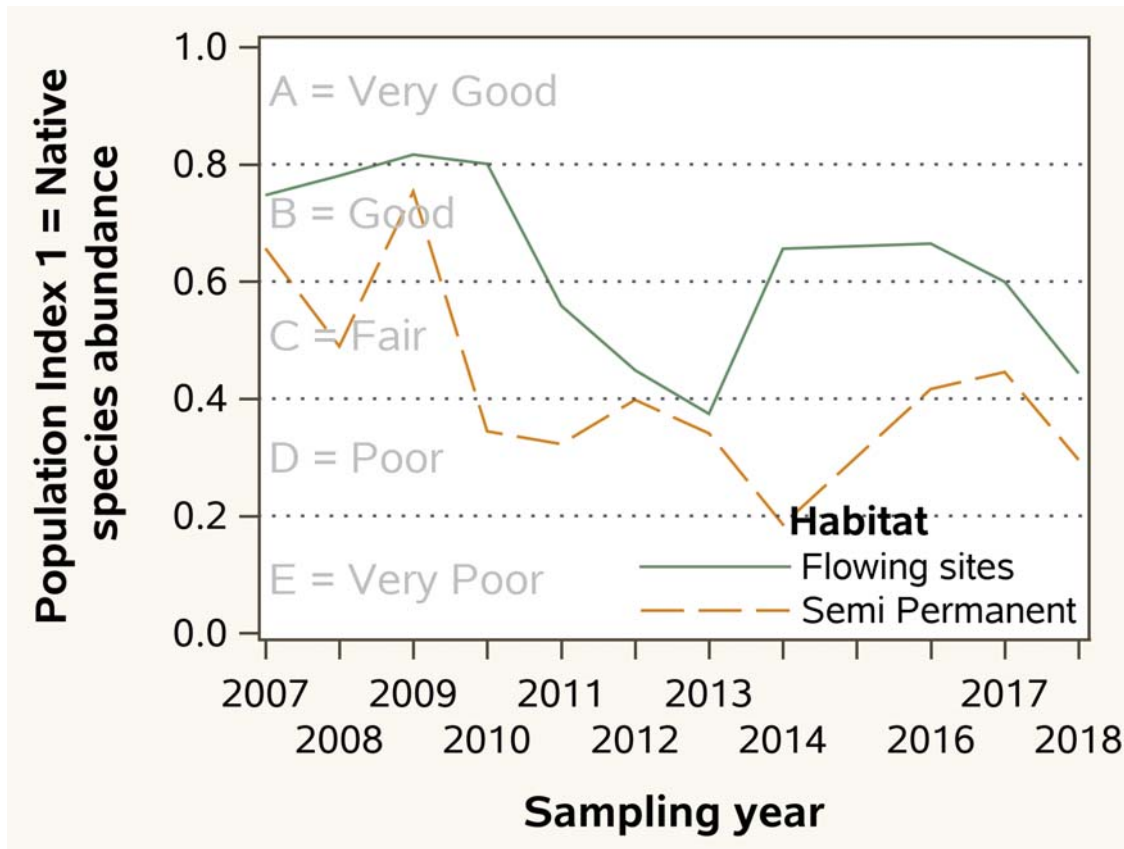


Figure 16. Population Index 1: Proportion of fish abundance that was native during B-MF fish condition monitoring, 2007 – 2018. Data were not collected in 2015.

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

Similar to previous years, the proportion of the fish biomass which is native in both the permanently flowing and semi-permanent sites remained low in 2018. Both strata were slightly up from last year, scoring E+ (Figure 17). Less than 20% of fish biomass in permanently flowing sites, and less than 10% of fish biomass in semi-permanent sites in BMF in 2018 was from native fish species.

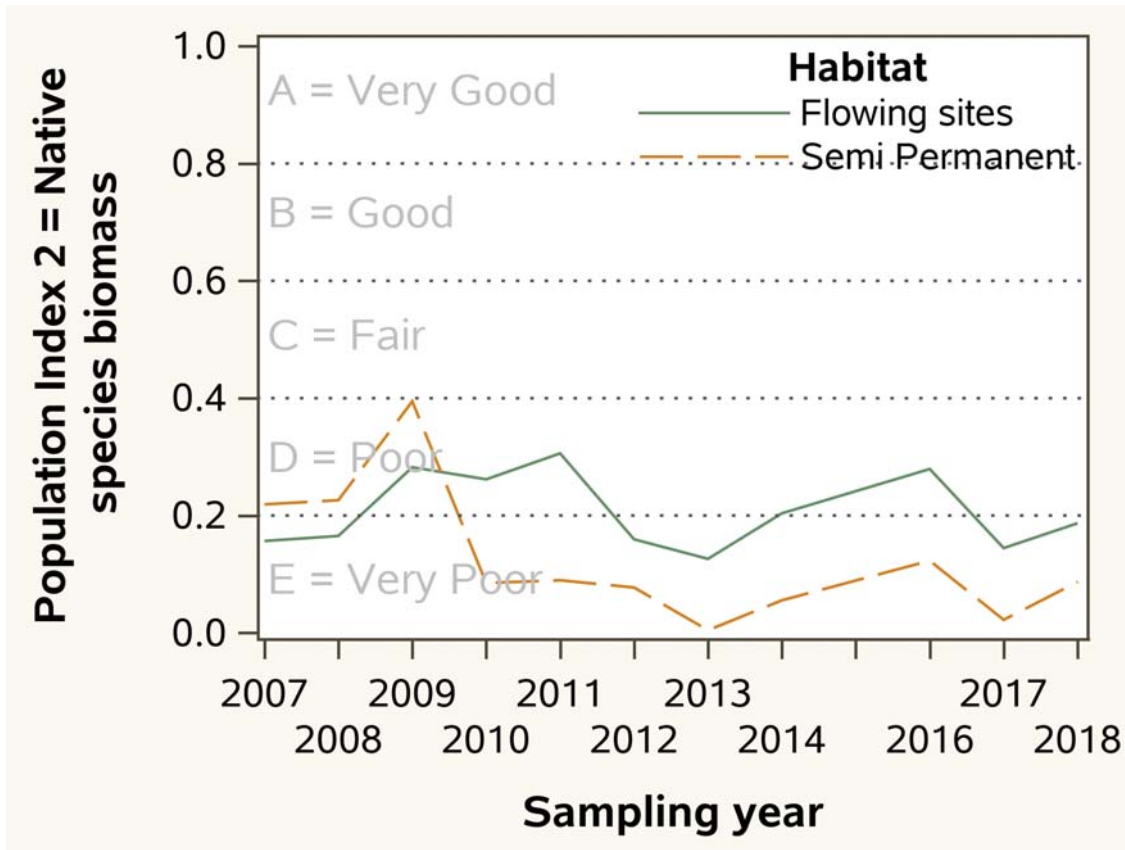


Figure 17. Population Index 2: Proportion of fish biomass that were native during B-MF fish condition monitoring, 2007 – 2018. Data were not collected in 2015.

The proportion of fish species that are native

Approximately 75% of the fish species collected in permanently flowing sites in 2018 were native, a relatively stable pattern since 2007, resulting in a score of B+ (Figure 18). The semi-permanent strata have approximately 40% native species per site, with a slight increase continuing from a low in 2013, scoring a C+.

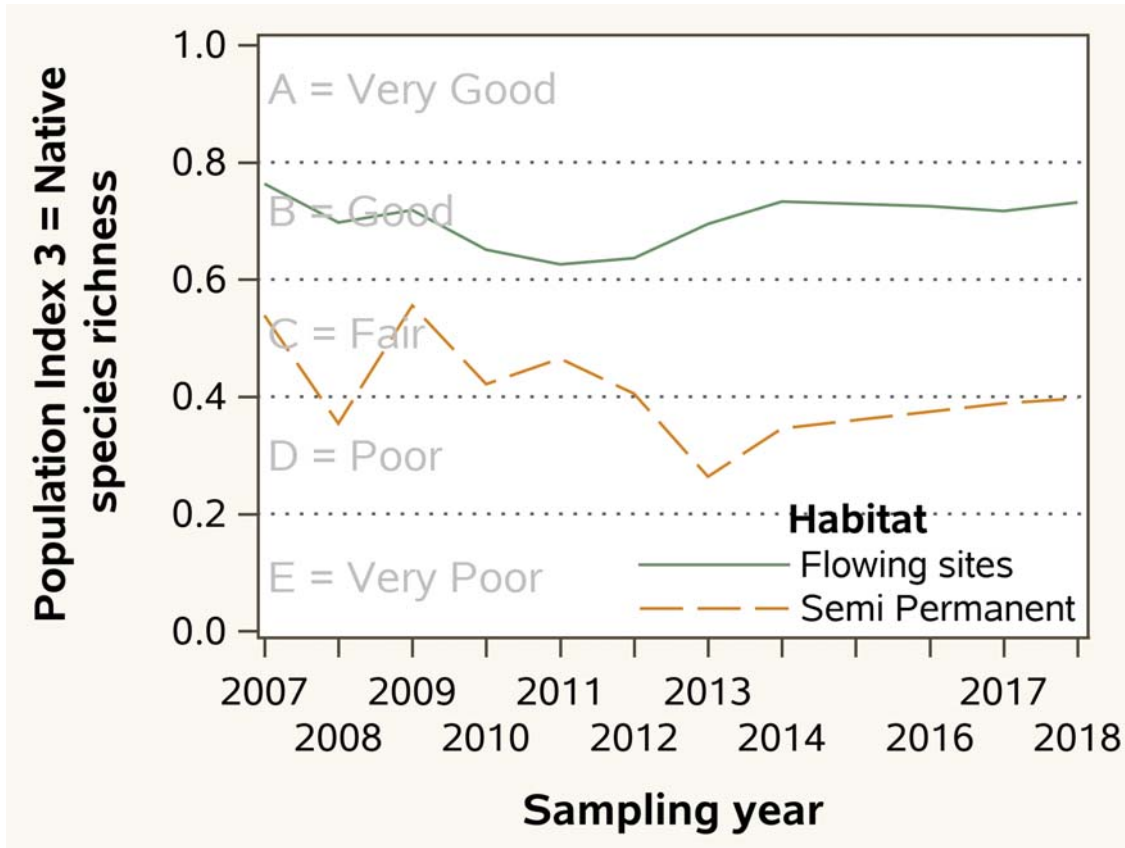


Figure 18. Population Index 3: Proportion of fish species that were native during B-MF fish condition monitoring, 2007 – 2017. Data were not collected in 2015.

3.3.3 Summary of Icon site indicators

Overall, the number of sites with native species recruits and the number of recruits as a proportion of the population received good scores (Table 4, indices 1 & 3), but the number of observed to expected species is still consistently low (indices 4a & 4b). The semi-permanent habitat fish community scores all showed a positive trend (+) in 2018 except index 1 which still scored an A. The flowing sites were not in as good a condition, scoring lower for every index apart from index 1 (Table 4).

Table 4. 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+	D-
Semi-permanent	A-	B+	A+	D+	C+		B+

Overall, the B-MF fish communities are dominated by alien species (Table 5), and the biomass of native fish in B-MF Icon site in particular is extremely low (Population Index 2). The permanently flowing sites have slightly higher native abundance and species richness than the semi-permanent sites. The trend for decreasing native fish abundance (P index 1) in both habitats in 2018 is indicative of the worst numerical dominance by alien fish species in B-MF since monitoring began.

Table 5. Scores determined for B-MF fish population nativeness indices.

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

3.4 Riverine larval drift

A total of 609 eggs and 423 larvae from four native and one alien fish species were collected in drift net sampling undertaken in the Murray River during spring 2017 (2017/18 study; Table 6). Larvae were predominantly Murray Cod (n=380) while eggs were mostly Golden Perch (n=307) and Silver Perch (n=302). Eighteen Trout Cod larvae were sampled (Table 6). Peak and average densities of target fish are provided in Appendix 5.

In the Murray River at Barmah, drift sampling was undertaken from mid-October to mid December 2017. Flows through the B-MF increased from around 10,000 to 15,000 ML/d prior to the first three sampling trips where the flow remained high and stable and sufficient to inundate the B-MF floodplain. Flows declined prior to the fourth trip and coincided with the receding limb of a minor (20,503 ML/d,) flood event in early December. In 2017, Golden Perch eggs (Figure 19) were collected earlier in the year compared with 2016, and at lower water temperatures than previous years. Peak (573 eggs/m³) and average (168 eggs/m³) densities of drifting Golden Perch eggs in 2017 were higher than the previous 10 sample years and consistent with record densities of drifting Golden Perch eggs in 2005 with peak (>500 eggs/m³) and average (>100 eggs/m³) densities recorded.



Figure 19. Mean abundance (+/- S.E.) of drifting Golden Perch eggs per sample trip (●) with flow (blue line) and temperature (orange line).

The average density of Murray Cod larvae per sampling trip recorded in 2017 was higher than 2016 and consistent with 2015, 2012 and 2009 (Appendix 5). The highest density of drifting Murray Cod larvae was recorded at the end of October in five (2004, 2005, 2006, 2008, 2009) of the 10 sample years. In 2017, drifting Murray Cod larvae were sampled from late October to the first week in December, coinciding with high and variable flows and increasing temperature (Figure 20). Murray Cod larvae were detected from all three sample sites, with most sampled from the upstream sites.

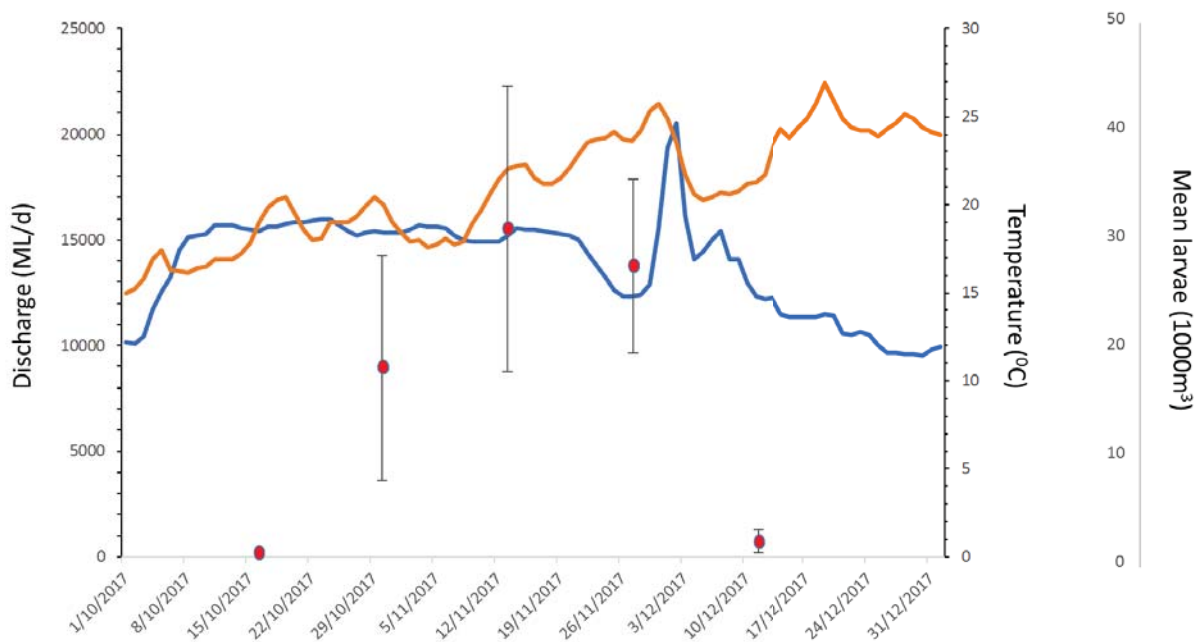


Figure 20. Mean abundance (+/- S.E.) of drifting Murray Cod larvae per sample trip (●) with flow (blue line) and temperature (orange line).

Drifting Trout Cod larvae were captured in 2010 (n=4), 2013 (n=1), 2014 (n=1), 2015 (n=2) and in low numbers in 2016 (n=4) with an average density ≤ 1 larvae m^3 per trip (Appendix 5, Table 6). Eighteen Trout Cod larvae were sampled from the 2017 larval drift surveys, at an average drift density of 1.6 larvae per m^3 , the highest density of Trout Cod sampled in the last 10 years. In 2017, drifting Trout Cod larvae were sampled from early to mid-November, coinciding with stable and high flows and increasing temperature.

In total, 302 Silver Perch eggs were collected from drift samples undertaken in the River Murray within B-MF from late-October to late-November 2017 (2017/18 study) with eggs collected from MR @ Morning Glory (211), Barmah choke (15) and Ladgroves Beach (n=76; Table 6). Peak and average densities of drifting Silver Perch was 58 and 14 eggs/ m^3 , respectively (Appendix 5). These densities were low when compared with data from previous years (2003-2014). The highest density of drifting Silver Perch was 8,275 eggs/ m^3 in December 2005 with remaining densities $< 2,100$ eggs/ m^3 . Through the study, Silver Perch eggs were most abundant at MR @ Morning Glory, followed by MR @ Ladgroves Beach, and least abundant at MR @ Barmah Choke (Table 6). Silver Perch eggs were recorded in high abundance (> 90) in each year from 2009 to 2016. Egg collection in 2017 was characterised by high and stable flows (Figure 21).



Figure 21. Mean abundance (+/- S.E.) of drifting Silver Perch eggs per sample trip (●) with flow (blue line) and temperature (orange line).

The majority (96%) of drifting Carp larvae were captured from MR @ Morning Glory in 2017, consistent with previous years (Table 6). An average density per trip of 7.1 larvae/m³ drifting Carp larvae was recorded in 2017. The density was similar to 2014 (1.9 larvae/m³) and 2010 (4 larvae/m³), however, greater than remaining years (average densities < 18 larvae/m³) (Appendix 6). Drifting Carp larvae were generally captured in October throughout the study years (Figure 22). No observed relationship was evident between flow and/or temperature with abundances of drifting Carp larvae in 2017/18.

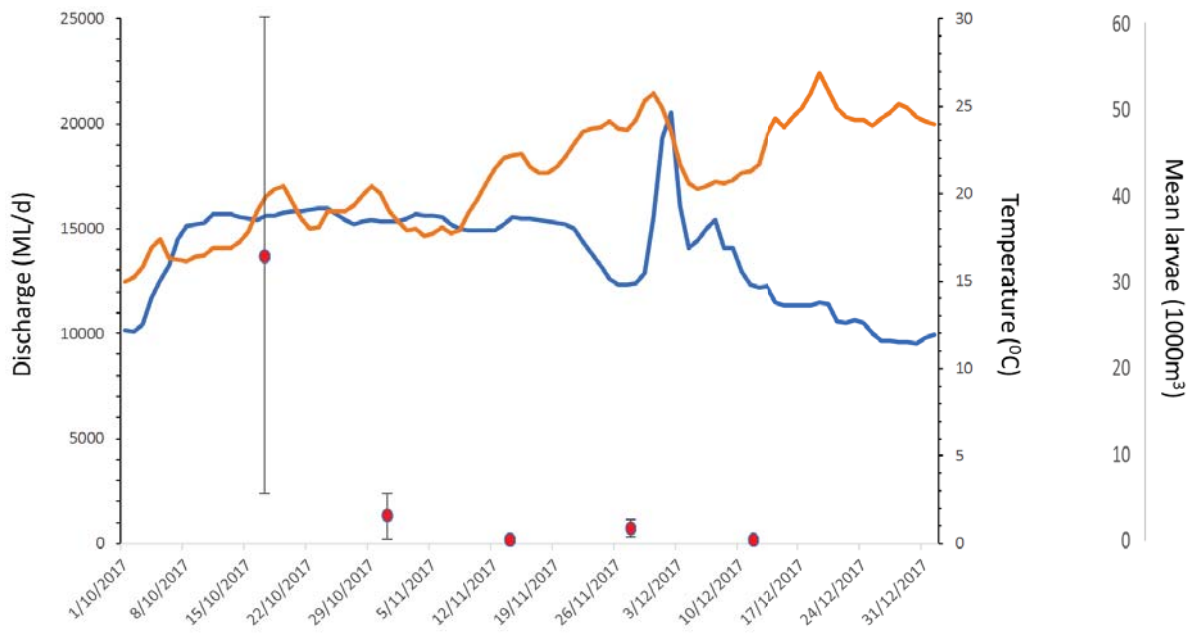


Figure 22. Mean abundance (+/- S.E.) of drifting Carp larvae per sample trip (●) with flow (blue line) and temperature (orange line).

Table 6. Raw abundances of drifting eggs (in parentheses) and larvae collected from the Murray River, 2008 – 2018.

Larval drift site	Common name	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
Morning Glory	<i>Native</i>											
	Murray Cod	16	10	0	2	5	10	2	14	1	31	
	Trout Cod	0	0	0	0	1	0	0	1	0	0	
	Silver Perch	(15)	(234)	0	(106)	(39)	(45)	(8)	0	(87)	(211)	
	Golden Perch	0	3	(1)	0	0	(3)	0	0	0	(152)	
	Murray crayfish	0	0	0	0	3	9	0	3	0	5	
	<i>Alien</i>											
	Goldfish	2	0	2	0	0	0	0	0	0	0	
	Common Carp	42	14	8	92	109	515	2	64	540	22	
	<i>sub-total (eggs and larvae)</i>	211	292	47	221	198	586	12	82	627	421	
	Barmah Choke	<i>Native</i>										
		Murray Cod	22	26	10	0	204	11	84	34	6	149
Trout Cod		0	4	0	0	0	0	2	1	4	12	
Silver Perch		2 (15)	2 (154)	0	(7)	(72)	(23)	(16)	1 (0)	(1)	(15)	
Golden Perch		1	3	(7)	0	0	(40)	0	(12)	(9)	(18)	
Murray crayfish		0	0	0	0	2	4	0	4	6	5	
<i>Alien</i>												
Goldfish		0	0	3	0	1	0	0	0	0	0	
Common Carp		0	6	0	0	9	1	0	21	12	0	
<i>sub-total (eggs and larvae)</i>		402	226	46	14	303	86	102	73	38	199	
Ladgroves Beach		<i>Native</i>										
		Murray Cod	4	0	38	5	13	14	4	3	4	200
	Trout Cod	0	0	0	0	0	1	0	0	0	6	
	Silver Perch	(231)	(426)	0	(139)	(559)	(427)	(175)	(160)	(11)	(76)	
	Golden Perch	0	0	(22)	1	0	(78)	0	(10)	(94)	(137)	
	Murray crayfish	0	0	0	0	0	0	0	0	0	3	
	<i>Alien</i>											
	Goldfish	1	0	1	0	0	0	0	0	0	0	
	Common Carp	12	2	0	1	1	0	0	1	8	1	
	<i>sub-total (eggs and larvae)</i>	277	497	121	151	574	556	179	174	117	423	
	Total (eggs and larvae)	890	1015	214	386	1075	1228	293	329	782	1043	

3.5 Murray crayfish

3.4.1. Icon site monitoring

This year (2018) represents the first year of reporting on the standardised sampling protocol for Murray crayfish within the B-MF (Raymond et al. 2017). The new regime (10 pots set at 13 sites, previously 10 pots at 6 Murray River sites) provides an Index of abundance and baseline data on sex ratios and size classes for future trend analysis.

Abundance

Thirty-six Murray crayfish were sampled in 2018, all from Murray River sites upstream of Lake Barmah (Figure 23, Appendix 6). Murray crayfish was most abundant at Murray River downstream of Picnic Point (n=9), Murray River @ Gulf 14 (n=9) and Murray River @ Gulf Creek (n=8) and in low (<5) abundance across remaining sample locations. Murray crayfish were not detected in the Edwards River in 2018. No Murray crayfish were sampled from the five most downstream Murray River sites, coinciding with their absence from previous study sites in the last six sample years.

Sex ratios and reproductive condition

Of the 36-crayfish sampled, 22 were female and 14 males, representing a sex ratio of 6:4 (female to male). Of the 22 females, 12 were in berry (carrying eggs). The current fishing regulations (VFA 2017) prohibit the removal of crayfish from the study reach. Ten females were within the legal-size range for removal (100-120 mm Occipital Carapace Length [OCL], VFA 2017) and four of the 10 females were not in berry, making them available for removal (if the current ban was removed). Four of the 10 male crayfish were in the size class designated for removal in regions upstream of Tocumwal on the Murray River, with regions downstream of Tocumwal protected from removal. In addition, 13 juveniles (< 2 mm OCL) Murray crayfish were sampled in larval drift nets set in the B-MF in spring/summer of 2017.

Size structure

The OCL of sampled crayfish ranged from 75 mm to 133 mm (Figure 23, Table 7). Mean OCL was 106 mm; 109 mm OCL for females (range 59-143) and 103 mm OCL for males (range 75 to 133 mm). Mean OCL of reproductively active females was 119 mm (range 104 to 133 mm) compared with females without eggs that had a mean OCL of 96 mm (range 76 to 112 mm) (Table 7). Of the potentially reproductive females (≥ 90 mm OCL, n= 19), seven (27 %) had no eggs. Four male crayfish (29%) fell within the size limit for potential removal from the population by anglers. The size structure of male and female crayfish sampled in 2018 (Figure 23, Table 7), was skewed toward larger individuals with a higher number of female crayfish > 100 mm OCL.

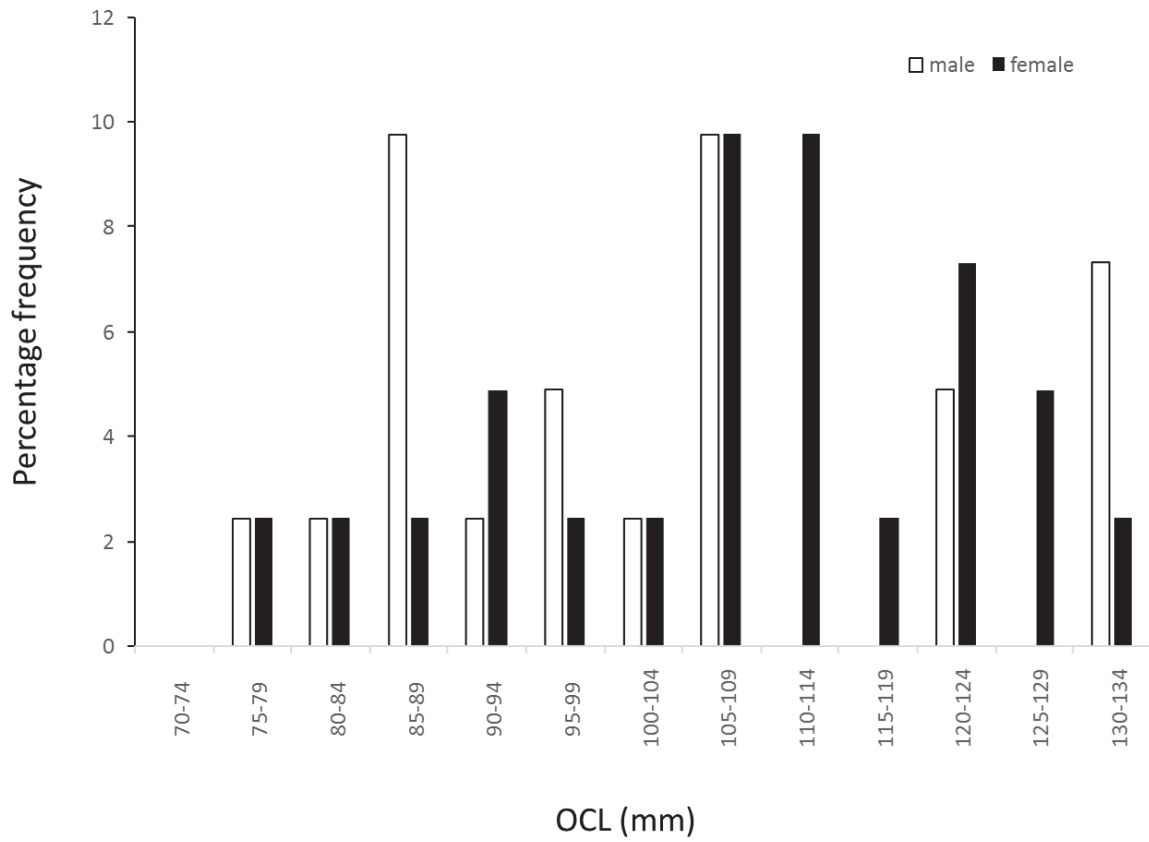


Figure 23 The percentage frequency of male (white columns) and female (black columns) Murray crayfish sampled in June 2018.

Table 7. Number and size of sampled and recaptured Murray crayfish

Crayfish sex	Number of crayfish sampled	OCL			Number within the slot limit
		Average (mm)	S. E	Range (mm)	
Males	14	103	4.1	75-133	5
Females with eggs	12	118.6	2.5	104-133	6
Females without eggs	10	96.3	3.9	76-112	4
Females total	22	109	3.3	76-133	10
Total	36	105.7	2.7	75-133	15

4 Discussion

4.1 Permanently flowing habitats

Over the course of the 11-year program, fish Condition and Population indices were generally high from 2007 to 2010, declined in 2011 and increased thereafter. Community fish condition indices were variable in 2018 with lower scores in three of the six indices (number of recruits as a proportion of the population, observed vs expected species and number of sites with native species) than in 2017, indicating that conditions over the last year have been stable. In addition, the number of sites with native recruits and the proportion of fish species that is native, improved over the last year and remain high. The overall condition of native fish within permanently flowing sites was stable over the past year, as indicated by minor changes across Community and Population indices.

While the number of permanently flowing sites with recruits was high (100%), the number of species with recruits and the number of recruits as a proportion of the population both scored 60 and 45%, respectively, indicating a preference of large-bodied fish for these habitats, differences in species' life-history strategies and detectability. The protracted temporal scale (weeks) of drifting eggs and larvae of Silver Perch and Golden Perch may result in them being dispersed below Torrumbarry weir, and consequently low numbers of this age class would be present during the late summer sampling. Also, sampling YOY of these species could be related to equipment inefficiencies for collecting this life stage (Dolan and Miranda 2003; Erős et al. 2009), that recruits for these species are in low abundance, or juvenile recruitment is occurring in areas not sampled. Lyon et al. (2008) and King et al. (2009) also found it difficult to collect YOY golden and Silver Perch. The presence of good numbers of Murray Cod recruits (supported by high numbers of larvae from drift sampling) in 2018, indicates that recent conditions appear to have been favourable for this species. Given the variable life-history strategies employed by native fish species and variable detectability, further refinement of the Community recruitment (indices 2 and 3) and distribution of cohorts (index 5) indices are required.

The proportion of the total fish abundance that is native averaged 38% across permanently flowing and semi-permanent sites in 2018. While these indices remain considerably lower than the target of 75% 'nativeness', 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, hence numerically most fish collected should be recruits.

The expectedness score of permanently flowing sites in 2018 was 50%, considerably below the target of 75% and consistent with the previous seven sample years. Expectedness declined steeply following the 2010 floods, largely due to the absence of small-bodied native fish such as Murray-Darling rainbowfish, *Melanotaenia fluviatilis* (2012 and 2013), Un-specked Hardyhead, *Craterocephalus stercusmuscarum fulvus* (2011 and 2012), Flat-headed Gudgeon, *Philypnodon grandiceps* and Bony Herring, *Nematalosa erebri* (2011 onwards). The decline in native fish numbers from 2010 to 2014 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 flows between sampling events. Competition with and predation by alien fish species may also negatively impact native fish within the riverine habitat.

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 and Silver Perch were recorded in greater abundances in 2018 than in 2017, while abundances were comparable with 2016 records. The increase in the distribution of age cohorts for large-bodied fish (Community Index 5) in 2018 is

likely an artefact of detectability and/or variation in life-history strategies employed by these species and requires further refinement.

Sampling of permanently flowing waters recorded the highest number of adult Murray Cod along with the highest proportion of adult fish within the population over the past 10 years of sampling. The importance of considering adults when interpreting spawning and recruitment outcomes are often ignored in the literature with some exceptions (Tonkin et al. 2015). Murray Cod larvae were collected from early November to early December, earlier than last year and similar to previous years. Delayed (and/or reduced) spawning/hatching (in 2016) may have been negatively impacted by lower than average temperatures, 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; King et al. 2016) and that Murray Cod spawning is closely related to the time of year and/or temperature.

River sites have supported high numbers of Carp throughout the condition monitoring program, and therefore the presence of the species has influenced population indices in permanent flowing habitats such as overall native abundance. The dramatic decline in the proportion of fish that are native (Population index 1) from 2010 (0.8) to 2011 (0.55) 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 catch. The subsequent decline in Carp from 2014 onwards was linked with an increase (from 0.4 to 0.7) in the proportion of fish that are native. The absence of prolonged and protracted flooding of B-MF will likely restrict suitable conditions for Carp spawning and recruitment in the future.

4.2 Semi-permanent flowing habitats

In general, community and population indices for native fish in semi-permanent habitats scored 0.5 or less, well below the target level of 0.75. Most indices declined over the course of the study, with recent improvement noted in 2018, indicating that conditions in these habitats has shown recent improvement conducive to native fish recruitment and survival. The decline in scores from the early study years generally coincided with the millennium drought where some sites dried up and natives were concentrated in remaining semi-permanently flowing sites, hence high native index scores. Then flooding resulted in dry sites being filled with water (hence the dilution of fish community indices) resulting in conditions conducive to recolonisation by exotic fish species, with recent years showing a slow recovery of native species.

The general decline across native fish indices (with the exception of sites natives were detected in [Index 6]) within B-MF semi-permanent habitats in 2011 and 2014, coincided with marked increases in Carp, 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) were present in 2011 and 2014. The marked variation in gambusia numbers across years highlights the rapid recolonisation and reproduction of habitats by this species (McDowell 1980; Tonkin et al. 2011) 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 habitats and also periods of isolation. Whilst periods of connectivity facilitated access to off-channel habitats for breeding by small-bodied species such as Australian Smelt, Murray-Darling rainbowfish and Gudgeons (and Murray Cod in 2018), improved connectivity may have also provided juvenile Carp (spawned after the 2010/11 and 2016/17 floods) with access to semi-permanent flowing habitats, that may have contributed to declines in nativeness and expectedness indices within this strata.

The dominance of small-bodied alien fish species and Carp in semi-permanently habitats following the 2010/11 and 2016/17 floods (and subsequent blackwater events) demonstrates that the recolonisation capacity of these species following flooding is high. However, good numbers of small-bodied native Australian Smelt and Carp Gudgeons suggest that these species are better equipped to re-colonise sites

than other small-bodied natives. While small-bodied species tend to have relatively broad spawning periods, optimal conditions for recruitment are not well understood (Humphries et al. 2002).

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*), Murray Hardyhead (*Craterocephalus fluviatilis*), Southern Pygmy Perch (*Nannoperca australis*), Purple Spotted Gudgeon (*Mogurnda adspersa*), Flathead Galaxias (*Galaxias rostratus*), Mountain Galaxias (*Galaxias 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 been lost more recently given their last detection was in 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 (due to the millennium drought, combined with a short life-span (Tonkin et al. 2008), and the proliferation of alien species 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, makes this unlikely (MacDonald et al. 2012). 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.

4.3 Riverine spawning assessment

The ninth year (2017) of egg/larval drift sampling has shown that the main channel of the Murray River remains a spawning habitat for all four large-bodied native species (Golden Perch, Silver Perch, Murray Cod and Trout Cod). In excess of 300 Silver Perch and Golden Perch eggs along with 380 Murray Cod and 18 Trout Cod larvae were collected during the 2017/18 B-MF drift sampling.

The low levels or failure of Golden Perch spawning in the Murray River at Barmah between 2008 and 2012 was thought to be a result of either low or stable flows during the core spring spawning window (see King et al. 2009; Raymond et al. 2013). The return of more variable overbank flows in 2013 and 2016, within channel pulses in 2015 resulted in an increase in Golden Perch spawning intensity. The dramatically higher abundance and peak densities of drifting Golden Perch eggs in 2017 (compared with previous years) suggests that recent flow conditions (particularly those leading up to early November), were suitable for spawning of this species. Consistent with 2016, Golden Perch eggs were captured following flows sufficient to inundate the B-MF floodplain, supporting previous research indicating that spawning magnitude is associated with high flows in both flood and within channel flow pulse years (King et al. 2016). These findings are important to management when considering the potential magnitude and timing of flow delivery through the system.

Silver Perch eggs were collected from early to late-November during over-bank flow conditions ($\approx 15,000$ ML/d), an increase in antecedent flows (10,000 to 15,000 ML/d), and a period of increasing temperature (17.9–25.7°C). No Silver Perch eggs were sampled in 2010, indicating that Silver Perch either did not spawn that year, or that conditions for the collection of their eggs was unsuitable. The lack of Silver Perch recruits from the mid-Murray following the 2011 blackwater event (Tonkin et al. 2017), suggests that the species did not spawn.

4.4 Murray crayfish

As this is the first year to provide baseline data on Murray crayfish comparison with previous years data is not possible. However, presence/absence and raw catch data show that crayfish were not recorded from sites impacted by blackwater in the previous year, and that since the blackwater event in 2010/11, only one crayfish was recorded from a blackwater impacted site in 2013. This is consistent with a recent

investigation where an 81% decline in Murray crayfish abundance was recorded following the 2010 blackwater event in the Murray River (McCarthy et al. 2014). The 2010 blackwater event resulted in large numbers of Murray crayfish 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 poaching by humans. Thus, it is reasonable to suggest that the Murray crayfish 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 crayfish have a small home range and limited dispersal (Ryan 2005, Gilligan et al. 2007), are moderately fecund (<1000 eggs/female) and take between six to 10 years to mature (Gilligan et al. 2007).

In 2018, 36 Murray crayfish were captured, establishing a baseline for an Index of Abundance, and for enabling trend analysis for future sampling. The unequal sex ratio of 6:4 (female to male) indicates that the population is biased toward females. While the unequal ratio may be indicative of the population, differences in sampling and past fishing may also explain the dominance of females sampled. Given the disproportionate number of females in the larger size cohorts (>110 mm OCL), the slow growth of individuals above 90 mm OCL, the recent ban from fishing Murray crayfish (2011 VFA) and past fishing regulations (removal size included crayfish >90 mm OCL) it appears that the lower number of males in the population is likely a carry-over from past fishing. This conclusion is in agreement with the findings of Zukowski et al (2013) who noted unequal sex ratios in Murray crayfish populations from regions of greater fishing pressure.

The length (OCL) of sampled Murray crayfish was strongly skewed toward larger (older) individuals and may reflect one or a combination of:

- sampling bias due to capture methods that select for larger individuals;
- a remnant of past fishing practices (see above) or;
- a real decline in younger animals, possibly due to reduced recruitment due to environmental impacts, such as blackwater.

Differences in catch rates between the sexes, uneven proportion of adult females 'in berry' and variability in size cohorts indicate differences in catchability for these parameters. These differences are likely to be influenced by variable energy requirements, life-history strategies, past fishing pressure and other biological and ecological constraints (Honan and Mitchell 1995; Ryan 2005; Zukowski et al. 2013). Further work (sampling and analysis) should focus on testing the factors responsible for differences in catchability, sex ratios, size structures and movement patterns of Murray crayfish.

While the current fishing regulations (VFA 2017) prohibit the removal of crayfish from the study reach, five males and 10 females were within the legal-size range for removal (100-120 mm Occipital Carapace Length [OCL], VFA 2017). Four of the 10 females were not in berry, making them available for removal (if the current ban was removed). The impact of variable rates of removal of male and female crayfish on long-term population persistence in B-MF requires further investigation.

Conclusion

The overall condition of the fish community in B-MF in 2018 was good, with indices showing stable or improved scores since 2017 (56-74%), yet below the target of 75%. Recruitment, expectedness and nativeness indices for native fish across years and strata were fair to good with recent improvement in recruitment driven by Australian Smelt and large-bodied native fish. Large-bodied native fish species (Murray Cod, Trout Cod and Golden Perch) were recorded in similar numbers from 2016 to 2018 and in comparatively higher numbers, relative to sample years prior to this period. 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 2018, following a decline in the two years post 2010 flooding and associated blackwater event. Expectedness was stable and low (0.5), while the number of sites that 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. An effective sampling protocol for assessing Murray crayfish condition has been established for the B-MF and provides a reliable means to determine future impacts.

Whilst 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. 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	2017	2018	
Barmah	Budgee Creek	✓	✓	✓	✓	#	✓	✓	✓	*	✓	✓	✓	
	Tullah Creek	✓	×	×	×	✓	✓	×	✓	*	×	✓	✓	
	Gulf Creek @ 4-mile	*	*	✓	✓	✓	✓	*	✓	*	✓	✓	✓	
	Barmah Lake	✓	✓	✓	✓	✓	✓	✓	✓	*	✓	✓	✓	
	Hut Lake	×	×	×	×	✓	✓	×	✓	*	✓	✓	✓	
	Flat Swamp	✓	×	×	×	✓	✓	×	✓	*	✓	✓	✓	
	Tullah Creek @ Gundry's Old Bridge	✓	×	✓
	Tarma Lagoon	*	*	*	*	*	*	*	*	*	*	✓	×	✓
	Punt Paddock Creek	*	*	*	*	*	*	*	*	*	*	*	✓	×
	Boals Creek	*	*	*	*	*	*	*	*	*	*	*	✓	×
	Mary Ada Creek @ regulator	*	*	*	*	*	*	*	*	*	*	*	✓	×
	Millewa	Toupna Creek	✓	✓	×	✓	✓	✓	✓	*	*	✓	×	×
Aratula Creek		✓	✓	✓	✓	✓	✓	✓	*	*	✓	✓	✓	
Moir Lake		✓	×	×	✓	✓	✓	✓	*	*	✓	×	✓	
Pinchgut Lagoon		✓	×	✓	×	✓	✓	✓	*	*	✓	✓	✓	
Fisherman's bend Billabong		✓	×	✓	✓	✓	✓	✓	*	*	✓	✓	✓	
Wild Dog Creek		*	*	*	*	*	*	*	*	*	*	*	*	✓
Toupna Creek backup site		*	*	*	*	*	*	*	*	*	*	*	*	✓

✓ Site contained water and successfully sampled

* Site not sampled

× Site dry and not sampled

. Site was inaccessible

Appendix 2. Sites where fish species were caught in river (permanently flowing) sites in B-MF in 2018.

Waterbody	Barmah - Moirá Lake Area	Edward River 5km Ds Regulator	Edward River Ds Gulpa Creek	Gulpa Creek	Ladgroves Beach	Morning Glory	Murray River @ Gulf Creek	Picnic Point	Tongalong Creek	Woodcutters
<i>Native species</i>										
Carp Gudgeon		14	2	15			1	10	16	60
Australian Smelt		450	270	28				2	1	
Un-specked Hardyhead								1		
Murray-Darling Rainbowfish				2						
Murray Cod	4	2	10	1	17	4	9	13		6
Golden Perch	6	3			1	6	11	11	2	3
Silver Perch	4	1	1	2		1		1		2
Trout Cod	2				8	1	3	2		2
<i>Alien species</i>										
Goldfish				8						1
Common Carp	87	122	27	18	62	28	117	71	26	65
Gambusia				1						
Oriental Weatherloach			1							

Appendix 3. Sites where fish species were caught in semi-permanent sites in B-MF in 2018.

Waterbody	Aratula Creek	Barmah Lake	Budgee Creek	Fishermans Bend Lagoon	Flat Swamp	Gulf Creek	Tullah Creek	Hut Lake	Moira Lake	Pinch Gut Lagoon	Tarma Lagoon	Toupna Creek no2	Tullah Creek	Wild Dog Creek
Native species														
Carp Gudgeon	102	4		3	82	124	122	46	5	31	22	12	195	24
Flat-headed Gudgeon				5										
Australian Smelt		1			27	86	42	10	15	27	1	2	308	
Un-specked Hardyhead		1			7		1							
Murray-Darling Rainbowfish					2					1				
Murray Cod					4								1	
Golden Perch														
Silver Perch														
Dwarf Flat-headed Gudgeon	1											2		
Trout Cod					1									
Alien species														
Goldfish		12	2	2	8	75	8		2	47	120	47	105	25
Common Carp	18	55	33	17	52	152	58		69	34	12	98	138	57
Gambusia	176			115	6	63	4	116	2	6	21	58	7	3
Oriental Weatherloach					4	48	2	17					40	
Redfin Perch				91				1				29		

Appendix 4. Fish species captured from B-MF, 2007 to 2018.

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

Appendix 5. 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, 2008-2017.

Common name	Egg/larvae	Trip number	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Murray Cod	larvae	1	0.0	0.0	0.0	0.0	0.0	0.0	2.2	31.8	0	0
Murray Cod	larvae	2	17	65.3	1.8	0.0	0.7	0.0	12.2	5.2	0	17
Murray Cod	larvae	3	11.2	4.9	8	0.0	47.9	3.7	3.6	36.2	0	29
Murray Cod	larvae	4	13.2	0.0	11.2	2.5	0.0	7.1	4.9	0.0	0	26
Murray Cod	larvae	5	3.1	0.0	1.4	0.7	6.6	1.1	0.0	0.0	20	1
Murray Cod (average)			8.9	14	4.5	0.65	11	2.79	5.73	14.6	4	14.7
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Trout Cod	larvae	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
Trout Cod	larvae	2	0.0	5.2	0.0	0.0	0.0	0.0	0.2	1.8	0	6
Trout Cod	larvae	3	0.0	0.0	0.0	0.0	1.9	0.6	0.0	0.0	0	1.6
Trout Cod	larvae	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
Trout Cod	larvae	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	0
Trout Cod (average)			0.0	1.0	0.0	0.0	0.4	0.1	0.1	0.4	0.9	1.6
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Golden Perch	egg	1	0.0	0.0	0.0	0.0	0.0	197.3	0.0	137.5	0	195
Golden Perch	egg	2	0.0	0.0	33.5	0.0	0.0	72.3	0.0	25.4	18.1	573
Golden Perch	egg	3	0.0	0.0	0.0	0.0	0.0	23.6	0.0	0.0	10.9	35
Golden Perch	egg	4	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	475	16
Golden Perch	egg	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	85	22
Golden Perch (average)			0.0	0.0	6.7	0.0	0.0	45.8	0.0	32.6	118	168
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Silver Perch	egg	1	0.0	524.8	0.0	0.0	0.0	0.0	270	0.0	0	0
Silver Perch	egg	2	146.9	270	0.0	0.0	2.11	12.3	497	7.8	0	5
Silver Perch	egg	3	49.1	129.2	0.0	77.6	1338	16.1	519	88.9	0	58
Silver Perch	egg	4	537.5	475.5	0.0	55.2	216.5	18.3	7.8	116.8	53.4	7.5
Silver Perch	egg	5	0.0	591.9	0.0	99.8	10.3	64.1	0.00	59.1	225	0
Silver Perch (average)			146.7	398.2	0.00	45.8	313.4	22.2	323	54.5	55.7	14
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Common Carp	larvae	1	258.6	49.6	16.7	48.5	323.8	391.1	7.7	5.3	96.3	32
Common Carp	larvae	2	11.1	33.6	2.5	2.8	2.7	64.8	0.00	247.1	0.6	2.6
Common Carp	larvae	3	0.0	1.1	0.00	4.3	0.32	123.7	0.00	61.1	30.4	0
Common Carp	larvae	4	60.7	0.0	0.00	0.00	1.03	1.9	0.00	4.97	7.2	1.2
Common Carp	larvae	5	0.0	0.7	1.04	0.00	0.00	0.00	0.00	0.00	0	0
Common Carp (average)			66.1	17	4.06	11.3	65.6	90.6	1.9	63.7	26.9	7.1

Appendix 6. Murray crayfish catch data

Number of Murray crayfish captured from Murray River monitoring sites, 2007 - 2018.

Site name	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018*
Ladgroves Beach	1	4	0	5	0	3	11	2	—	6	2	4
Downstream of Ladgroves Beach	—	—	—	—	—	—	—	—	—	—	—	0
Upstream of Gulf Creek	—	—	—	—	—	—	—	—	—	—	—	3
Murray River @ Gulf Creek	2	1	5	3	0	6	4	8	—	22	12	8
Gulf #14	—	—	—	—	—	—	—	—	—	—	—	9
Gulf #1	—	—	—	—	—	—	—	—	—	—	—	1
Woodcutters	1	9	7	2	ns	4	3	2	—	6	0	1
Picnic Point	1	0	1	8	5	1	9	2	—	10	6	1
Downstream Picnic Point	—	—	—	—	—	—	—	—	—	—	—	9
Barmah - Moira Lake area	1	4	0	1	0	0	1	0	—	0	0	0
Downstream Choke	—	—	—	—	—	—	—	—	—	—	—	0
Upstream Morning Glory	—	—	—	—	—	—	—	—	—	—	—	0
Morning Glory	3	10	39	5	0	0	0	0	—	0	0	0
Edwards River (d/s regulator)	0	0	0	0	0	0	2	ns	—	0	0	0
Total	9	28	61	24	5	14	30	14		44	20	36

- Seven additional sites sampled in 2018 (2017 refinement study recommendation)

Length, weight, sex and presence of eggs in Murray crayfish captured from Murray River sample sites in 2018. Seven new/additional sites (yellow highlight) were sampled in 2018 compared with previous sample years.

Site name	Length (mm)	Weight (g)	Sex	Eggs present
Murray River @ Ladgroves Beach	99	445	F	N
Murray River @ Ladgroves Beach	94	338	F	N
Murray River @ Ladgroves Beach	121	770	M	
Murray River @ Ladgroves Beach	108	634	F	N
Murray River Upstream of Gulf Creek	107	556	M	
Murray River Upstream of Gulf Creek	85	298	M	
Murray River Upstream of Gulf Creek	124	860	F	Y
Murray River @ Gulf Creek	98	458	M	
Murray River @ Gulf Creek	117	690	F	Y (10%)
Murray River @ Gulf Creek	113	762	F	Y
Murray River @ Gulf Creek	96	446	M	
Murray River @ Gulf Creek	104	516	F	Y
Murray River @ Gulf Creek	88	344	M	
Murray River @ Gulf Creek	85	328	F	N
Murray River @ Gulf Creek	132	1142	M	
Murray River @ Gulf #14	83	254	F	N
Murray River @ Gulf #14	109	546	F	Y
Murray River @ Gulf #14	125	846	F	Y (50%)
Murray River @ Gulf #14	112	568	F	Y
Murray River @ Gulf #14	123	716	F	Y
Murray River @ Gulf #14	121	760	F	Y (50%)
Murray River @ Gulf #14	113	600	F	Y
Murray River @ Gulf #14	108	464	F	N
Murray River @ Gulf #14	76	208	F	N
Murray River @ Gulf #1	107	556	F	N
Murray River @ Woodcutters	91	358	F	N
Murray River @ Picnic Point	106	490	M	

Murray River Downstream of Picnic Point	90	322	M	
Murray River Downstream of Picnic Point	112	666	F	N
Murray River Downstream of Picnic Point	133	992	M	
Murray River Downstream of Picnic Point	133	1014	F	Y
Murray River Downstream of Picnic Point	75	218	M	
Murray River Downstream of Picnic Point	105	570	M	
Murray River Downstream of Picnic Point	129	874	F	Y
Murray River Downstream of Picnic Point	100	474	M	
Murray River Downstream of Picnic Point	84	274	M	

