Koondrook–Perricoota Forest Icon Site Fish Condition Monitoring 2017 Annual Report

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Cover image: Grasses Waterhole 16th February 2017 (Kate Martin)

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Acknowledgments

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Non-technical summary

Koondrook–Perricoota Forest Icon Site Fish Condition Monitoring 2017 Annual Report.

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Objectives

The KPF Fish Condition Monitoring project has two major monitoring objectives:

- Annual status assessment of the condition of the Koondrook-Perricoota Forest fish community.
- Trend assessment of the condition of the Koondrook-Perricoota Forest fish community.

Key words

Koondrook-Perricoota Forest, Native Fish, Environmental Water, The Living Murray

Summary

The Koondrook-Perricoota Forest (KPF) is a large floodplain forest located adjacent to the Murray River in southern New South Wales and is one of The Living Murray (TLM) icon sites, containing significant wetland and creek ecosystems.

To assess the condition of the fish community and monitor progress toward the KPF refined ecological objective for fish, a fish condition monitoring project was implemented in 2011 after drought-breaking floods entered the KPF in 2010 and created fish habitat in wetlands and creeks. The KPF Fish Condition Monitoring project has two major monitoring objectives:

- Annual status assessment of the condition of the KPF fish community; and
- Trend assessment of the condition of the KPF fish community.

This report documents the results of the fish condition monitoring at Koondrook-Perricoota Forest project in 2017 and the changes in the fish community monitored since 2011.

The main findings are:

- KPF provided habitat for eight native species in 2017;
- The native fish community in KPF is in very poor condition based on SRA indices. Native fish biomass within KPF waterbodies in 2017 averaged just 7% of total fish biomass, the second lowest since 2011. Abundance of native fish in KPF waterbodies in 2017 averaged 27% (of total catch), the lowest since monitoring began;
- While abundance and biomass of native species was low, observed to expected index (OE) was comparable to previous years, indicating similar native species were present from year to year;
- Common carp young-of-year (YOY) were present in extremely high numbers in KPF in 2017. A spring flood event in KPF resulted in a high proportion of YOY common carp (recruits) in the following autumn. Flooding in June and July did not promote the same level of recruitment and thus may be the most suitable time to deliver environmental flows if the goal is to minimise carp spawning and recruitment response;
- The condition of the native fish community in KPF is unlikely to improve further until additional management actions are implemented, such as controlling carp populations or reintroducing locally extinct species.

Introduction

Koondrook–Perricoota Forest and The Living Murray initiative

The Living Murray (TLM) river restoration program was initiated in 2002 in response to evidence of the declining health of the Murray River ecosystem (MDBA 2012). The focus of TLM is on achieving agreed ecological objectives at six icon sites along the Murray River and thereby benefiting the entire Murray River system. The six icon sites are:

- Barmah–Millewa Forest
- Gunbower and Koondrook–Perricoota Forest
- Hattah Lakes
- Chowilla Floodplain and Lindsay–Wallpolla Islands
- Lower Lakes, Coorong and Murray Mouth
- River Murray Channel.

The four TLM ecological objectives associated with the Gunbower–Koondrook–Perricoota Forest:

- Protect and enhance a diverse range of healthy wetlands
- Protect and enhance diverse, healthy vegetation communities
- Provide for successful waterbird breeding and recruitment events
- Protect and enhance viable native fish communities

To achieve the icon site ecological objectives, approximately 500 GL water has been recovered and water management infrastructure has been installed at each icon site to facilitate delivery of the recovered water. Where possible, environmental water is used in conjunction with natural freshes and high flows, and used at more than one location when return flows occur.

The Gunbower and Koondrook–Perricoota Forests (GKP) icon site is located downstream of Echuca, with the Koondrook–Perricoota Forest to the north in southern New South Wales (NSW) and the Gunbower Forest to the south of the Murray River in northern Victoria. The GKP icon site is a Ramsar-listed wetland, has significant ecological values.

The objective for fish at KPF is to: protect and enhance viable native fish communities (MDBA 2012). This objective has been refined from The Living Murray First Step Decision (FSD) interim ecological objective for fish — healthy populations of resident native fish in wetlands (MDBMC 2003). The refined objective encompasses a number of specific aims for native fish, including improved recruitment of large and small-bodied native fish and restore self-sustaining populations of southern pygmy perch (*Nannoperca australis*) and other small native fish (MDBA 2012).

To determine if progress is made toward TLM ecological objectives, a major environmental monitoring program was established in 2005–06 as part of the implementation of TLM program. The monitoring activities include both condition or ‘health’ monitoring and response or ‘intervention’ monitoring. Condition monitoring (this report) provides information to enable an understanding of the ecological condition of the site, how the condition changes over time and if progress is being made toward TLM ecological objectives. Intervention monitoring is designed around the objectives of watering events and seeks to answer specific questions and knowledge gaps about ecological responses to environmental watering (not covered by this report). The KPF Fish Condition Monitoring project was established in 2011 under the umbrella of TLM initiative.

Fish and the Koondrook–Perricoota Forest

Prior to this project, the fish community of KPF had not been previously studied in detail. At the end of the millennium drought in 2009, all waterbodies in KPF were dry and consequently there were no fish in KPF to provide a baseline. As part of the development of the KPF Fish Condition Monitoring Project, a reference condition was required to provide a perspective on the fish communities that may be expected to establish when water is delivered. To develop this, information from the Murray–Darling Basin Authority (MDBA) Sustainable Rivers Audit (SRA) was examined. The SRA sampled fish in the main river channels in the overall Central Murray region (21 sites) three times between 2005 and 2011.

In the first two SRA reports, the fish community of the region was rated in a very poor condition (Davies et al. 2008, Davies et al. 2012). Many expected native species were absent, species diversity, abundance and biomass were dominated by alien species, and recruitment levels among native species were low (Davies et al. 2012). However, the ratio of native fish to alien fish was higher than in most valleys of the Murray–Darling Basin. Evidence of recruitment was observed for eight of the 12 native species observed in the Central Murray in the 2008–2010 SRA report (Davies et al. 2012).

KPF is in the middle section of the Central Murray SRA reporting zone which scored only 20/100 (very poor) for overall fish condition in the most recent SRA report (Davies et al. 2012). Since European settlement, the valley has lost much of its native species richness, and alien species contributed over 70% of the biomass in SRA samples (SRA 2) (Davies et al. 2012). Overall native fish abundance in the region was dominated by small-bodied native species, such as carp-gudgeon (*Hypseleotris spp.*), Australian smelt (*Retropinna semoni*) and unspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*). Notably, however, a number of small-bodied native species predicted to be present in the region under reference conditions were not caught at any of the 21 SRA sampling sites. These included the endangered southern purple-spotted gudgeon (*Mogurnda adspersa*), olive perchlet (*Ambassis agassizii*) and critically endangered Murray hardyhead (*Craterocephalus fluviatilis*) which are typically regarded as off-channel specialists (Baumgartner et al. 2014). Several large-bodied native species were present in small to moderate numbers. These included Murray cod (*Maccullochella peelii peelii*), golden perch (*Macquaria ambigua ambigua*), silver perch (*Bidyanus bidyanus*) and trout cod (*Maccullochella macquariensis*). River blackfish (*Gadopsis marmoratus*) and freshwater catfish (*Tandanus tandanus*) were rare, while Macquarie perch (*Macquaria australasica*) was not recorded (Davies et al. 2012).

Widespread rainfall events in the southern Murray–Darling Basin in late 2010 to early 2011 resulted in increased flows in the Murray River system and flooding throughout most of KPF and its ephemeral wetlands, creeks and flood runners. The flooding created large areas of habitat for fish. This triggered the commencement of fish condition monitoring in KPF in 2011. Further rainfall events and minor flooding in subsequent years allowed repeat sampling in autumn 2012, 2013 and 2014. The initial formal environmental watering event from August to October 2014 resulted in areas of fish habitat and sampling for condition monitoring was in autumn 2015. A lack of subsequent flooding limited condition monitoring in 2016 to only four sites. However, an extremely wet winter and spring in 2016 enabled the full condition monitoring program to be carried out in 2017.

The KPF Fish Condition Monitoring project has two major monitoring objectives:

- Annual status assessment of the condition of the KPF fish community; and
- Trend assessment of the condition of the KPF fish community.

This report documents the findings of the first six years of fish condition monitoring at KPF.

Methods

Sampling design

The KPF Fish Condition Monitoring project design is based largely (but not strictly) on the SRA Fish Sampling Protocol (Davies et al. 2008). The project is based on annual (rather than 3-yearly) sampling of the fish community in KPF in late summer to autumn. The monitoring is designed to examine fish community characteristics using the SRA indices for nativeness, expectedness and recruitment by large-bodied and small-bodied fish. The SRA recruitment metric is acknowledged as coarse, and supplementary assessment is provided by examining length-frequency distributions of native and exotic fish species present in the forest.

KPF includes two main types of waterbodies — creeks and wetlands. Sites that contain water from year to year will vary and for this reason, it is not possible to have fixed sampling sites from year to year. Thus, a reconnaissance visit is carried out prior to autumn condition monitoring, to identify all available waterbodies in any year. Approximately twenty sites are then randomly selected for sampling, with approximately 67% of these as re-sampling sites (sampled in the previous year) and including 33% new sites where possible. The proportion of available sites sampled has ranged from 37% to 100% during the program (Table 1). In 2017, 18 waterbodies were surveyed, three for the first time (Table 1). These represented 37% all of the available waterbodies within the forest at the time of sampling. Their locations are shown in Figure 1.

Table 1 Waterbodies sampled for fish KPF condition monitoring from 2011 to 2017. Shaded boxes indicate the site contained water#

KP Forest Sites	Lat.	Long.	Sampled						
			2011	2012	2013	2014	2015	2016	2017
Pollack Lagoon	-35.5609	144.1555	Y	Y	Y	Y			
Swan Lagoon	-35.9082	144.4410	Y	Y	Y	Y	Y	Y	Y
Little Burrumbury Creek 1	-35.8770	144.4310	Y	Y					
Horseshoe Lagoon	-35.8510	144.4013	Y		Y	Y	Y		
River Road 1	-35.8374	144.3955	Y	Y					
Black Box Lagoon	-35.8256	144.3933	Y	Y	Y				
Black Gate Lagoon	-35.8086	144.3810	Y	*	Y				Y
390 mile lagoon	-35.7735	144.3588	Y	Y	Y				Y
Boundary Lagoon	-35.7395	144.3360	Y		Y	Y	Y		
Myloc Creek 1	-35.7135	144.3064	Y						
Myloc Creek 2	-35.7003	144.2823	Y	Y	Y		Y		
Barbers Head	-35.6892	144.2625	Y	Y	Y	Y	Y		
2003 Thinnings	-35.6901	144.2586							
Return Channel Lagoon	-35.6925	144.2284	Y	Y					
Crooked Creek	-35.6739	144.2288	Y	Y					
Barbers Creek 1	-35.6489	144.2050	Y	*			*		
Scottys Lagoon	-35.6497	144.2493	Y	Y	Y				Y
Barbers Creek 3	-35.5896	144.1908	Y	Y					
Barbers Creek 2	-35.6030	144.2070	Y	Y		Y	Y		
Pothole Creek	-35.7549	144.4062	Y	Y		Y	Y		Y
Belbins Creek	-35.7599	144.3974	Y			Y			
Twin Lagoon 1	-35.7023	144.2527		Y					
Twin Lagoon 2	-35.7169	144.2750		Y					
Cumbungie 1	-35.6478	144.2535		Y	*	Y	*		
McMahons Waterhole	-35.6654	144.2698					Y		
Smokehouse Lagoon 1	-35.6273	144.2490			Y		Y		
Smokehouse Lagoon 2	-35.6316	144.2471		Y	Y	Y	Y		
Long Lagoon	-35.6115	144.2292		Y	Y	Y	Y		Y
Penny Royal	-35.7550	144.3615		Y					
Penny Royal Actual	-35.7565	144.3630				Y	Y		
BC 1	-35.8099	144.4160				Y			
BC	-35.7668	144.3752		Y	Y	Y	Y		Y
Egg Lagoon	-35.8009	144.3785		Y					
Clarkes Lagoon	-35.7908	144.4243			Y		Y		Y
Boysons	-35.7162	144.3352				Y			Y
Sandy's Crossing	-35.6932	144.2658				Y	*		
Sandy's Crossing 2	-35.6933	144.26578							
Myloc Creek 3	-35.7150	144.3212		Y		Y			Y
Myloc Creek 4	-35.7149	144.3040					Y		
Nelsons	-35.6795	144.2457					Y		Y
BC 2	-35.7497	144.3571					Y		
Belbins 1	-35.7447	144.3570					Y		Y
Lock lagoon	-35.9397	144.4680						Y	Y
Dead River lagoon	-35.8384	144.3846						Y	Y
Broken River lagoon	-35.9290	144.4507						Y	Y
Corduroy Crossing	-35.8656	144.43484							Y

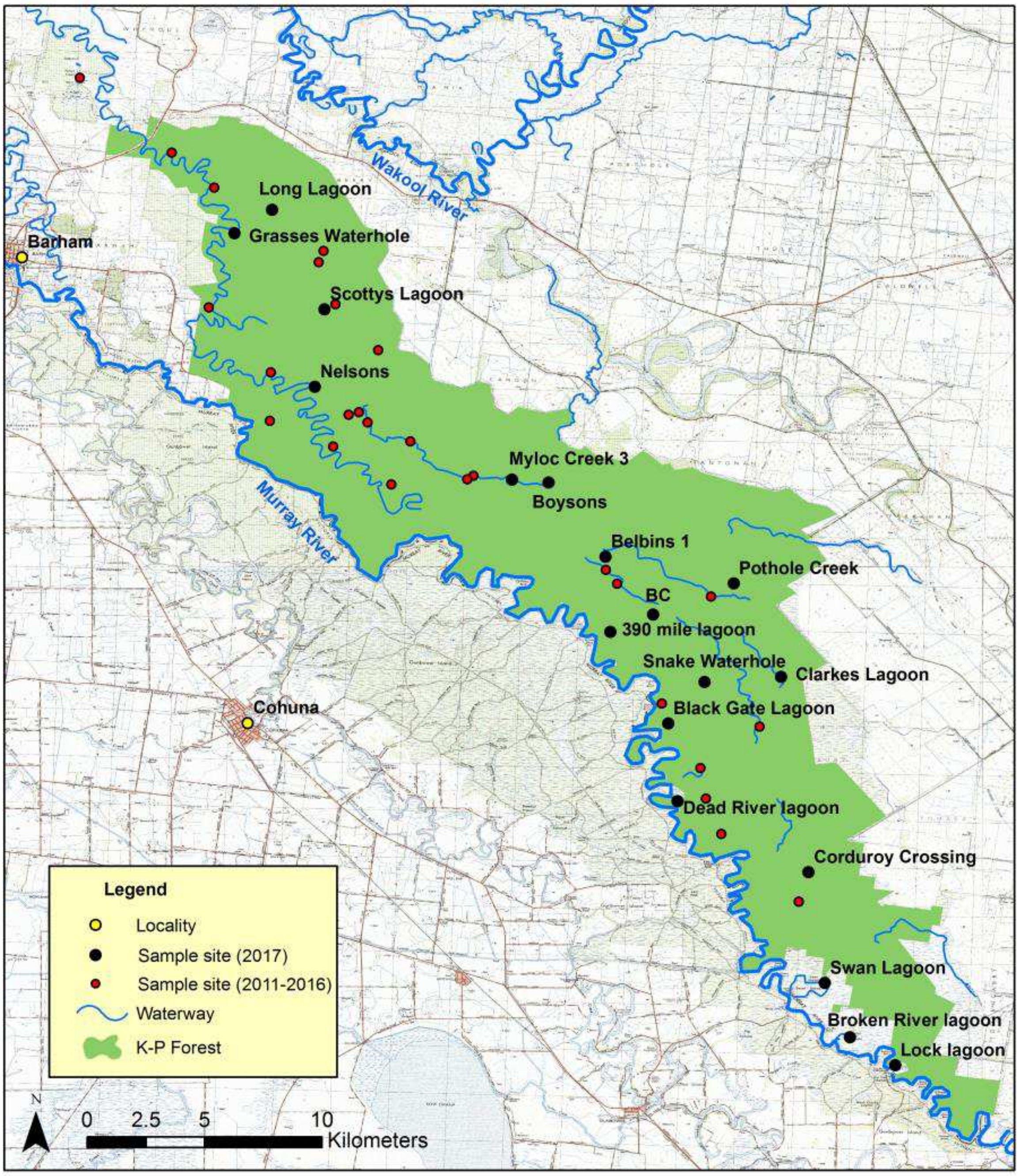
Snake Waterhole	-35.7927	144.39497							Y
Grasses Waterhole	-35.6205	144.2148							Y
River Road 2	-35.8350	144.39273							
Greys swamp	-35.7323	144.26161							
Lagoon near Myloc 3	-35.7161	144.32452							
West Boundary Lagoon	-35.7287	144.30728							
Near Allens Waterhole	-35.8321	144.42808							
Allens Waterhole	-35.836	144.426							
Smokehouse Creek	-35.6627	144.24846							
Total sites sampled			20	23	15	17	18	4	18
Percentage of available sites			91%	71%	100%	65%	90%	100%	37%

[*] Water too low for sampling and not included as available for sampling.

[†] Water inaccessible, but site considered as available for sampling.

[#] Note, the available sites each year were determined from a site selection trip prior to sampling. It is possible that some suitable sampling sites were overlooked. In addition, sites that may have been suitable for sampling at the time of site selection, were no longer suitable once sampling was undertaken.

Figure 1 Sites sampled for fish communities in Koondrook–Perricoota Forest in 2017. See Table 1 for site details.



Drone surveys

Site selection was carried out prior to commencing condition monitoring to locate all available waterbodies. Previously, this was done by driving and walking through the forest to identify all waterbodies containing water and to determine what sampling equipment would be required. Given the size of the forest, it is possible that some sites were missed as it is not possible to cover every waterway in search of remnant waterholes. In mid-2016 a DJI Phantom 4 drone was purchased and two staff received training to obtain their Remotely Piloted Operator Certificate from CASA. During the week of the 13th to 17th of February 2017, aerial surveys of KPF were conducted with the goal of identifying every waterbody in KPF. Staff drove to various points inside the forest and deployed the drone and used video footage relayed back to the linked iPad. When waterbody was found, staff went to assess each site whereby the coordinates were recorded and whether a boat or backpack were required to sample the site. A total of 49 sites were found to contain water (including the four sites sampled in 2016) Microsoft excel was used to generate a random number for each site (excluding the four sites sampled in 2016 which were to be sampled regardless according to our study design). To determine the sites to be sampled, the sites were arranged in ascending order by their random number and the top 14 sites were selected for sampling (Appendix 1 and 2).

Fish sampling 2017

Sampling in 2017 was conducted between the 15th of February and 16th of April. All randomly selected sites were sampled with the exception of Barbers Creek 2 as it had insufficient water by the time sampling occurred. It was substituted with Black Gate Lagoon, the next randomly selected site (Appendix 1). Waterbodies were sampled using the methodology developed for the SRA (Davies et al. 2008), utilising either boat or backpack electrofishing and unbaited traps. Boat electrofishing consisted of 12 replicate shots of 90 seconds of electrofishing using a 2.5 GPP Smith-Root boat-mounted electrofishing unit. Backpack electrofishing consisted of eight replicate shots of 150 seconds electrofishing time using a Smith-Root LR24 backpack unit. During each operation, dip netters removed all stunned individuals and placed them in an aerated live-well (boat fishing) or bucket (backpack fishing). All fish that could not be dip-netted but could be positively identified were recorded as ‘observed’. Ten unbaited traps were set at each sampling site for a minimum of 90 minutes (consistent with SRA methodology). Following each electrofishing and bait-trap operation, fish were identified, counted and measured before being released. All fish were recorded to species level except for the carp-gudgeon species complex that were recorded as *Hypseleotris* spp. given the current taxonomic uncertainty of these species (Bertozzi et al. 2000).

Water quality parameters of temperature, pH, conductivity, turbidity and dissolved oxygen were recorded at each sampling site with a Horiba U-50 series meter. The meter was calibrated at the beginning of each week’s survey work. To assist in understanding the hydrological conditions at KPF, flow data for the Murray River at Torrumbarry (gauge 409207B) was obtained from the MDBA live river data website (http://riverdata.mdba.gov.au/sitereports/409207b/mdba_409207b_site_report.html).

Data analysis

Analyses are guided by the SRA analysis methodology which uses indicators across three themes of fish community health: Nativeness, Expectedness and Recruitment (Table 2). Each SRA indicator consists or two or three indices and this project reports only those that are directly interpretable in relation to the project aims. The three nativeness indices are simply interpreted as the proportion of fish that were native by species, by abundance or by biomass. To calculate biomass, the weight of fish was estimated based on their length using length–weight relationships established on existing data (NSW DPI Fisheries, unpublished data). Expectedness and recruitment indices use a Reference Condition for Fish (RCF) score for each species and these were adjusted from SRA values to suit the habitat for fish in KPF (Table 3). The score allocates species to one of three categories and incorporates expert opinion and recent and historical catch records into a score that represents catch-ability and rareness for each taxon in KPF. Species that were common and easily collected using the SRA protocol score 5, species that were rare and difficult to collect score 1, and intermediate species score 3 (MDBC 2004). The Observed to Expected (OE) metric is a measure of α-diversity—the diversity within each site—and the Observed to Predicted (OP) metric is a measure of the β-diversity, the diversity across the entire KPF. A healthy forest would return high OE and OP indices (values close to 1). The recruitment indices do not identify the source of recruitment, just the presence of recruits. As the KPF condition monitoring samples annually, compared to every three years for the SRA, we use length at maturity as a cut-off for differentiating new recruits for species in the short-lived life guild group when calculating the recruitment indices, to overcome the bias in the SRA indices when the ecosystem consists of primarily short-lived fish species. The values used to differentiate new recruits within the recruitment indices are given in Table 3. For further information and example calculations, refer to Robinson (2012).

The three nativeness indices and the OE metric are scored at the site scale (Table 2) and were averaged to derive an overall KPF icon site score with confidence intervals. A mixed model analysis (sites as subjects) was used to determine whether there has been a significant change in the icon site scores for each metric through the five years of this project. Significant differences were compared using Scheffé corrections to maintain the family-wise error rate at 0.05. All statistical analyses were performed using SAS® (SAS 2012).

All analyses in 2017 (and 2016) use updated knowledge that affects the calculation of the metric scores and the absolute value of scores in this report should not be compared with those in previous reports. These updated calculations have been applied retrospectively and all results presented in *this* report, including for all previous years, are up to date and scores between years within this report can be compared.

Table 2 **Indices used to assess fish condition in Koondrook–Perricoota Forest. Full descriptions are available in Robinson (2012). Note that only fish in Table 3 (Reference Condition for Fish (RCF) species) contribute to the Expectedness and Recruitment indices.**

SRA indicator (Theme)	SRA metric	Description	Scale of calculation
Nativeness	Native species richness	Average proportion of fish species in each site that are native	Sampling site
	Native biomass	Average proportion of fish biomass in each site that is from native fish	
	Native abundance (or catch)	Average proportion of fish abundance in each site that is from native fish	
Expectedness	Observed/Expected species (OE)	Proportion of expected fish species that occur in a site	
	Observed/Predicted species (OP)	Proportion of predicted (the historical list in Table 3) fish species that occur	
	Recruiting sites	Average number of sites each RCF	

Recruitment		species recruited in ÷ number of sites it was expected to recruit in.	Icon site
	Recruiting taxa	Proportion of fish species recruiting in the icon site	
	Recruit abundance	Proportion of all RCF fish in the icon site that were recruits	

Management targets have not been finalised for KPF relative to the SRA indicators, so a value of 0.75 of pre-European reference condition was arbitrarily chosen as an interim target for all indices. Achieving 0.75 would put KPF fish communities approximately 20% above the best achieved for the Central Murray River system in SRA 1 (Davies et al. 2008) and SRA 2 (Davies et al. 2012). Note that the overall aim of this project is to document the annual status and the trend in fish condition in KPF. This target of 0.75 should purely be regarded as an interim target until targets are refined for KPF (Robinson and Duncan in prep).

Multivariate

While the SRA indices are designed to track significant differences across years, they don't present patterns for individual species. To visualise the change in abundance and biomass of each species throughout the duration of this study, the raw catch data (total number caught) and raw biomass data (predicted weight of each individual based on length-weight relationships) was used to calculate the average catch and average biomass per species per site. Sites with zero catch for a species were included in the analysis. These data were graphed to enable patterns across years to be visualised. To determine if there were any significant differences in the raw biomass and abundance data, a pairwise permutational analysis of variance (PERMANOVA) (Anderson 2001) was conducted. The analysis used the raw number of fish caught and raw biomass data that was fourth-root transformed. Bray-Curtis similarities were then calculated. The PERMANOVA consisted of a single factor (year) and significance values were calculated based on 9,999 permutations of the data. If there was a significant difference between years, species that contributed the most to the dissimilarity were calculated using SIMPER.

Cumulative-frequency distributions were constructed for Australian smelt, carp gudgeon, eastern gambusia and common carp. Unlike the distributions presented in previous reports, these distributions utilised all fish that were measured at a site, rather than including sites only if a minimum of five fish were caught.

Table 3 Native fish expected to naturally occur within Koondrook–Perricoota Forest (Muschal et al. 2010*, Robinson 2012).

Common name	Scientific name	Rarity score (RCF)	Life guild	Length at YOY or sexual maturity (mm)*
Large-bodied species				
Murray cod	*Maccullochella peelii peelii*	3	LL	235
Trout cod	*Maccullochella macquariensis*	1	LL	150
Golden perch	*Macquaria ambigua ambigua*	3	LL	75
Silver perch	*Bidyanus bidyanus*	1	LL	75
Freshwater catfish	*Tandanus tandanus*	3	LL	83
Bony herring	*Nematalosa erebi*	1	IL	67
River blackfish	*Gadopsis marmoratus*	0	IL	80
Short-headed lamprey**	*Mordacia mordax*	0	–	–
Macquarie perch	*Macquaria australasica*	0	LL	127
Small-bodied species				
Murray–Darling rainbowfish	*Melanotaenia fluviatlis*	5	SL	45
Murray hardyhead	*Craterocephalus fluviatiis*	1	SL	40
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	5	SL	38
Australian smelt	*Retropinna semoni*	3	SL	40
Carp-gudgeon	*Hypseleotris* spp.	5	SL	35
Flathead gudgeon	*Philypnodon grandiceps*	5	IL	58
Southern pygmy perch	*Nannoperca australis*	3	SL	20
Purple spotted gudgeon	*Mogurnda adspersa*	1	IL	49
Flathead galaxias	*Galaxias rostratus*	3	IL	30
Obscure galaxias	*Galaxias oliros*	1	IL	30
Olive perchlet*	*Ambassis agassizii*	3	SL	31
Dwarf flathead gudgeon	*Philypnodon macrostomus*	1	SL	30

* Except olive perchlet which is listed as expected in the region by the MDBA Sustainable Rivers Audit (Robinson 2012).
**Short-headed lampreys were not included in the recruitment calculations due to insufficient knowledge of their biology and they are riverine.
Note: Reference Condition for Fish (RCF) scores were derived from those derived for the MDB SRA Central Murray River, Middle Section—but revised to reflect the nature of the available waterbodies within the KPF; life guilds are short-lived (SL), intermediate-lived (IL) and long-lived (LL).

Results

Hydrology

KPF experienced major inflows in 2000–2001, followed by a decade of drought. A drought-breaking flood occurred in KPF in July 2010, and high flows continued throughout 2010 and into early 2011 (Figure 2). Further flooding occurred in June/July 2011 and in March 2012, followed by the first managed environmental watering in August-October 2014. In autumn 2016, KPF was essentially dry with only sites directly adjacent to the Murray River persisting until a flood occurred from July to November 2016, resulting in most of the KPF being inundated.

Summary of 2017 fish catch

11,354 fish were collected from KPF in 2017, representing thirteen fish species comprised of eight native and five exotic species (Table 4). The native fish species collected were similar to the previous four years and included carp-gudgeon (*Hypseleotris* spp.), Australian smelt (*Retropinna semoni*), flathead gudgeon (*Philypnodon grandiceps*), Murray–Darling rainbowfish (*Melanotaenia fluviatilis*), bony herring (*Nematalosa erebi*), unspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*) a single golden perch (*Macquaria ambigua ambigua*) and two silver perch (*Bidyanus bidyanus*). One silver perch and the golden perch were collected from Lock Lagoon, which at the time of sampling was connected to the Murray River. As a result, this site was the most species-rich of all 18 sites. The second silver perch was collected from Broken Lagoon. The exotic fish species collected were common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), Oriental weatherloach (*Misgurnus anguillicaudatus*) and eastern gambusia (*Gambusia holbrooki*) (Table 4).

Figure 2 Hydrograph of Murray River flows (ML/d) at Torrumbarry from July 2000 to February 2017. The dashed line indicates the approximate* flow when water begins to enter the Koondrook–Perricoota Forest via Swan Lagoon and the dotted line indicates the approximate flow when the creeks begin to flow. (*Approximate as the commence to flow level at Swan Lagoon varies depending on the silt load).

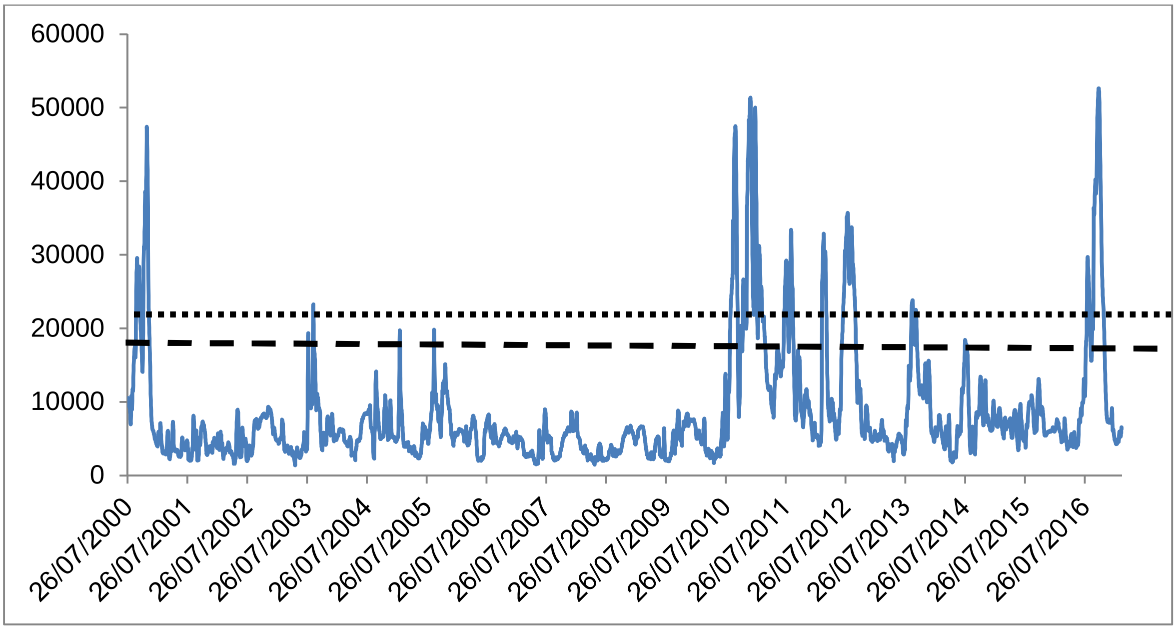


Figure 3 Hydrograph of Murray River flows (ML/d) at Torrumbarry from August 2010 to February 2017 with sampling period indicated by the black arrows. The dashed line indicates the approximate* flow when water begins to enter the Koondrook–Perricoota Forest via Swan Lagoon and the dotted line indicates the approximate flow when the creeks begin to flow. (*Approximate as the commence to flow level at Swan Lagoon varies depending on the silt load). The grey arrow indicates when the managed environmental flow into KPF occurred in 2014 (flow does not appear on the hydrograph).

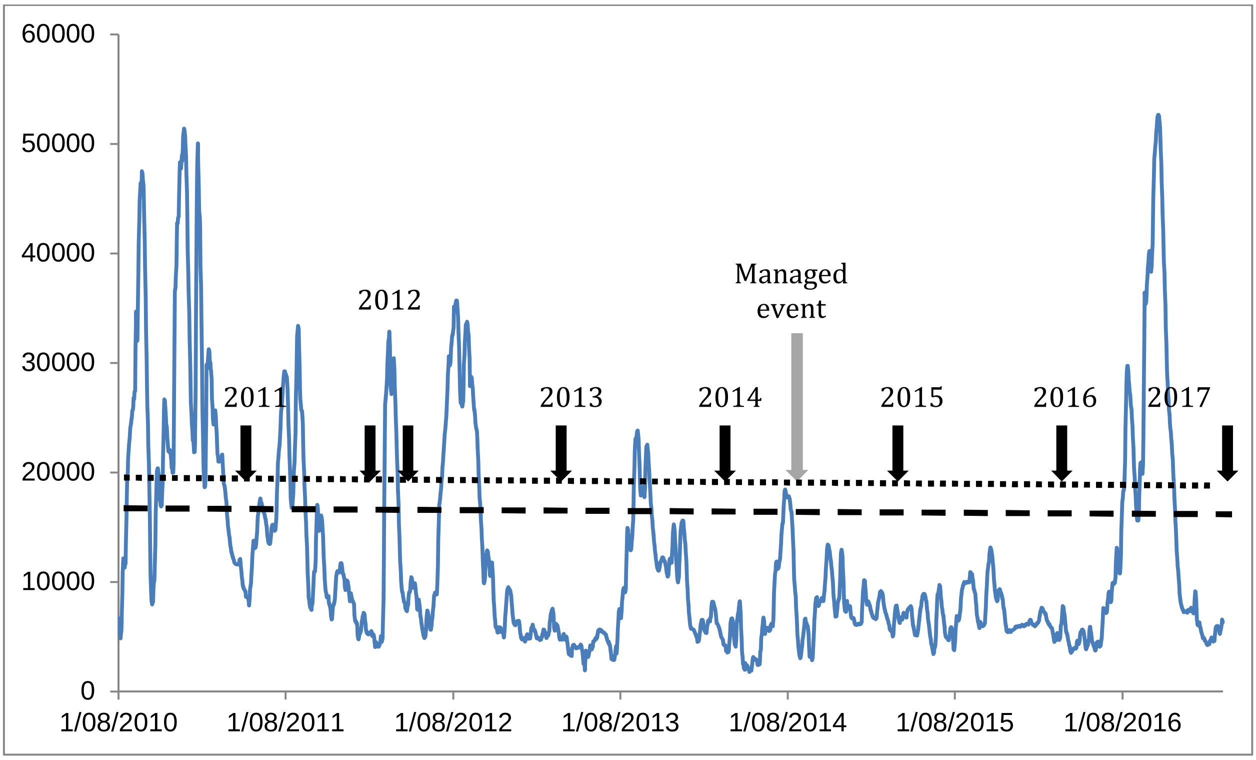


Table 4 Abundance of fish collected (caught data only) in Koondrook–Perricoota Forest sites in 2017.

	Australian smelt	Bony herring	Carp gudgeon	Flathead gudgeon	Golden perch	Murray-Darling rainbowfish	Silver perch	Unspecked hardyhead	Common carp*	Eastern Gambusia*	Goldfish*	Oriental weatherloach*	Redfin*
Bc	15		1						224		4		
Belbins 1	2		47						204		13	1	
Pothole Creek			48						271	109	27		
Boyson			5						155	1	2		
Grasses Waterhole			8						220		8		
Scottys Lagoon			51						33	9	3	1	
Black Gate Lagoon	26		387			3			526	13	2		1
390 Mile Lagoon	6		51						244	8			
Clarkes Lagoon	2		119						603	6	38		
Lock Lagoon[†]		40	57		1	5	1	2	49		7		
Broken River Lagoon	3		27	1			1		51	7	5		
Swan Lagoon		2	30	3					32	6	11		
Myloc 3			7			1		2	215	12	104		
Nelsons			7						391		76	2	
Corduroy Crossing	1		77			1		1	179	10	94		

Dead River Lagoon	2		89	5					9	8			
Snake Waterhole	7		87						332	4	9		
Long Lagoon	1		6						93		6	1	
Total	65	42	1104	9	1	10	2	5	3831	193	409	5	1

*exotic species

†This site was connected to the Murray River.

SRA indices 2011 to 2017

Nativeness

Status

In 2017, only 27% of fish that were collected per site were native (Figure 4), the lowest average since TLM monitoring began. There was an average of 0.43 native species per site (species richness), and this is comparable with all years between 2011 and 2015 (range 0.4 to 0.7, Figure 4). Only 7% of fish biomass was from native fish, the lowest since the 4% recorded in 2011 (Figure 4).

Trend

The difference in the average proportion of native fish was significantly different between years ($F = 8.46$, $df = 6, 63$, $p <.0001$) and the 2017 average is significantly lower ($p < 0.05$) than all other years except 2011 and 2014 (Figure 4). Overall, there has been no significant difference in the average proportion of native fish species per site ($F = 1.4$, $df = 6, 63$, $p = 0.23$). There was almost a significant difference between 2016 and 2017 ($p =0.06$). However, the 2016 value is probably anomalous as only a few sites were sampled. There have been large and significant differences in the average proportion of native fish biomass in KPF since TLM monitoring began ($F = 4.1$, $df = 6, 61$, $p < 0.002$). This also indicates a significant ($p < 0.01$) decrease in average native fish biomass from the 2016 high of 63%.

Expectedness

Status

An average of 34% of expected (historical) native fish species were present in KPF sites in 2017 (Figure 5) and this is comparable with the range (0.31 to 0.34) observed between 2011 and 2015. The OP index, the diversity across the entire forest, was 0.4, the second highest since monitoring began (Figure 5).

Trend

Overall there has been no significant difference in the OE index since monitoring began ($F = 1.13$, $df = 6, 58$, $p = 0.357$), even though the 2016 average was up to 55%, this average was based on only 4 sites (hence has low statistical consequence). OP was relatively unchanged since monitoring began.

Recruitment

Status

Four small-bodied native species—carp-gudgeon, flathead gudgeon, Australian smelt and Muray-Darling rainbowfish—had recruits in 2017. The abundance of recruits in KPF in 2017 was only 0.37, comparable with the initial scores (prior to watering) in 2011 and 2012. None of the large bodied species (silver perch, golden perch and bony herring) were recruits.

Trend

The abundance of recruits in 2017 was (0.37) was well down on the 2013 to 2015 highs of 0.60 to 0.63 (Figure 6). The index for the number of sites with recruits (I Rsites) in 2017 was only 0.30, the lowest since monitoring began, and whilst 63% of taxa in KPF in 2017 had recruits, this was also the lowest score since monitoring began (Figure 6). The overall Recruitment index was consistently above 0.60 from 2013 to 2016, and less than 0.50 in 2011, 2012 and 2017 (Figure 6).

Figure 4 Average nativeness indices for abundance (Ncatch -proportion of fish that were native), biomass (Nbiomass-proportion of fish biomass that was native) and species richness (Nrich-proportion of fish species that were native) in sites in Koondrook–Perricoota Forest from 2011 to 2017 (± standard error). The unbroken line is the Overall Average nativeness index. The dashed line is the interim target of 0.75.

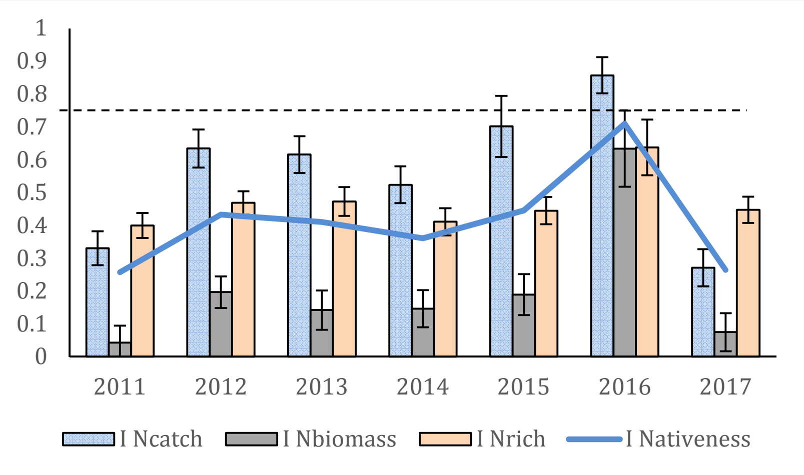


Figure 5 Observed historical fish species Expectedness indices (± standard error) Observed/Expected (OE) and Observed/Predicted (OP) for native fish in Koondrook–Perricoota Forest from 2011 to 2017. Note, the OP does not have a standard error. The unbroken line is the Overall Average expectedness index The dashed line is the interim target of 0.75.

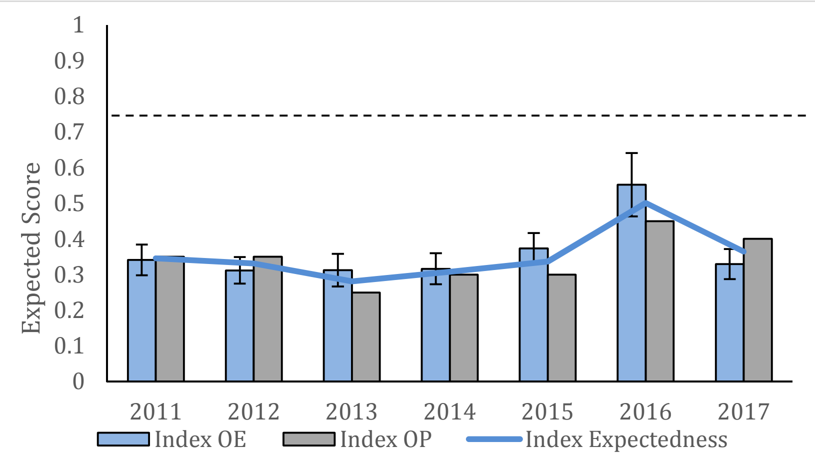
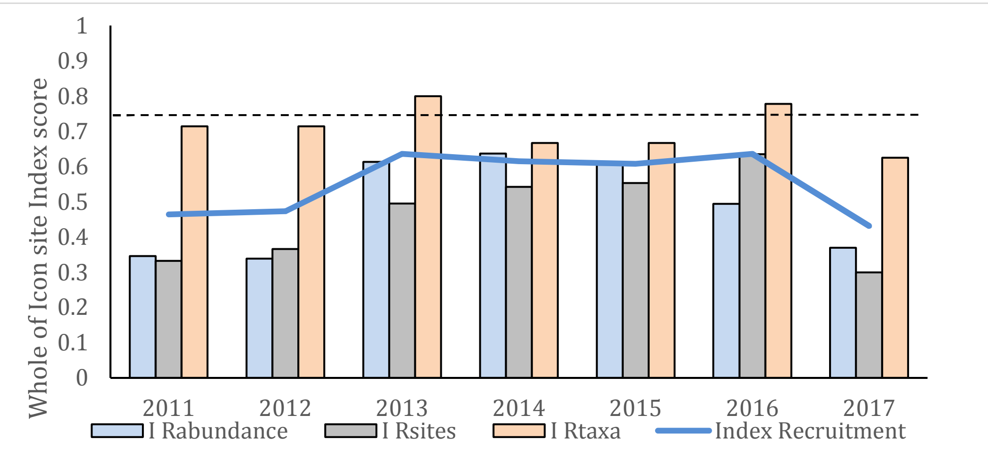


Figure 6 Average recruitment indices for native fish in Koondrook–Perricoota Forest from 2011 to 2017. Recruit abundance (Rabundance), number of sites with recruits (Rsites) and number of recruiting taxa (Rtaxa). These indices do not include a standard error. The unbroken line is the Overall Average recruitment index The dashed line is the interim target of 0.75.



Multivariate

The average abundance per site and average biomass per site are presented in figures 7 and 8. Pairwise permutational analysis indicated that there were significant differences in the abundance and biomass of fish species between many year combinations (Table 5 and 6). Follow-up SIMPER analysis indicated that the disimilarity in biomass across most year combinations were primarily due to fluctuating abundances of exotic common carp and goldfish (Table 5). The disimilarity in average abundance per site was driven by carp gudgeon and carp. (Table 6). The fish community in 2017 was significantly different in both abundance and biomass to every other year (Table 5 and 6). These differences were driven primarily by greater average abundance per site of common carp and greater average biomass of goldfish in 2017. The biomass of carp in 2017 was actually lower in comparison to 2011, 2012 and 2015, because most carp sampled in 2017 were YOY (Figure 9).

Figure 7 Average abundance (catch) per site across all years. Note that the vertical scale was reduced to enable less abundant species to be visualised. Some species are off the scale and their value is given directly on the figure.

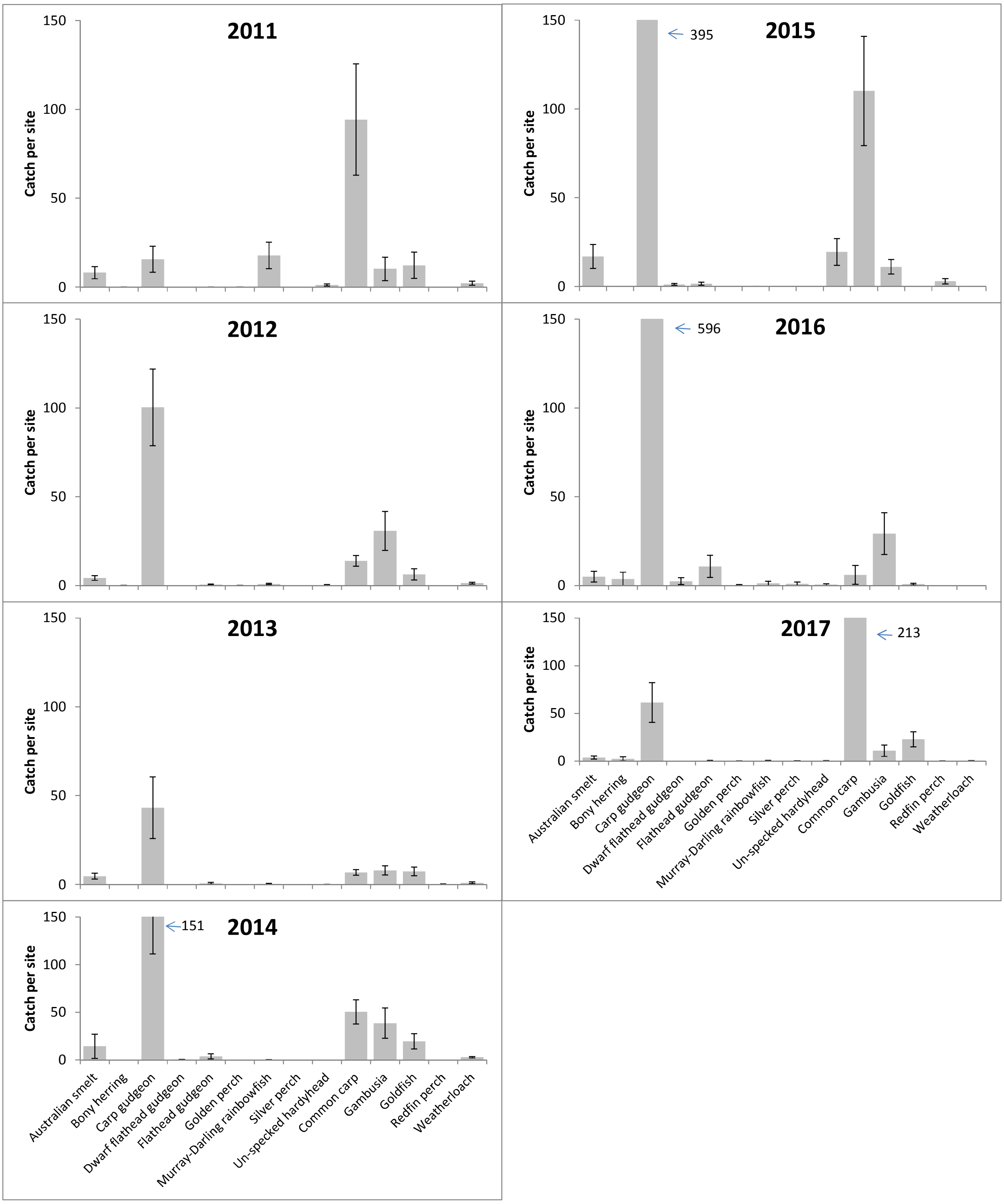


Figure 8 Average biomass (g) per site across all years. Note that the vertical scale was reduced to enable species with low biomasses to be visualised. Some species are off the scale and their value is given directly on the figure.

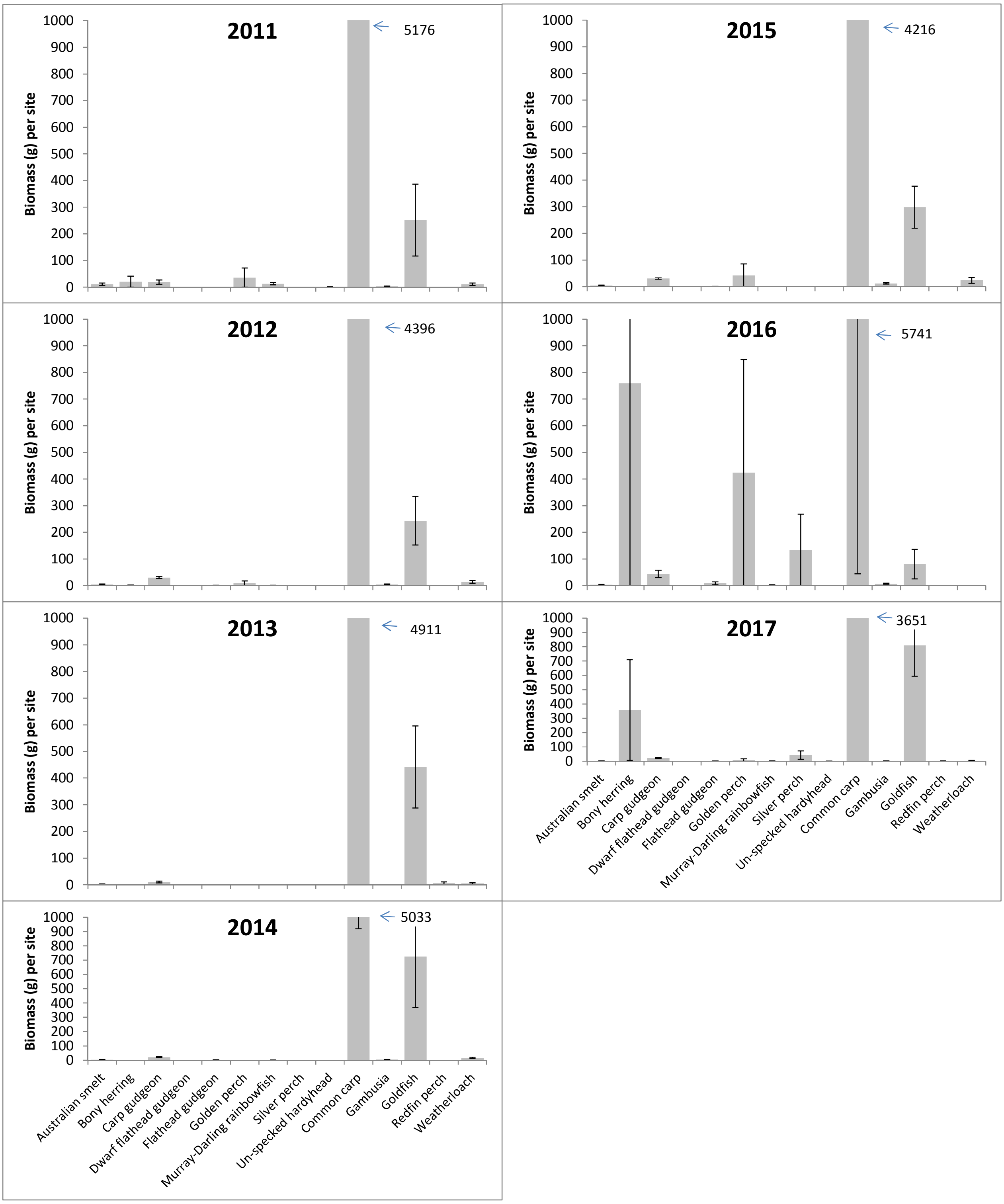


Table 5 Pairwise PERMANOVA results for comparison of total fish community biomass (across all species) across years. Significant results (α=0.05) *P* values are in bold. *P* values were based on 9,999 permutations of the raw data. Year comparisons involving 2017 are highlighted in grey. Species contributing at least 20% to the dissimilarity in biomass between year comparisons (SIMPER results) are shown as well as their average abundance.

Pairwise PERMANOVA biomass					
Year comparison	*t*	*P*	Contributing species (>20%)	Average biomass (year)	Average biomass (year)
2011, 2012	2.17	**0.001**	Common carp	7.37 (2011)	5.90 (2012)
2011, 2013	1.8	**0.01**	Common carp	7.37 (2011)	5.65 (2013)
2011, 2014	2.82	**<0.001**	Common carp Goldfish	7.37 (2011) 2.19 (2011)	4.48 (2014) 2.84 (2014)
2011, 2015	3.02	**<0.001**	Common carp	7.37 (2011)	5.20 (2015)
2011, 2016	2.49	**0.001**	Common carp	7.37 (2011)	3.92 (2016)
2011, 2017	2.45	**<0.001**	Common carp Goldfish	7.37 (2011) 2.19 (2011)	5.08 (2017 4.14 (2017)
2012, 2013	1.14	0.263			
2012, 2014	1.48	0.08			
2012, 2015	1.87	**0.013**	Common carp Goldfish	5.90 (2012) 1.96 (2012)	5.20 (2015) 3.22 (2015)
2012, 2016	1.37	0.104			
2012, 2017	2.14	**0.002**	Common carp Goldfish	5.90 (2012) 1.96 (2012)	5.08 (2017) 4.14 (2017
2013, 2014	1.45	0.089			
2013, 2015	1.57	0.056			
2013, 2016	1.56	0.059			
2013, 2017	1.39	0.094			
2014, 2015	1.49	0.076			
2014, 2016	1.66	**0.038**	Common carp	4.48 (2014)	3.92 (2016)
2015, 2016	1.48	0.081			
2017, 2014	1.82	**0.007**	Common carp Goldfish	4.14 (2017) 5.08 (2017)	2.84 (2014) 4.48 (2014)
2017, 2015	1.8	**0.007**	Common carp Goldfish	5.08 (2017) 4.14 (2017)	5.20 (2015) 3.22 (2015)
2017, 2016	2.06	**0.007**	Common carp Goldfish	5.08(2017) 4.14 (2017)	3.92 (2016) 1.75 (2016)

Table 6 Pairwise PERMANOVA results for comparison of total fish abundance (across all species) across years. Significant results (α=0.05) *P* values are in bold. *P* values were based on 9,999 permutations of the raw data. Year comparisons involving 2017 are highlighted in grey. The species contributing at least 20% to the dissimilarity in biomass between year comparisons (SIMPER results) are shown as well as their average abundance.

Pairwise PERMANOVA abundance					
Year comparison	t	P	Contributing species (>20%)	Average abundance (year)	Average abundance (year)
2011, 2012	2.7	**<0.001**	Carp gudgeon	1.17 (2011)	2.82 (2012)
2011, 2013	2.16	**0.001**	Carp gudgeon	1.17 (2011)	2.23 (2013)
2011, 2014	2.53	**<0.001**	Carp gudgeon	1.17 (2011)	3.16 (2014)
2011, 2015	3.52	**<0.001**	Carp gudgeon	1.17 (2011)	4.05 (2017)
2011, 2016	2.23	**<0.001**	Carp gudgeon	1.17(2011)	4.38 (2016)
2011, 2017	2.16	**<0.001**	Common carp	2.49 (2011)	3.55 (2017
2012, 2013	1.06	0.356			
2012, 2014	1.24	0.181			
2012, 2015	2.39	**<0.001**	Carp gudgeon	2.82 (2012)	4.05 (2015)
2012, 2016	1.44	0.076			
2012, 2017	2.94	**<0.001**	Common carp	1.55 (2012)	3.55 (2017)
2013, 2014	1.8	**0.007**	Common carp	1.3 (2013)	2.22 (2014)
2013, 2015	2.48	**<0.001**	Carp gudgeon	2.23 (2013)	4.05 (2015)
2013, 2016	1.73	**0.021**	Carp gudgeon	2.23 (2013)	4.38 (2016)
2013, 2017	2.6	**<0.001**	Common carp	1.30 (2013)	3.55 (2017)
2014, 2015	1.72	**0.02**	Eastern gambusia	2.72 (2015)	1.85 (2014)
2014, 2016	1.66	**0.035**	Common carp	2.22 (2014)	0.84 (2016)
2015, 2016	1.14	0.253			
2017, 2014	2.51	**0.001**	Common carp	3.55 (2017)	2.22 (2014)
2017, 2015	3.82	**<0.001**	Common carp	3.55 (2017)	1.58 (2015)
2017, 2016	2.9	**<0.001**	Common carp	3.55 (2017)	0.84 (2016)

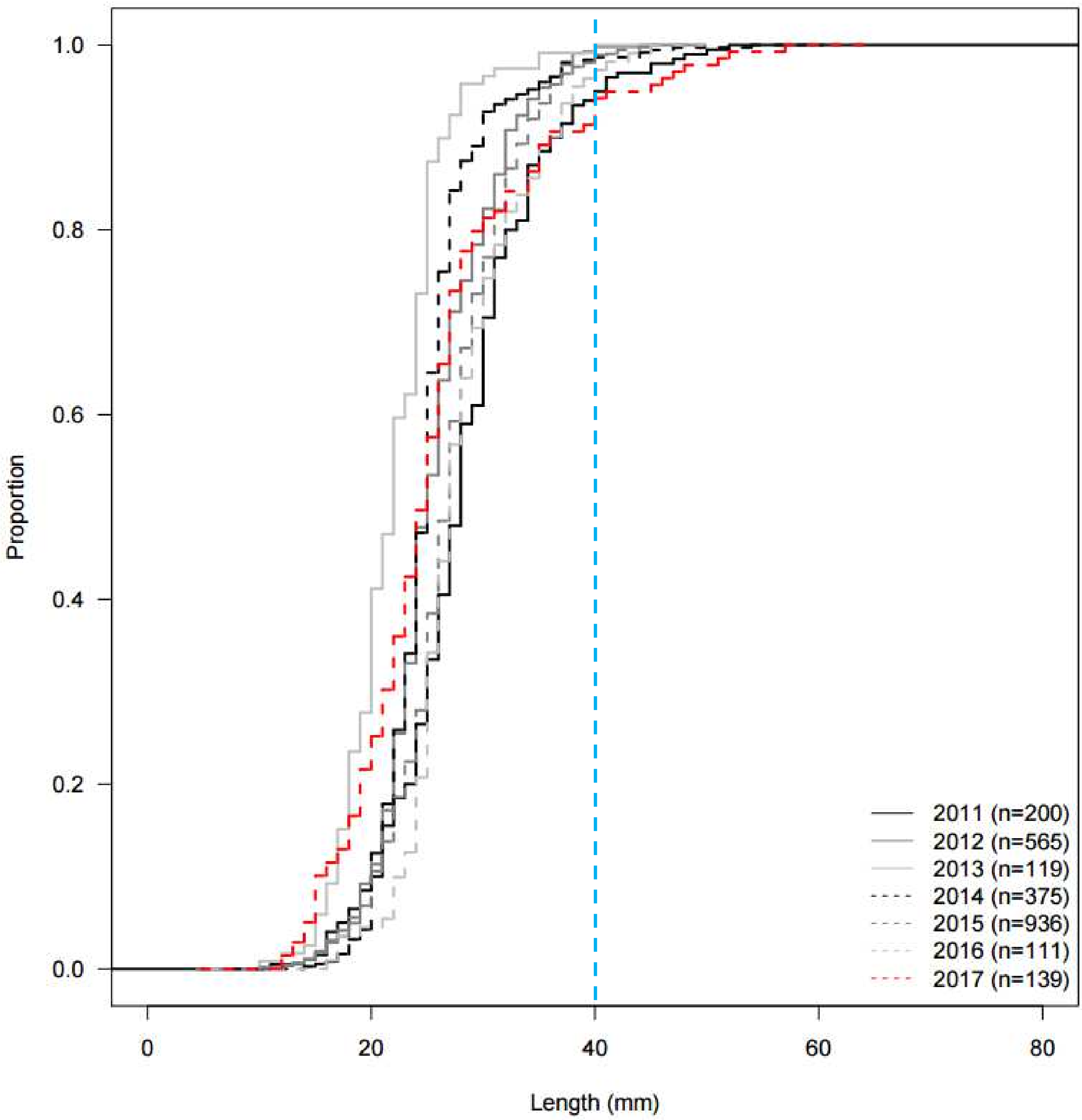
Length-frequency distributions

Length-frequency distributions were plotted for two native and two exotic species that had sufficient (Figure 9). There was minimal difference in length-frequency of Australian smelt across all years of the study (Figure 9). Carp gudgeon were similar but the larger size classes were more dominant in 2011. The length-frequency distributions of the small-bodied exotic species, eastern gambusia, was more variable but showed a similar pattern to carp gudgeon with larger individuals more common in 2011. Most size classes of common carp were present in KPF across all years of the study with the exception of 2017 where large fish were heavily outnumbered by YOY, which comprised over 90% of the fish included in this analysis (Figure 9).

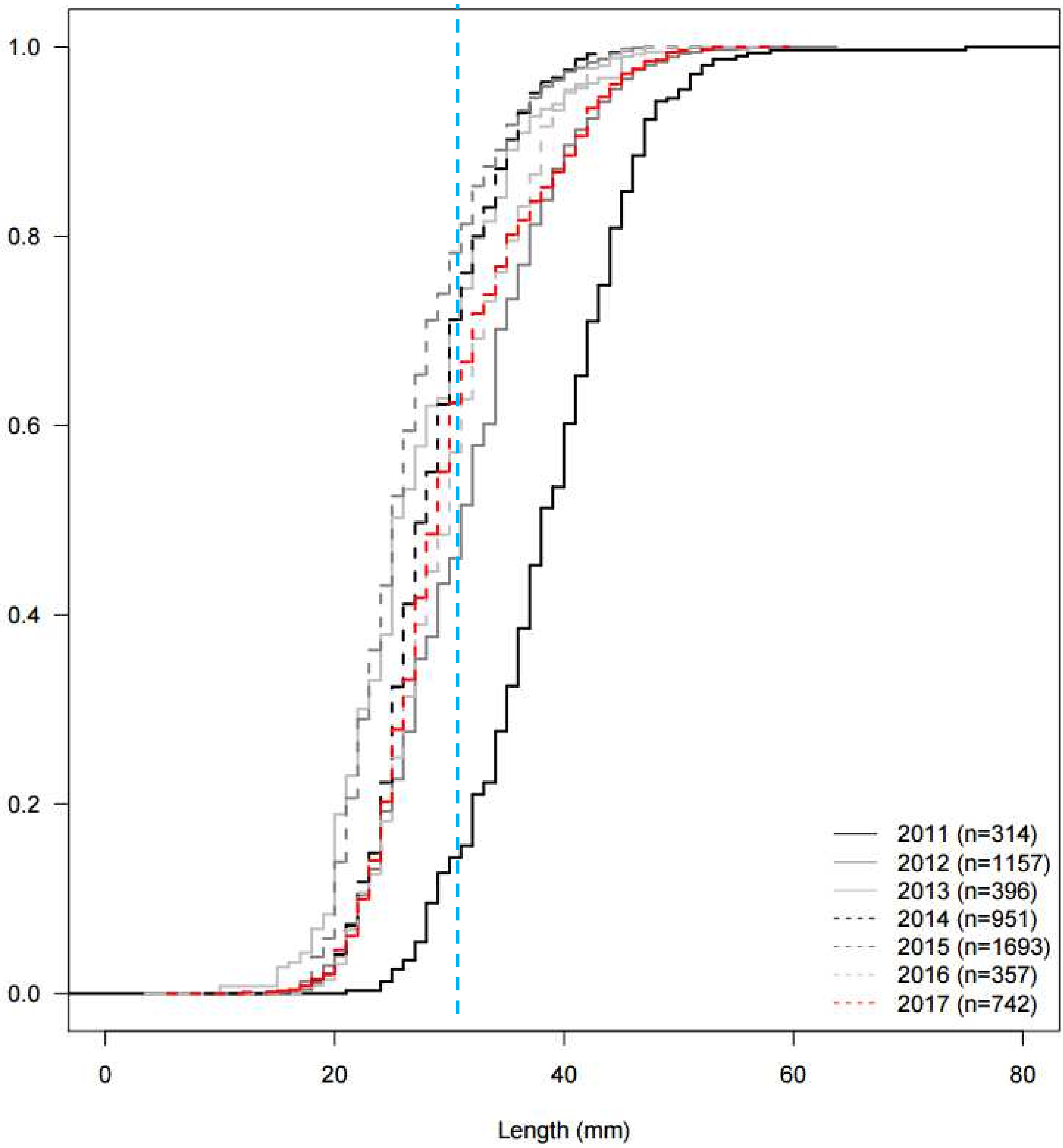
YOY common carp comprised a greater proportion of the population in years following a spring flood (2011, 2014, 2015 and 2017)

Figure 9 Cumulative-frequency length distributions for a) Australian smelt (*Retropinna semoni*), b) carp gudgeon (*Hypseleotris* spp.), c) eastern gambusia (*Gambusia holbrooki*) and d) carp (*Cyprinus carpio*) in Koondrook–Perricoota Forest from 2011 to 2017. Dashed line indicates the approximate maximum length of young-of-year fish.

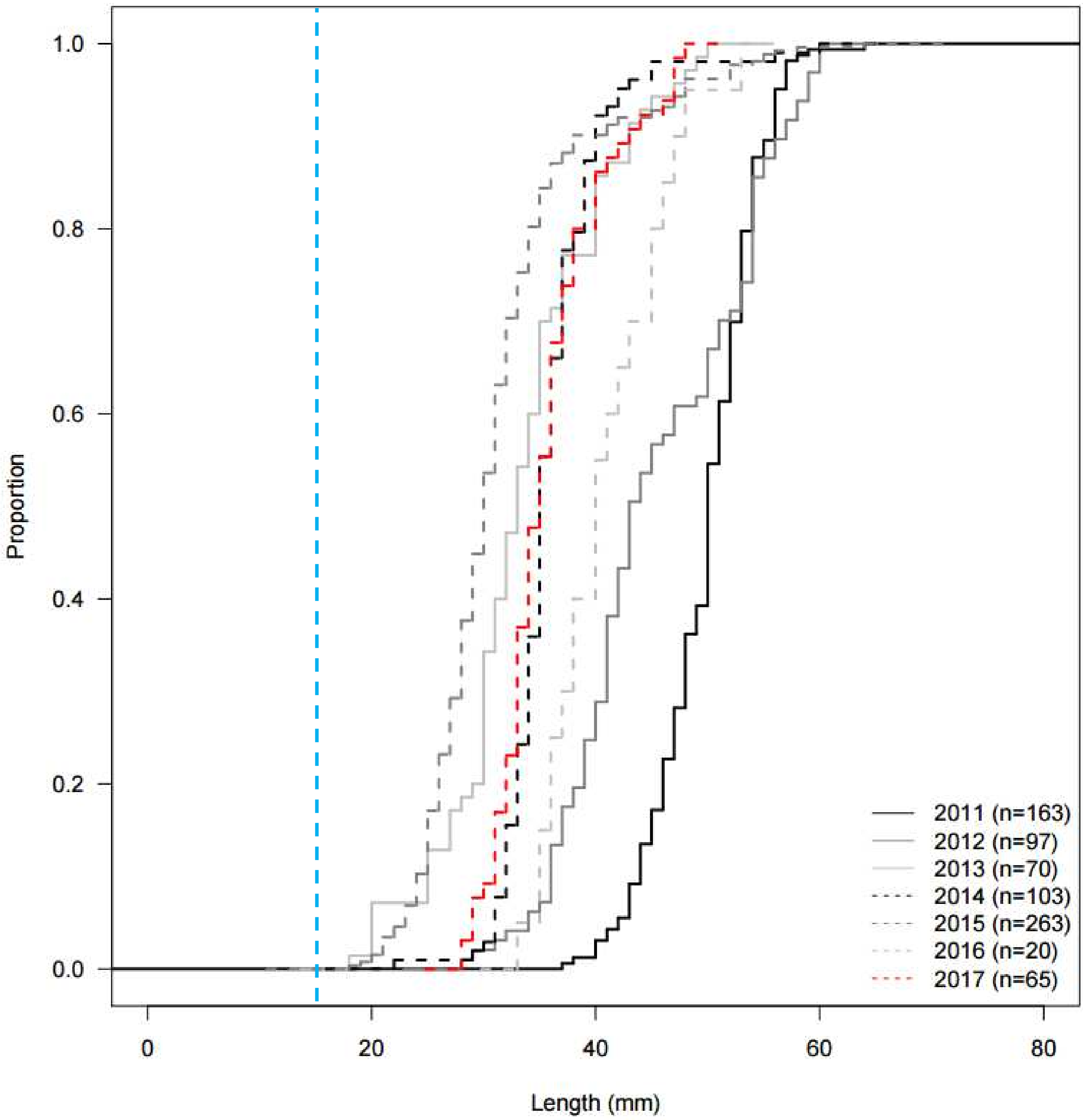
a) Australian smelt



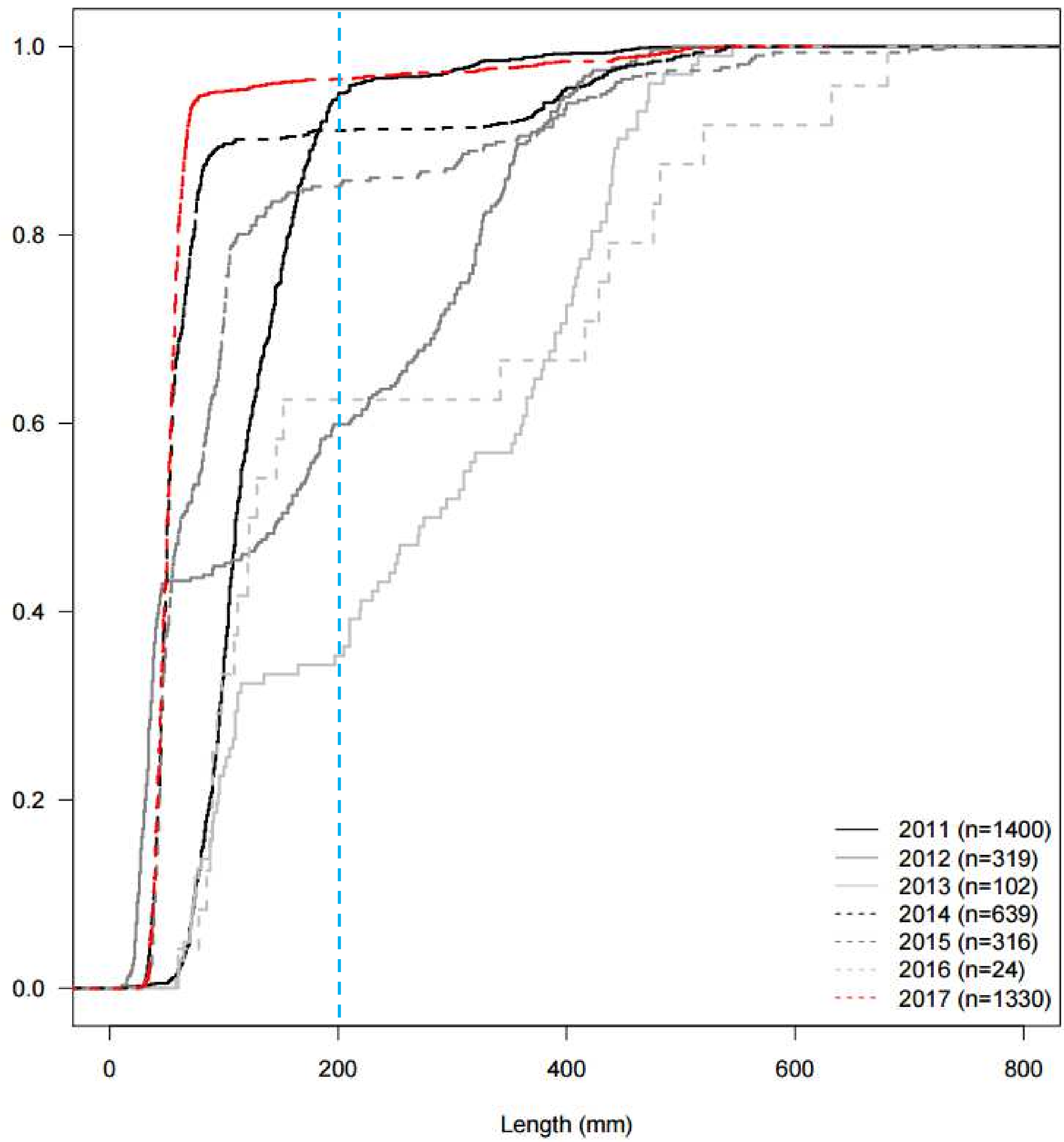
b) Carp gudgeon



c) Eastern gambusia



d) Common carp



Water quality

Water quality varied widely. According to ANZECC guidelines (ANZECC 2000), dissolved oxygen was low in some sites, and the pH at others was high (>8). Turbidity should range between 6-50 NTU, but greatly exceeded these at all sites. Temperature varied widely depending on time of day and weather conditions over the sampling period (Table 5). Dissolved oxygen at most sites was within acceptable limits, with the exception of one site that was just 1.5mg/L.

Table 7 Summary of water quality parameters across waterbodies sampled for fish in Koondrook–Perricoota Forest in 2017.

Parameter	Average	Minimum	Maximum
Temperature (°C)	22.6	16.3	31.1
Dissolved oxygen (mg/L)	6.0	1.5	11.4
pH	7.5	6.2	9.4
Conductivity (mS/cm)	0.2	0.1	1.0
Turbidity (NTU)	100.2	28.6	189
Depth (m)	0.3	0.2	1.0

Murray River

Sites from the Murray River are typically included in this report and are provided by Clayton Sharpe (CPS Environmental Research). However, these surveys were not carried out in 2017. Given that we have a very good understanding now of the fish community in the Murray River adjacent to KPF, it was deemed unnecessary to sample the sites as part of this project.

Discussion

The KPF Condition Monitoring project is designed to provide: a) status assessment of the condition of the KFP fish community; and b) trend assessment of the condition of the fish community since monitoring commenced. The project is not designed to quantitatively link the observed fish community condition to all the possible factors driving that condition, but some general links can be made.

Native species in KPF

While native species richness throughout the study has remained relatively constant, their abundance and biomass (SRA indices) have fluctuated significantly. However, when the average abundance and biomass of native species is taken into account, most were not substantially different to other years, and some native species were still present as recruits (though not to the extent of 2013-2015). It is the sheer abundance of exotic species that drove down the nativeness indices in 2017 (Figures 7 and 8).

The most common native species (carp gudgeon) were present in KPF in high numbers in years following flooding (e.g. 2014, 2015) as well as years following no flooding (2013). This species is a generalist and these results are consistent with what has been found in other studies, i.e. they are present whether there are droughts or floods (Gilligan *et al.* 2009). In contrast, Murray-Darling rainbowfish were caught in reasonable numbers during the first year of sampling (2011) following the breaking of the drought. They have only been caught sporadically since and have not do not appear to have benefited from regular flooding of KPF. The highest nativeness indices were achieved in 2016, when the forest was almost completely dry and was primarily due to one site being connected to the Murray River (therefore increasing the number of native species present) and because carp were nearly absent. The return of flooding in 2017 did not result in a dramatic increase of native fish. This may be the result of direct competition between native fish and the abundant population of common carp (and to a lesser extent goldfish).

The results over the duration of the study show a consistently poor condition of the native fish community. This is the likely the result of a combination of: the carrying capacity of individual wetlands or creek sites being low (possibly as a function of dominance/displacement by common carp); and the regional pool of available species unable to seed many new species records. Few new native fish species are recolonising the forest. The occasional subtle changes in OP are because of the infrequent and/or irregular collection of rarer or uncommon species. The condition of the fish community at KPF should be considered in the context of the condition of fish communities in the Murray River channel that supplies water to the forest. A rigorous assessment of fish communities based on seven sites in the adjacent channel was used for the SRA ecosystem health assessment 2008–2011 for the Central Murray region. The 2011 SRA results are not in the public domain but some fish community indices have been made available to us for this report (Table 7). The comparison clearly shows that low nativeness in KPF is related to low nativeness of fish in the source populations in the channel (Table 7).

Table 7 Sustainable Rivers Audit (SRA) Expectedness and nativeness indices in the Central Murray River in 2011 and waterbodies in Koondrook–Perricoota Forest (KPF in 2017).

SRA theme	Metric	Central Murray 2011	KPF 2017
Nativeness	Species	0.61	0.43
	Biomass	0.10	0.07
	Abundance	0.45	0.25
Expectedness	OE	0.38	0.34
	OP	0.48	0.4

Large-bodied fish

The general absence of large-bodied native species recorded at KPF raises questions about the extent to which they may actually be expected to use the forest aquatic habitats when they are available. The 2014 KPF Fish Condition Monitoring report (Duncan et al. 2014) provides detail of available evidence of the likely use of floodplain wetland habitats by larvae and juvenile stages of large-bodied native species. In brief, the large-bodied species Murray cod, golden perch, bony herring and silver perch have all been recently recorded in the Murray River adjacent to KPF. However, excluding the Lock Lagoon site (connected to the Murray River), only three adult golden perch (one each in 2011, 2012 and 2015), five bony herring (one in 2011, two in 2012 and 2 in 2017) and one silver perch (2017) have been sampled within the forest during this 7-year study. Furthermore, no juvenile large-bodied native fish have been sampled, despite several floods occurring during the course of the study.

It is not known to what extent large-bodied native species would have utilised the KPF floodplain historically. An account of a fish rescue from drying waterholes in the vicinity of the nearby Murrumbidgee River in 1917 and 1918 details many thousands of small fry and juveniles of Murray cod, golden perch, silver perch, Macquarie perch, river blackfish and catfish being netted and returned to the river and to Burrinjuck Dam (Anderson 1920). This suggests that these species may utilise the floodplain as nursery habitat, but does not indicate whether the adult fish spawned in the wetlands or the rivers. A recent study utilising radio-telemetry has demonstrated that Murray cod, trout cod and golden perch all utilised habitat on the floodplain proper and floodplain channels between Cobram and Yarrawonga (Koehn and Nicol 2016). Acoustic tagging of golden perch, silver perch and common carp caught in Thule Creek, Barber Creek (both downstream of KPF) and Swan Lagoon prior to the 2016 flood in KPF was undertaken to determine the response of these species to flooding. While common carp typically moved into KPF as soon as the flood reached them, the native species either didn't move, or quickly moved long distances downstream as far as Mildura (NSW DPI unpublished data). There was an anoxic blackwater event that occurred around the tagging location (Sandy Bridge) of some of these fish from around the 16th of October. The downstream movements of the native fish tagged at Sandy Bridge occurred when dissolved oxygen levels were still high, though beginning to fall. Thus it is possible that these fish were escaping poor water quality. Alternatively, their downstream movement may have been associated with a spawning migration. Downstream movement of this species is not unusual (O'Connor *et al.* 2005) and may possibly be associated with spawning (Koster *et al.* 2014).

Common carp

A pattern in the abundance of YOY common carp within KPF is beginning to emerge. YOY form the bulk of the common carp population present in KPF in years where a flood event precedes autumn sampling. However, the timing of the flood appears to be quite important. In 2011, 2014, 2015 and 2017 there was a much greater proportion of YOY carp within KPF. These years were preceded by flooding in the previous spring and early summer (September, through to December). In 2012, there was also a large flood preceding sampling, but it occurred in winter (July and August 2011), as well as during March 2012 (in the middle of the sampling period). The 2013 sampling was also preceded by a reasonably large flood in July and August 2012. Carp YOY were not as prevalent in 2012 and 2013 following a winter flood. Consequently, the data collected over the course of this study suggests that to minimise major carp spawning events in KPF, environmental watering should be completed prior to September. While flooding during winter may not be considered the ideal time for native species, the data over the last seven years of this study indicates that the native species do not respond to spring flooding by spawning and recruiting in large numbers as might be expected. This may be due in part to competition with large numbers of common carp (and other exotic species).

Conclusions and recommendations

Condition monitoring of KPF has been underway for seven years. In this time, the refined TLM objective—*protect and enhance viable native fish communities*—has so far not been achieved. What has become clear is that spring flooding results in an immediate boom of exotic species, particularly common carp. During this study, two very large spring floods occurred when the floodplain was dry (2010 and 2016). Common carp immediately took advantage of the new habitat to spawn in large numbers based on the abundance of YOY fish that were sampled the following autumn, which resulted in low native fish abundance and biomass. However, smaller floods that served to maintain refuge water bodies within KPF over consecutive years resulted in more stable native fish abundance and biomass. It is apparent that lack of permanent fish habitat within KPF for extensive periods has prevented the development and persistence of a viable and diverse native fish community. As a consequence, nativeness and expectedness indices are driven by generally depauperate native fish communities in the main channel that feed KPF, as well as the exotic fish community. In the short term, these indices are unlikely to substantially improve upon the results of the past seven years until other management actions are implemented. For example, the potential future release of the cyprinid herpesvirus-3 may reduce carp numbers to an extent that could allow native fish populations to partially recover. Those species that are locally extinct (i.e. wetland specialists such as southern pygmy perch) could then be reintroduced given that regular environmental flows would ensure critical wetland habitat does not completely dry out. In the meantime, it is important to the existing native fish community in KPF that refuge habitat be maintained over the summer.

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Appendices

Appendix 1.

Sites identified during aerial surveys. All the sites that contained water are listed below. They are ordered randomly based on a random number generated in Microsoft excel to determine the sites to be sampled. Method refers to the sampling method required based on the amount of water present and access; either backpack electrofishing, boat electrofishing or combined boat and backpack electrofishing (for sites with not quite enough water to complete 12 boat electrofishing shots).

Random sampling order	Site Name	Latitude	Longitude	Method
NA	Broken River lagoon	-35.9290	144.4507	Small boat
NA	Dead River lagoon	-35.8384	144.3846	Small boat
NA	Lock lagoon	-35.9397	144.4680	Small boat
NA	Swan Lagoon	-35.9082	144.4410	Small boat
1	Belbins 1	-35.7447	144.3570	Backpack
2	Snake Waterhole	-35.79271	144.39497	Backpack
3	BC	-35.7668	144.3752	Backpack
4	Barbers Creek 2	-35.6030	144.2070	Backpack
5	Long Lagoon	-35.6115	144.2292	Backpack
6	Scottys Lagoon	-35.6497	144.2493	Backpack
7	Nelsons	-35.6795	144.2457	Small Boat
8	390 Mile Lagoon	-35.7735	144.3588	Small Boat
9	Clarkes Lagoon	-35.7908	144.4243	Small Boat
10	Grasses Waterhole	-35.6205	144.2148	Backpack
11	Pothole Creek	-35.7549	144.4062	Backpack
12	Myloc Creek 3	-35.7150	144.3212	Backpack
13	Boysons	-35.7162	144.3352	Backpack
14	Corduroy Crossing	-35.8656	144.4348	Backpack
15	Black Gate Lagoon	-35.8086	144.3810	Backpack
16	Greys Swamp	-35.73237	144.26161	Backpack
17	Smokehouse Lagoon 1	-35.6273	144.2490	Backpack
18	Cumbungie 1	-35.6478	144.2535	Backpack
19	Smokehouse Creek	-35.6624	144.2484	Backpack
20	Myloc Creek 4	-35.7149	144.3040	Hybrid
21	Crooked Creek	-35.6739	144.2288	Backpack
22	Smokehouse Lagoon 2	-35.6316	144.2471	Hybrid
23	Pollack Swamp	-35.5609	144.1555	Small Boat

24	Egg Lagoon	-35.8009	144.3785	Small Boat
25	Twin Lagoon 1	-35.7023	144.2527	Backpack
26	Twin Lagoon 2	-35.7169	144.2750	Backpack
27	Myloc Lock 2	-35.7003	144.2823	Small Boat
28	BC 1	-35.8099	144.4160	Backpack
29	Sandy Crossing	-35.6932	144.2658	Hybrid
30	Horseshoe Lagoon	-35.8510	144.4013	Small Boat
31	Belbins Creek	-35.7599	144.3974	Backpack
32	Boundary Lagoon	-35.7395	144.3360	Hybrid
33	Near Allens Waterhole	-35.8321	144.4280	Backpack
34	River Road 2	-35.8350	144.3927	Backpack
35	McMahons Waterhole	-35.6654	144.2698	Hybrid
36	Barbers Head	-35.6892	144.2625	Backpack
37	Penny Royal Actual	-35.7565	144.3630	Small Boat
38	Return Channel Regulator	-35.6925	144.2284	Backpack
39	Black Box Lagoon	-35.8256	144.3933	Small Boat

Appendix 2

Black Gate Lagoon

Nelsons

Myloc Creek 3

Boysons

Dead River Lagoon

Corduroy Crossing

Long Lagoon

Lock Lagoon

Swan Lagoon

390 Mile Lagoon

Grasses Waterhole

Broken River Lagoon

Scottys Lagoon

BC (Burrumbary Creek)

Pothole Creek

Clarkes Lagoon

Snake Waterhole

Belbins