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Koondrook–Perricoota Forest Icon Site Fish Condition Monitoring 2015 Annual Report

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Cover image: Myloc Creek #2, Koondrook–Perricoota Forest, March 2015 (Peter Graham)

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Non-technical summary

Koondrook–Perricoota Forest Icon Site Fish Condition Monitoring 2015 Annual Report

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Objectives

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

- annual assessment of the condition of the Koondrook-Perricoota Forest fish community
- assessment of change in the condition of the Koondrook-Perricoota Forest fish community over time.

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 in project has two major monitoring objectives:

- Annual assessment of the condition of the KPF fish community; and
- Assessment of change in the condition of the KPF fish community over time.

This report documents the results of the fish condition monitoring at Koondrook-Perricoota Forest project in 2015 and the changes in the fish community monitored since 2011.

The main findings are:

- Exotic fish species dominated the fish community in KPF waterbodies in 2015. Native fish biomass within KPF waterbodies in 2015 averaged only 17% of total fish biomass. Abundance of native fish in KPF waterbodies in 2015 averaged 70% of all fish collected and this the highest recorded since monitoring began;
- Adult goldfish and common carp were the dominant component of biomass in KPF waterbodies in 2015 and recruits of both species were commonly recorded;
- A relatively high abundance of native species (e.g. carp gudgeon and Australian smelt), but low native biomass, highlights the prominence of small-bodied native species and an almost total absence of large-bodied native species in KPF;
- KPF has a poor native fish community and only 30% of native fish species on the historical species list for KPF were recorded in 2015; and
- Four small bodied native fish species had recruits present in KPF in 2015, however there were fewer recruits than in previous years.

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.

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 and a number of refined ecological objectives under TLM. For detail on the GKP icon site ecological objectives, refer to the Koondrook–Perricoota Environmental Water Management Plan (MDBA 2012) or <mdba.gov.au>.

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.

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 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. 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 species were absent, species count, 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*), golden perch (*Macquaria 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 conducted in March 2015.

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

- annual assessment of the condition of the KPF fish community
- assessment of change in the condition of the KPF fish community over time.

This report documents the findings of the first 5 years of fish condition monitoring at KPF.

Methods

Sampling design

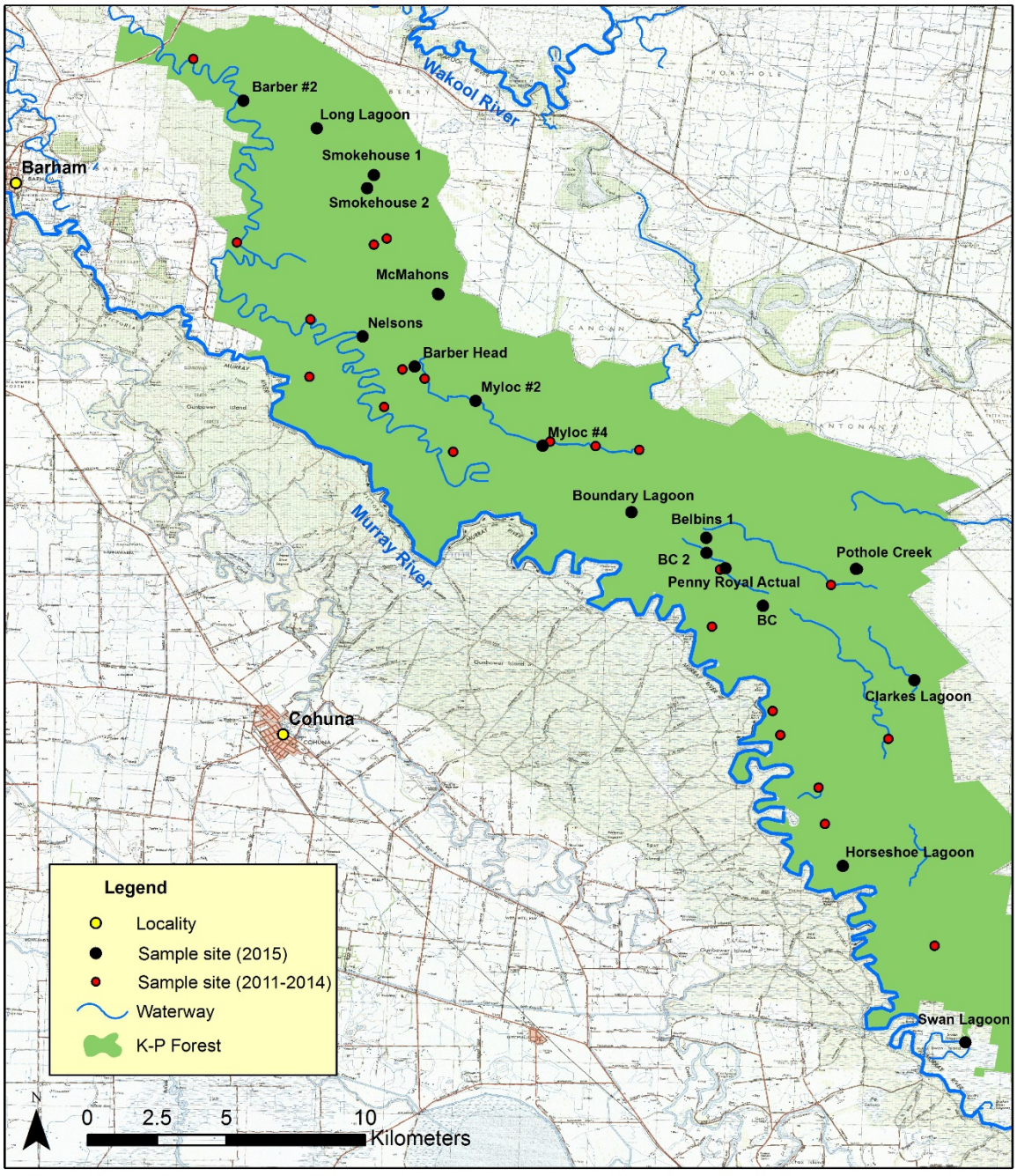
The KPF Fish Condition Monitoring project design is based largely (but not strictly) on the SRA Fish Sampling Protocol (Davies et al. 2008). The project is based on annual (rather than 3-yearly) sampling of the fish community in KPF in late summer to autumn. The monitoring is designed to examine fish community characteristics using the SRA metrics 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 looking at length-frequency distributions for native and exotic fish species present in the forest.

KPF includes two main types of waterbodies — creeks and wetlands. The KPF fish monitoring program was stratified prior to commencement in 2011 to sample in two habitat types — permanent and semi-permanent waterbodies. However, these strata do not correspond to creeks and wetlands. The strata classification used to design the sampling was based only on expert opinion, as the entire forest had been dry since previous flooding of the forest in September 2003. Despite the 2015 environmental watering event, as in previous years the forest had dried out substantially by the time sampling was undertaken in autumn and site selection was based on those waterholes that remained. Therefore, the 5 years of samples come from varied sampling frames (Table 1). Nevertheless, within each of the 5 years sampled, at least 80% of the entire population of available waterbodies within the KPF were sampled, and the spatial extent was always widely dispersed within the forest, hence the results provide an accurate description of the KPF fish fauna. In 2015, 18 waterbodies were surveyed with five surveyed for the first time (Table 1). These represented all of the available waterbodies within the forest at the time of sampling. Their locations are shown in Figure 1. Although some of the sampling sites are on the same channel (e.g. Myloc Creek), they are classified as discrete waterbodies because they are not connected when sampled.

Table 1 Waterbodies sampled for fish in Koondrook–Perricoota Forest (KPF) condition monitoring from 2011 to 2015.

KPF sites	Latitude	Longitude	Sampled				
			2011	2012	2013	2014	2015
Pollack Lagoon	–35.5609	144.1555	✓	✓	✓	✓	
Swan Lagoon	–35.9082	144.4410	✓	✓	✓	✓	✓
Little Burrumbury Creek 1	–35.8770	144.4310		✓			
Horseshoe Lagoon	–35.8510	144.4013	✓		✓	✓	✓
River Road 1	–35.8374	144.3955		✓			
Black Box Lagoon	–35.8256	144.3933	✓	✓	✓		
Black Gate Lagoon	–35.8086	144.3810	✓		✓		
390 Mile Lagoon	–35.7735	144.3588	✓	✓	✓		
Boundary Lagoon	–35.7395	144.3360	✓		✓	✓	✓
Myloc # 1	–35.7135	144.3064	✓				
Myloc # 2	–35.7003	144.2823	✓	✓	✓		✓
Barber Head	–35.6892	144.2625	✓	✓	✓	✓	✓
2003 Thinnings	–35.6901	144.2586		✓			
Return Channel Lagoon	–35.6925	144.2284	✓	✓			
Crooked Creek	–35.6739	144.2288	✓	✓			
Barber # 1	–35.6489	144.2050	✓				
Scottys Lagoon	–35.6497	144.2493	✓	✓	✓		
Barber # 3	–35.5896	144.1908	✓	✓			
Barber # 2	–35.6030	144.2070	✓	✓		✓	✓
Pothole Creek	–35.7549	144.4062	✓	✓		✓	✓
Belbins Creek	–35.7599	144.3974				✓	
Twin Lagoon 1	–35.7023	144.2527		✓			
Twin Lagoon 2	–35.7169	144.2750		✓			
Cumbungie 1	–35.6478	144.2535		✓		✓	
McMahons Waterhole	–35.6654	144.2698					✓
Smokehouse 1	–35.6273	144.2490			✓		✓
Smokehouse 2	–35.6316	144.2471		✓	✓	✓	✓
Long Lagoon	–35.6115	144.2292		✓	✓	✓	✓
Penny Royal	–35.7550	144.3615		✓			
Penny Royal Actual	–35.7565	144.3630				✓	✓
BC 1 (Burrumbury Creek)	–35.8099	144.4160				✓	
BC (Burrumbury Creek)	–35.7668	144.3752		✓	✓	✓	✓
Egg Lagoon	–35.8009	144.3785		✓			
Clarkes Lagoon	–35.7908	144.4243			✓		✓
Boysons	–35.7162	144.3352				✓	
Sandy's Crossing	–35.6932	144.2658				✓	
Myloc # 3	–35.7150	144.3212		✓		✓	
Myloc # 4	–35.7149	144.3040					✓
Nelsons	35.6795	144.2457					✓
BC 2 (Burrumbury Creek)	35.7497	144.3571					✓
Belbins 1	35.7447	144.3570					✓

Figure 1 Sites sampled for fish communities in Koondrook–Perricoota Forest in 2015. See Table 1 for site details.



Fish sampling 2015

Sampling in 2015 was conducted between 2 and 27 March. 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 electrofished 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 metrics and this project reports only the total eight metrics as they are directly interpretable in relation to the project aims. The three nativeness metrics 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 metrics 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 metrics (values close to 1). The recruitment metrics do not identify the source of recruitment, just the presence of recruits. As the KPF condition monitoring samples annually, compared to the 3-year samples 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 metrics, to overcome the bias in the SRA metrics when the ecosystem consists of primarily short-lived fish species. The values used to differentiate new recruits within the recruitment metrics are given in Table 3. For further information and example calculations, refer to Robinson (2012).

The three nativeness metrics 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 5 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 2015 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.

Table 2 Metrics 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 metrics.

SRA indicator (Theme)	SRA metric	Description	Scale of calculation
Nativeness	Native species	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	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	Icon site
Recruitment	Recruiting sites	Average number of sites each RCF species recruited in ÷ number of sites it was expected to recruit in.	
	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 metrics. 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).

Length distribution histograms were generated for species that had at least 20 individuals collected in the icon site. The icon site histogram is the average of the site histograms. Any waterbodies that had less than five individuals from each of the key species were not included in the average for the entire icon site as the small sample size is more likely to give spurious results.

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

Common name	Scientific name	Rarity score	Life guild	Length at YOY or sexual
Large-bodied species				
Murray cod	*Maccullochella peelii*	3	LL	235
Trout cod	*Maccullochella macquariensis*	1	LL	150
Golden perch	*Macquaria 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	*Melanotenia fluviatilis*	5	SL	45
Murray hardyhead	*Craterocephalus fluviatilis*	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	*Galaxius 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

In the 2014–15 water year, 26,420 ML was delivered into the forest from 11 August to 29 September in a managed environmental flow delivery. Small inflows were maintained until 8 October 2014 to allow operation of the vertical slot fishway at the inlet channel to KPF. The watering event inundated approximately 4,500 ha of wetlands, creeks and low-lying River Red Gum forest within KPF.

Prior to 2014, KPF experienced major inflows in 2000–2001, with flows of approximately 48,000 ML/day at Torrumbarry and resulting in substantial inundation of the forest. An extended dry period followed from mid-2001 to mid-2010 (Figure 2). There was a slight peak in flow in 2003 (< 23,000 ML/day), however this resulted in only minor flooding. From 2006 to mid-2010 a significant drought period resulted in no inflows into KPF. A drought-breaking flood occurred in KPF in July 2010, and high flows continued throughout 2010 and into early 2011 (Figure 2). There was a significant flood at the beginning of March 2012, followed by a relatively dry period through to July 2013 (Figure 3). Some minor inundation of KPF occurred in August and September 2013 following a slight increase in flows. From September 2013 to the initial watering event in August 2014, the forest did not receive any inflows (Figure 3). A small amount of water entered Swan Lagoon in July 2014 immediately prior to the managed flood event.

Summary of 2015 fish catch

Ten fish species were collected from KPF in 2015, comprising six native and four exotic species (Table 4). The native fish species collected were similar to the previous 4 years and included carp-gudgeon (*Hypseleotris* spp.), Australian smelt (*Retropinna semoni*), flathead gudgeon (*Philypnodon grandiceps*), dwarf flathead gudgeon (*Philypnodon macrostomus*), Murray–Darling rainbowfish (*Melanotenia fluviatilis*) and one individual large-bodied native fish, golden perch (*Macquaria ambigua ambigua*). The exotic fish species were common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), eastern gambusia (*Gambusia holbrooki*), and oriental weatherloach (*Misgurnus anguillicaudatus*) (Table 4).

Figure 2 Hydrograph of Murray River flows at Torrumbarry from 1 January 1999 to 16 June 2015. The red line indicates the approximate* flow when water begins to enter the Koondrook–Perricoota Forest via Swan Lagoon and the green line indicates the approximate flow when the creeks begin to flow. (* Approximate as the commence to flow level at Swan Lagoon is variable as the silt in the mouth shifts around).

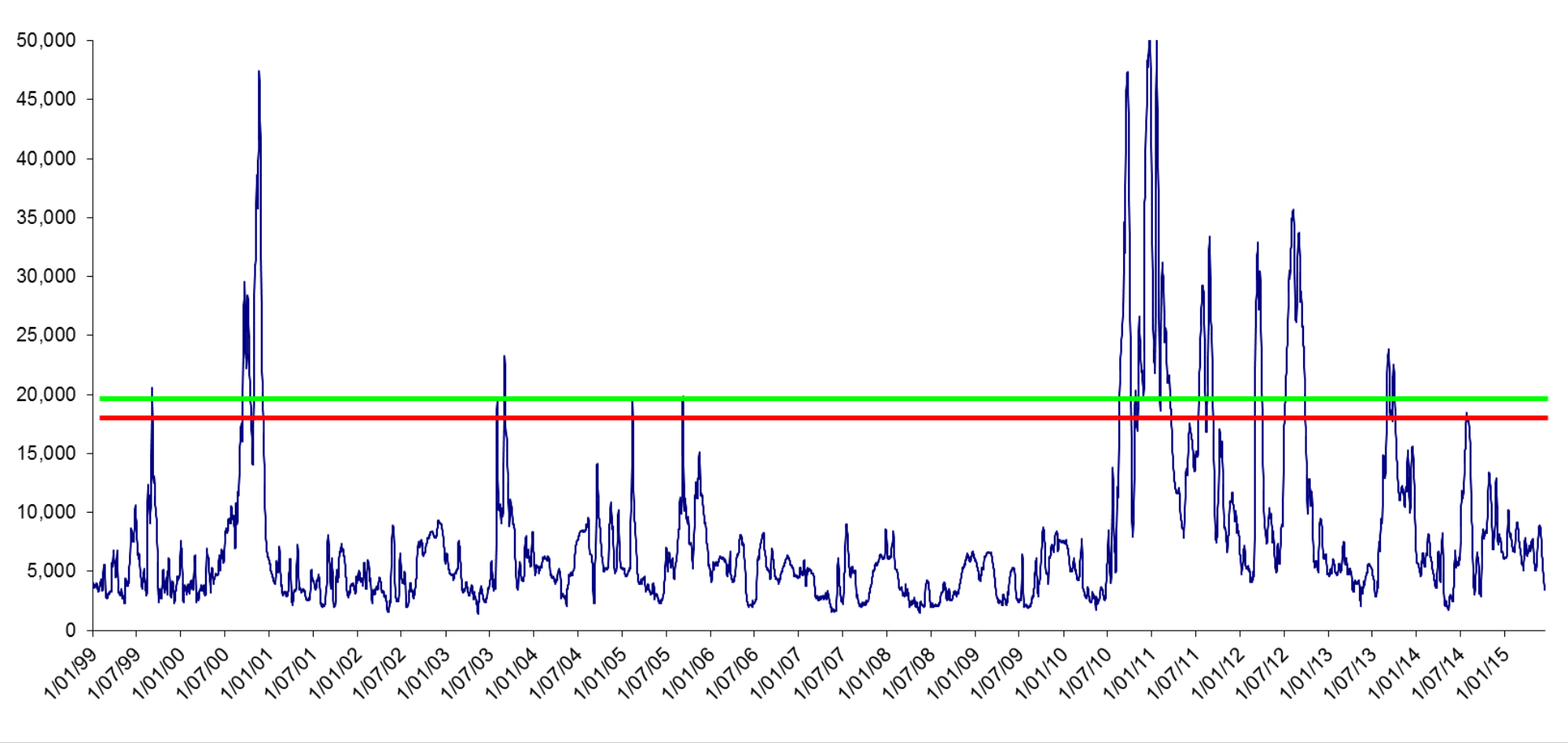


Figure 3 Hydrograph of Murray River flows at Torrumbarry from 1 January 2011 to 16 June 2015. The red line indicates the approximate* flow when water begins to enter the creeks within the Koondrook–Perricoota Forest via Swan Lagoon and the green line indicates the approximate flow when the creeks begin to flow. Light green vertical bars indicate sampling times. (* Approximate as the commence to flow level at Swan Lagoon is variable as the silt in the mouth shifts around).

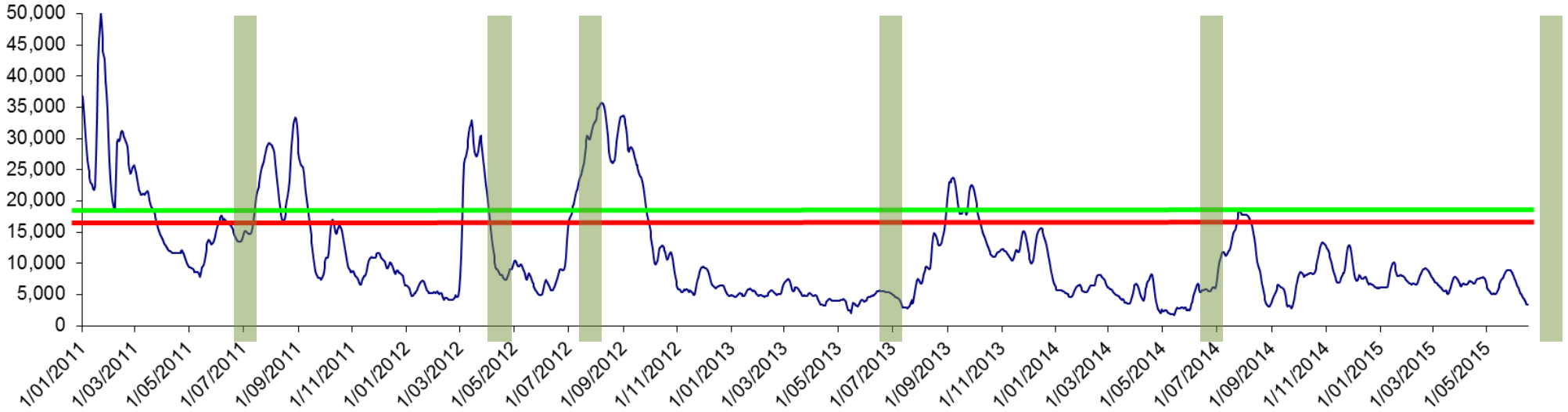


Table 4 Abundance of fish collected (caught data only) in Koondrook–Perricoota Forest sites in 2015.

*** Exotic species. There were 10,077 individual fish collected and a further 2,331 individuals observed and identified but not captured.**

Site name	Gold-fish*	Common Carp*	Eastern gambusia*	Carp-gudgeon	Golden perch	Murray–Darling rainbowfish	Oriental weather loach*	Flathead gudgeon	Dwarf flathead gudgeon	Australian smelt
Barber # 2	1	33	58	682			3			1
Barber Head	2	6	49	29					1	7
BC (Burrumbury Creek)	60	2	60	217			8		1	4
BC 2 (Burrumbury Creek)	8		39	304					2	3
Belbins 1	27	6	80	602				3	4	60
Boundary Lagoon	50	7	19	520			1			
Clarkes Lagoon	10		23	1101						109
Horseshoe Lagoon		15	3	193				8		1
Long Lagoon	2		246	564			3			
McMahons	4	126	333	348			5		7	25
Myloc # 4	4	34	12	25				1		32
Myloc # 2		2	39	92				1	4	15
Nelsons	6	70	29	66				1	2	41
Penny Royal Actual	13	18	21	181				1		2
Pothole Creek	10	2	330	1521			26			
Smokehouse 1		8	307	267			8			2
Smokehouse 2		2	334	376					1	
Swan Lagoon	4	21		39	1	2		15		4
Total	201	352	1982	7127	1	2	54	30	22	306
Number of sites	14	15	17	18	1	1	8	7	8	14

SRA metrics 2011 to 2015

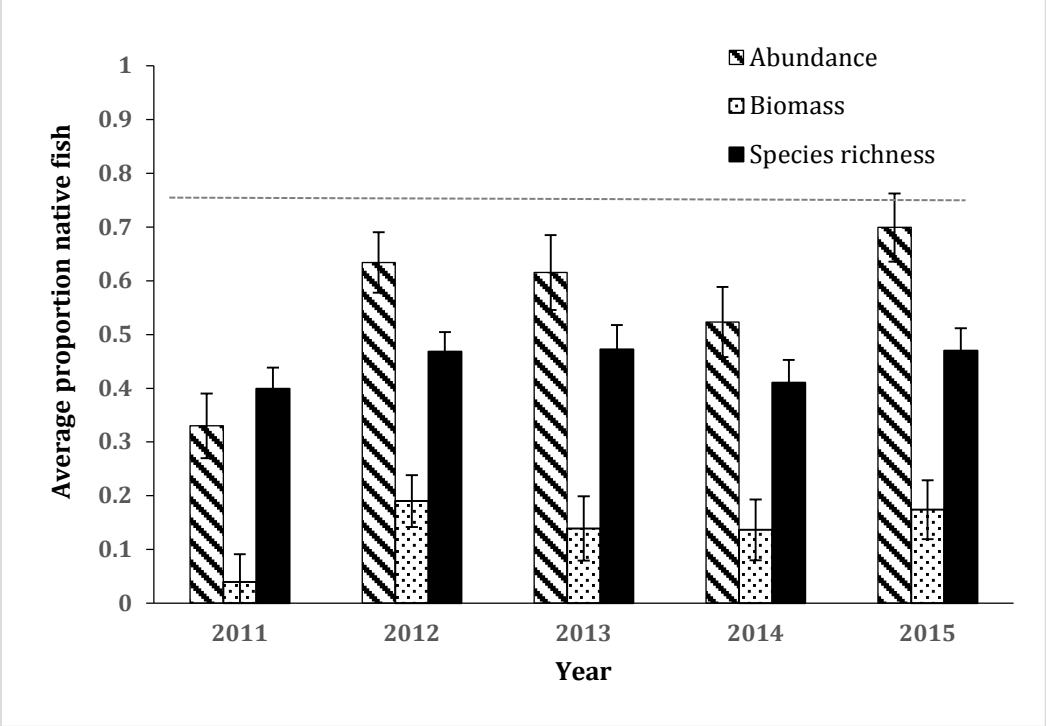
Nativeness

The average proportion of native fish species in the waterbodies of KPF in 2015 was 0.47, not different to any other years since 2011 ($F_{4,49}$ = 0.79, p = 0.5382) (species richness in Figure 4).

Biomass of native fish averaged 0.17 of total biomass in KPF sites in 2015. There has been no significant difference in the average proportion of native fish by biomass throughout the 5 years of the study ($F_{4,49}$ = 1.30, p = 0.2827), ranging between 0.04 in 2011 and 0.19 in 2012 (Figure 4).

The abundance of native fish averaged 0.7 of all fish collected in KPF sites in 2015, the highest since monitoring begun in 2011. Since 2012, the average native abundance has ranged between 0.52 and 0.7, all significantly higher than the 0.33 recorded in 2011 ($F_{4,49}$ = 5.52, p < 0.001) (Figure 4).

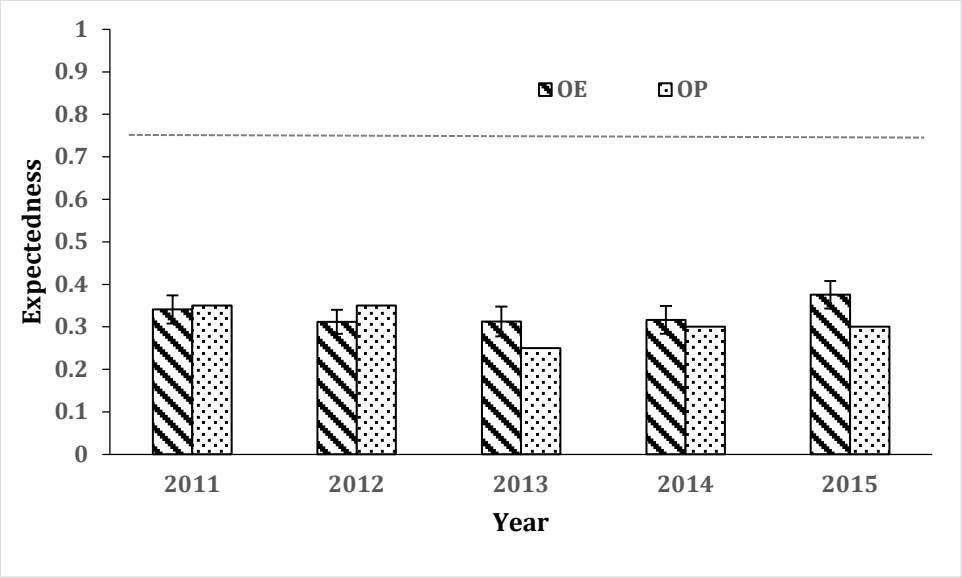
Figure 4 Average (+/- standard error) nativeness metrics for species richness, biomass and abundance in sites in Koondrook–Perricoota Forest from 2011 to 2015. The dashed line is the interim target of 0.75.



Expectedness

There was an average of 0.38 of expected species (OE metric) collected in KPF waterbodies in 2015 (Figure 5). This is the highest recorded in the 5 years of this project, but there has been no statistically significant difference in the average OE score between the years ($F_{4,46}$ = 0.52, p = 0.7215). Of species on the historical species list (Table 3), 0.30 were collected in 2015 (OP metric), within the range of 0.25 to 0.35 experienced since 2011 (Figure 5).

Figure 5 Expectedness metrics (+/- standard error) Observed/expected (OE) and Observed/predicted (OP) for native fish in Koondrook–Perricoota Forest from 2011 to 2015. The OP metric does not include a standard error. The dashed line is the interim target of 0.75.

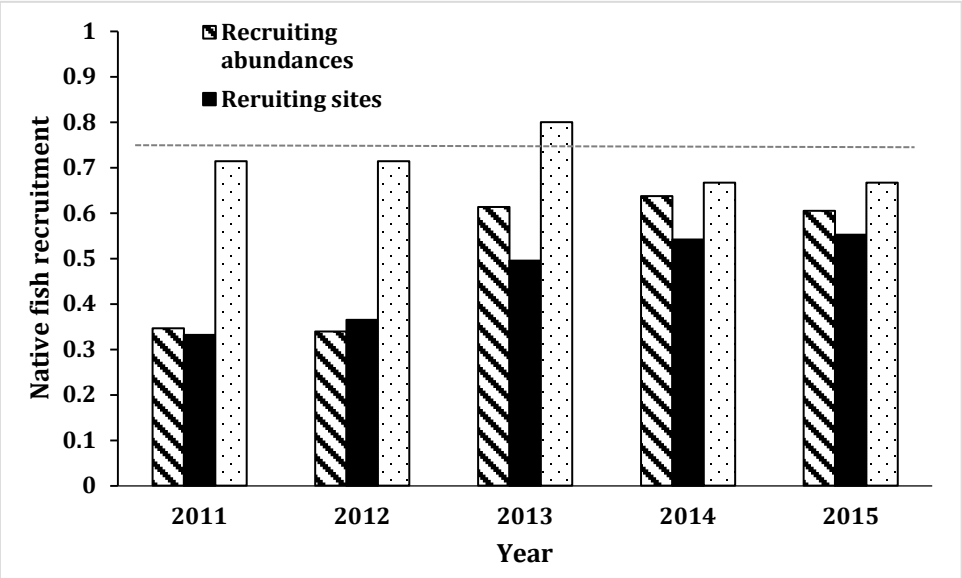


Recruitment

In 2015, native fish species recruited in an average of 0.55 of KPF sites within which they were expected to recruit—the highest since monitoring began (Figure 6). Two-thirds (0.66) of native species had recruits in 2015 — equivalent to 2014 and slightly lower than the best achieved (0.80) in 2013 ('recruiting taxa' in Figure 6). An average of 0.60 of native fish collected in 2015 were recruits, which was equivalent to 2013 and 2014 (0.61 and 0.63, respectively), and better than in 2011 and 2012 (both 0.34) ('recruit abundance' in Figure 6).

The four small-bodied native species—carp-gudgeon, flathead gudgeon, dwarf flathead gudgeon and Australian smelt—had recruits in 2015, but the small-sized Murray–Darling rainbowfish and large-bodied golden perch did not.

Figure 6 SRA recruitment metrics for native fish in Koondrook–Perricoota Forest from 2011 to 2015. The dashed line is the interim target of 0.75.



Length-frequency distributions

Three exotic and two native fish species were collected in sufficient numbers in every year for length distribution analyses (Figures 7–11). The native species, Australian smelt and carp-gudgeon(Figures 7 and 8, respectively), showed a general increase in smaller size classes from 2012 to 2013, indicating they were successfully recruiting in KPF. The small-bodied exotic species, eastern gambusia, followed a similar pattern (Figure 9). Small goldfish (<100 mm) were consistently present each year, with fewer large individuals collected in 2014, but returning in 2015 (Figure 10). Most size classes of common carp were present in KPF in all 5 years, with more small individuals (<100 mm) and a decline of larger carp in 2014 (Figure 11).

Figure 7 Length distributions for Australian smelt (*Retropinna semoni*) in Koondrook–Perricoota Forest in 2011 to 2015. Only waterbodies where at least five individuals were collected are included. Dashed line indicates the approximate maximum length of young-of-year fish (Milton and Arthington 1985).

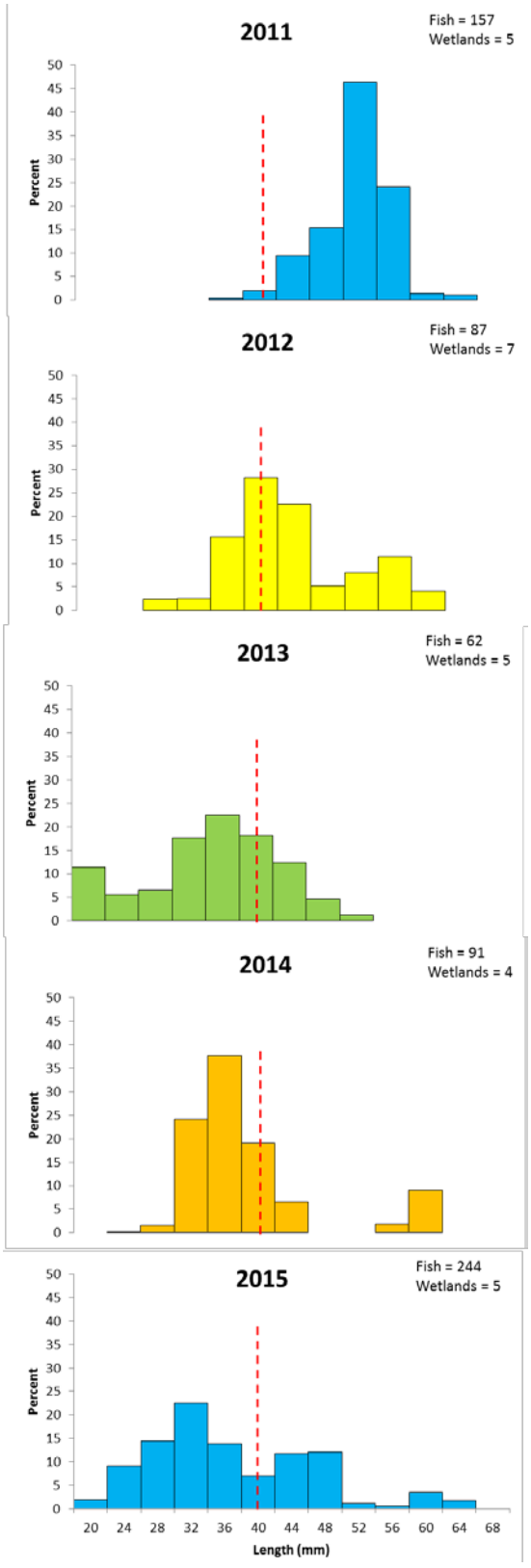


Figure 8 Length distributions for carp-gudgeon species (*Hypseleotris* spp.) in the Koondrook–Perricoota Forest in 2011 to 2015. Only waterbodies where at least five individuals were collected are included. Dashed line indicates the approximate maximum length of young-of-year fish (Gilligan et al. 2009).

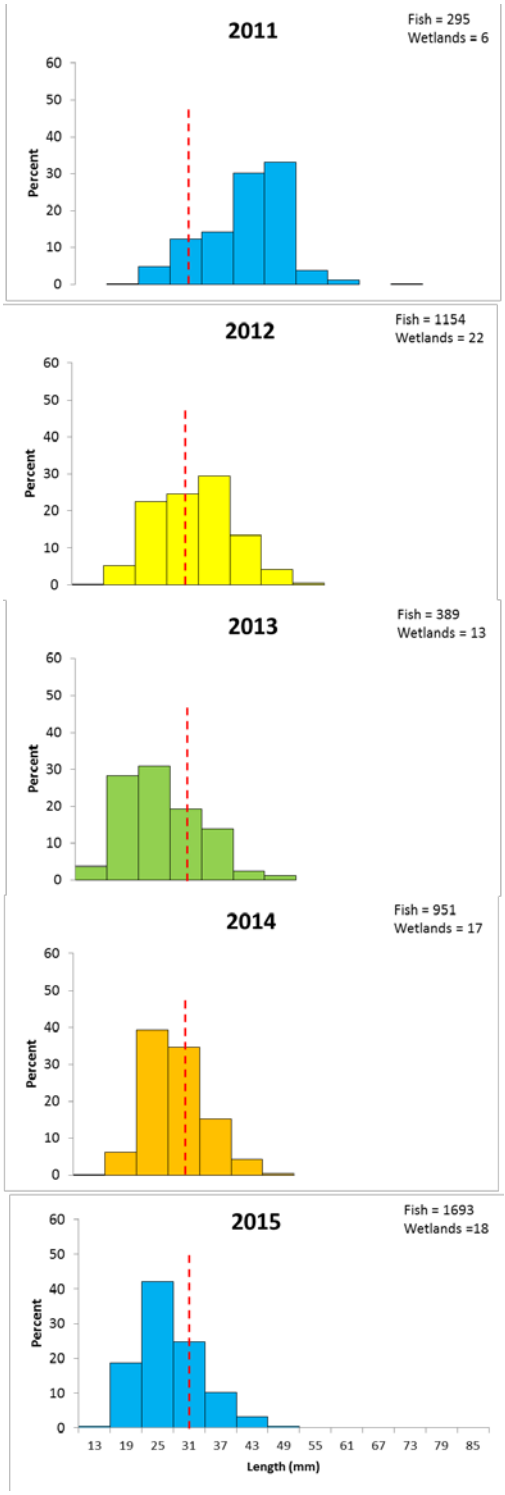


Figure 9 Length distributions for eastern gambusia (*Gambusia holbrooki*) in Koondrook–Perricoota Forest in 2011 to 2015. Only waterbodies where at least five individuals were collected are included. Dashed line indicates the approximate maximum length of young-of-year fish (McDowall 1996).

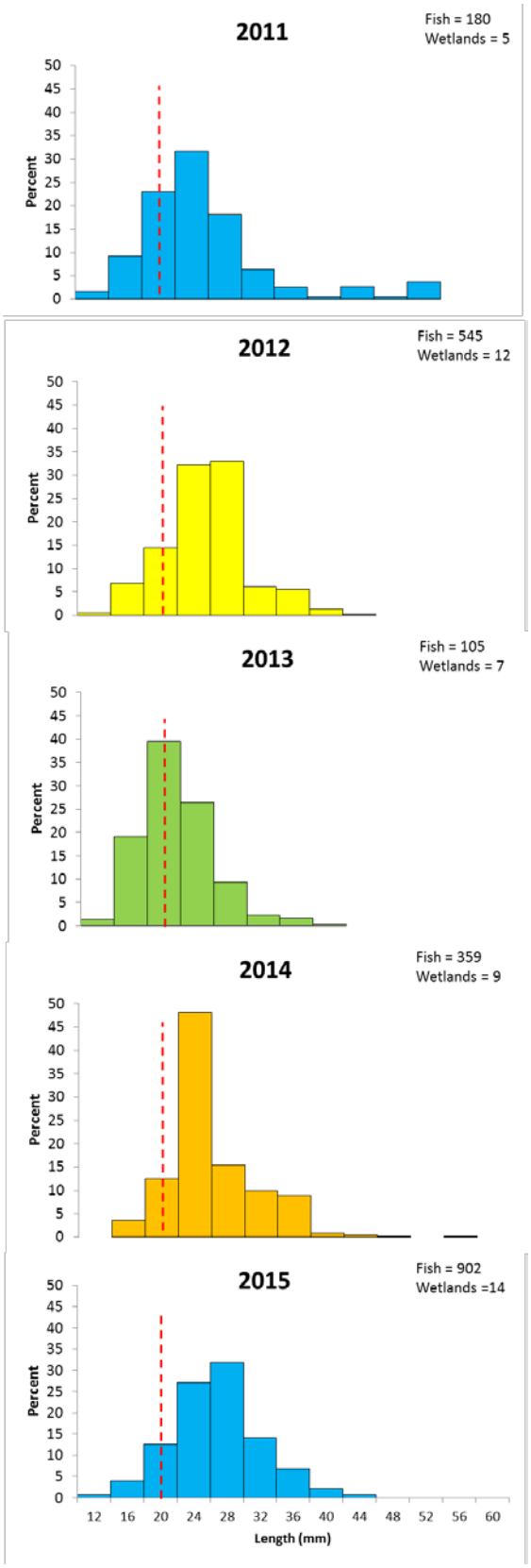


Figure 10 Length distributions for goldfish (*Carassius auratus*) in the Koondrook–Perricoota Forest in 2011 to 2015. Only waterbodies where at least five individuals were collected are included. Dashed line indicates the approximate maximum length of young-of-year fish (Lorenzoni et al. 2007).

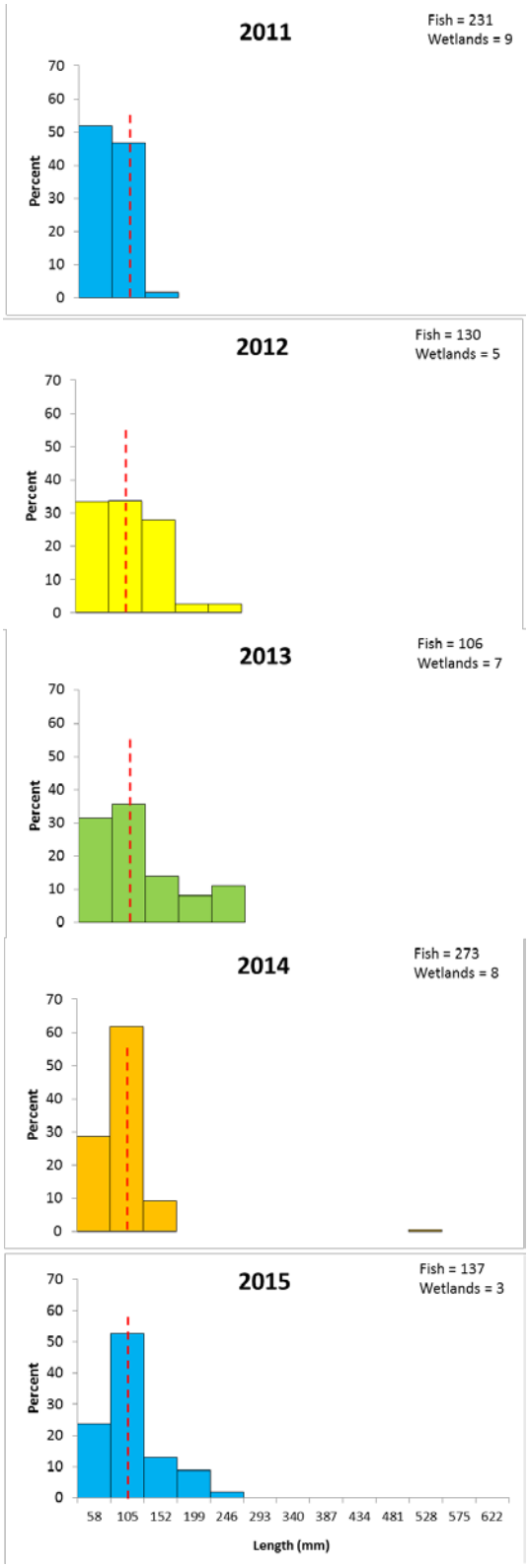
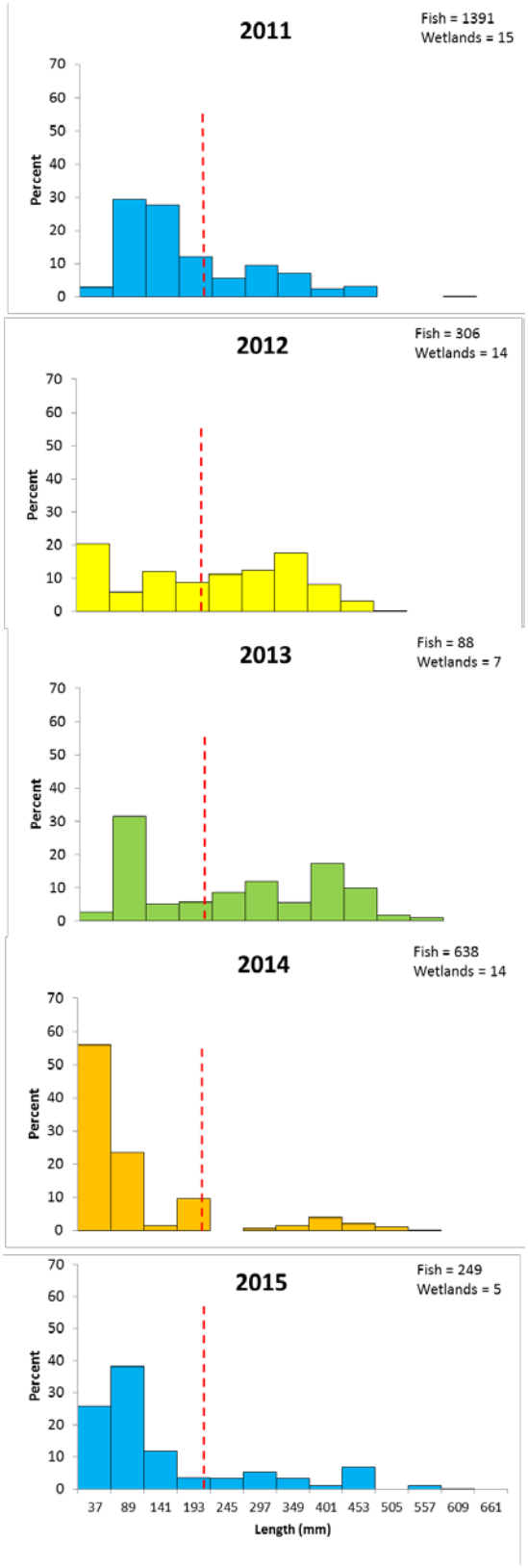


Figure 11 Length distributions for common carp (*Cyprinus carpio*) in the Koondrook–Perricoota Forest in 2011 to 2015. Only waterbodies where at least five individuals were collected are included. Dashed line indicates the approximate maximum length of young-of-year fish (Brown et al. 2003).



Water quality

Most of the water quality parameters were within acceptable limits defined for fish refuge sites in the nearby Wakool River (Gilligan et al. 2009). Most of the sites surveyed had a maximum depth of 0.6 m and 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, indicated by the average of 8.12 mg/L. The Boundary Lagoon site had a very low dissolved oxygen value of 0.31 mg/L at 08:25 am (12/03/15) but five fish species (one native, four exotic) and freshwater yabbies were recorded.

Table 5 Summary of water quality parameters across waterbodies sampled for fish in Koondrook–Perricoota Forest in 2015.

Parameter	Average	Minimum	Maximum
Temperature (°C)	22.2	14.6	30.0
Dissolved oxygen (mg/L)	8.1	0.3	16.4
pH	7.5	6.5	9.5
Conductivity (mS/cm)	0.24	0.13	0.58
Turbidity (NTU)	135.4	21.5	357.0

Discussion

The Koondrook–Perricoota Forest Fish Condition Monitoring project is designed to provide: a) annual assessment of the condition of the KFP fish community; and b) assessment of change in the condition of the fish community over time. 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.

The condition monitoring sampling was conducted in March and April 2015, after the environmental watering event was completed. This means the previous 4 years of data from this project provide a pre-environmental water delivery condition assessment of the fish community, albeit a quite atypical period encompassing drought-breaking flooding at the end of a very severe drought. The 2015 results provide the first year of fish condition information post-watering using The Living Murray water management infrastructure. A separate monitoring project assessing a number of ecological objectives for fish was implemented through the watering event and will be reported separately (Duncan et al. in press).

The native fish assemblages in KPF wetlands and creeks were in poor condition in 2015 as with the previous 4 years of assessment. 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. There have been occasional fish sampling in just three sites in the Murray River channel adjacent to KPF as part of the Gunbower Forest fish condition monitoring, but this was not performed in 2015 because of budget constraints. A rigorous assessment of fish communities based on seven sites in the adjacent channel available from 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 metrics have been made available to us for this report (Table 6). The comparison clearly shows that low nativeness in KPF is related to low nativeness of fish in the source populations in the channel (Table 6). Nevertheless, the abundance of native fish in KPF in 2015 of 0.70 is the best since monitoring of the forest began in 2011, and is considerably higher than the average abundance of native fish in the channel (0.45) in 2011. The species list (OP metric) in KPF since monitoring begun has never been as high as in the channel in 2011 (0.48) and the KPF metric in 2015 (0.30), again reflecting that large-bodied native fish have not entered KPF in recent years. Further, many small wetland specialist species have been lost from the river system, and in the Central Murray region several are considered locally extinct. Therefore, several species likely to have been historically present in KPF have been lost and have little capacity to recolonise the forest through natural processes.

Table 6 Sustainable Rivers Audit (SRA) Expectedness and nativeness metrics in the Central Murray River in 2011 and waterbodies in Koondrook–Perricoota Forest (KPF in 2015).

SRA theme	Metric	Central Murray 2011	KPF 2015
Nativeness	Species	0.61	0.47
	Biomass	0.10	0.17
	Abundance	0.45	0.70
Expectedness	OE	0.38	0.39
	OP	0.48	0.30

The poor condition of the fish community in KPF is a result of many complex factors, including the dominance of common carp and goldfish within the fish assemblage. Exotic species were

recorded at every site sampled in 2015 (those not captured are not included in Table 4) and the biomass of exotic species far exceeded the biomass of the native species. Further, the long history of river regulation has resulted in the forest floodplain and its wetlands and creeks enduring long periods without any surface water. The lack of permanent fish habitat within KPF for extensive periods has prevented the development and persistence of a viable native fish community. As a consequence, nativeness and expectedness metrics are driven by generally depauperate fish communities in the main channel that supply water to KPF.

Nativeness—species, biomass and abundance

A consistent aspect of the results throughout the 5 years of monitoring is the combination of very low native fish biomass, but relatively high native abundance of two native small-bodied species (carp-gudgeon and Australian smelt). As in previous years, only one individual large-bodied native species, a golden perch, was recorded in KPF in 2015, but the biomass is dominated by large-bodied exotic species (carp and goldfish). These results are have been consistent through time, with the step up in proportion of native abundance from 0.33 in the first year to 0.70 in 2015 the only significant improvement. Unfortunately, the SRA is no longer conducted, as a continuing rigorous assessment of fish communities in the channel would assist in understanding KPF fish communities from a regional perspective.

Expectedness

The 2015 expectedness score of 0.38, consistent with all previous years and well below the interim target of 0.75. The result can be interpreted as a 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 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. These results are indicative of poor fish assemblage condition.

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 on the consideration 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, only three adult golden perch (one each in 2011, 2012 and 2015) and three bony herring (one in 2011 and two in 2012) have been sampled within the forest during this 5-year study. Importantly, no *juvenile* large-bodied native fish at all 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. A rare historical 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. Further monitoring of the fish community at KPF will enable this question to be further explored, particularly when larger volumes of environmental water are delivered to KPF using the water management infrastructure (see conclusion section regarding future environmental watering).

Recruitment

The 2015 recruitment results are positive in that the proportion of native species with recruits, recruits by abundance, and average proortion of sites with recruits by species are all generally higher than the expectedness and nativeness metrics, and all were within 0.2 of the 0.75 target.

Thus, although fewer native species are present than expected, those that are present are recruiting within the forest. Unlike the expectedness and nativeness metrics, for which a best possible condition score of 1.0 is achievable (all historical species present and no alien species present), the absolute reference condition for the recruitment metrics is not so intuitive. That is, the reference values are based on expert opinion and biological parameters of each species, which are generally averages (e.g. length at maturity). But on an evolutionary scale, endemic Australian species have had to deal with large-scale spatial and temporal variability, and how this influences the expected levels of recruitment is not directly understood. The current recruitment metric methodology uses the RCF scores to assist with setting reference, but the RCF was designed to address rarity and catchability of the species in general. Recruitment may warrant its own RCF and these data will assist future research in that direction. In the current project, recruitment in KPF is considered satisfactory for the species present and just below the target.

Length-frequency distributions

The annual sampling design used for this project allows length distributions of sampled fish to be used as an additional indicator of recruitment. In 2015, sampling was completed after the conclusion of the initial watering event and the majority of Australian smelt recorded were less than 40 mm in length, indicating they were likely to be immature individuals and new recruits to the population (Milton and Arthington 1985) and therefore likely to have been recruited within KPF. This was also the case in 2013 and 2014 which also had spring inflows to KPF. In contrast, in 2011 the vast majority of Australian smelt recorded were greater than 40 mm in length and therefore likely to be adult fish. While it is acknowledged that the age of the fish was not confirmed using daily aging of otoliths, these results along with the SRA recruitment metric results (and their limitations) are suggestive of recruitment by Australian smelt in KPF in 2015.

In 2015, the majority of carp-gudgeons recorded were less than 35 mm in length, indicating they were likely to be immature individuals (Gilligan et al. 2009) and potentially recent recruits to the population. This was also the case in 2013 and 2014. However, as for Australian smelt, in 2011 the majority of carp-gudgeons sampled were greater than 35 mm in length and therefore sexually mature individuals that may or may not have been spawned within KPF in the previous year. That is, they may have spawned before flows began entering KPF in August 2010. This species has been routinely recorded from the Central-Murray region (Gilligan et al. 2009; Lyon et al. 2010) and it is likely that the adult fish sampled in 2011 had moved into KPF with the inundation flood flows in 2010. Carp-gudgeons are likely to continue to spawn and recruit within KPF providing surface water habitats are available within the forest.

The vast majority of common carp and goldfish recorded in 2015 were recruits. However, adult and juvenile fish of both species have been recorded in each year of this project since 2011. Other studies have used otolith microchemical analyses to confirm that the majority of young-of-year common carp above Torrumbarry Weir are spawned in Barmah–Millewa Forest (Macdonald and Crook 2014). It is therefore possible that the common carp recruits from the Barmah–Millewa Forest also colonise KPF with inflows rather than being spawned locally. A concurrent project as part of TLM intervention monitoring is collecting otoliths and assessing their microchemistry to assist with determining the place of spawning.

Conclusions and recommendations

This project has provided 4 years of information on the condition of the KPF fish assemblage prior to commissioning of TLM KPF flood enhancement works and with the 2015 results, 1 year post-commissioning. Based on the 5 years that this project has been assessing the condition of the fish community in KPF, the refined TLM objective—*protect and enhance viable native fish communities*—has so far not been achieved. This is mainly because of the dominance of exotic species in the fish community. The results from 2015 indicate that the watering has resulted in the protection of some native species, with recruits from two native species recorded, and is a step toward achieving the objective of enhancing a viable native fish community. To fully measure progress toward or achievement of this objective, several more years of watering events and monitoring are required.

While at present the condition of the fish community is poor, there are some positive aspects to the results from 2015. Of particular note is the collection of dwarf flathead gudgeon for the second year in KPF in 2015. Dwarf flathead gudgeon is a cryptic species and is very patchily distributed in the Murray–Darling Basin, having only been recorded from a few locations (Lintermans 2007). Specimens of dwarf flathead gudgeon that were collected in 2015 were submitted to the Australian Museum to assist in documenting the distribution of this species. The sampling of one individual golden perch in 2015 is a positive result because it demonstrates that it is possible for large-bodied native species to enter and/or survive in the available habitats within KPF.

The opportunity for improvement in the condition of the fish community is now greatly enhanced with the completion of water management infrastructure at KPF that will enable a more suitable watering of the forest. Noting this, it must be recognised that being an active working forest, the ecological objectives for KPF under TLM initiative are not solely about viable native fish communities—they also include healthy vegetation communities, healthy wetlands and successful waterbird breeding.

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Appendices

Appendix 1 - 2015 site photos

All photos taken by Peter Graham.

Barber Creek #2

Barber Head

Clarkes Lagoon

Horseshoe Lagoon

Myloc Creek # 2

Myloc Creek # 4

Nelsons

Penny Royal Actual

Swans Lagoon

Belbins 1

Boundary Lagoon

Long Lagoon

McMahons

Pothole Creek

Smokehouse Lagoon 1

Smokehouse Lagoon 2

BC 2 (Burrumbury Creek)

BC 1 (Burrumbury Creek)

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No. 22 Williams, R.J., Watford, F.A. and Balashov, V., 2000. Kooragang Wetland Rehabilitation Project: History of changes to estuarine wetlands of the lower Hunter River. 82pp.

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