Monitoring fish in the Koondrook–Perricoota Natural Flooding Event in 2017

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Cover image: Murray cod captured at Murray River Swan Lagoon Inlet ready for acoustic tagging 9th August 2017 (Kate Martin)

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Non-technical summary

Monitoring fish in the Koondrook–Perricoota Natural Flooding Event in 2017: Acoustic monitoring component

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Objectives

This project describes the responses of native fish and common carp to a natural flood in Koondrook–Perricoota Forest that occurred in December 2017 The key objectives were to:

1. Determine if large-bodied native fish and common carp entered Koondrook–Perricoota Forest during the flood and;
2. Determine if common carp and carp gudgeon spawned in Koondrook–Perricoota Forest during or following the flood.

Key words

Koondrook–Perricoota Forest, native fish, common carp, daily ageing, fish movement.

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. River regulation and the associated reduction of natural flooding of the forest have resulted in the decline of the health of the forest. To address this decline, water management infrastructure has been constructed as part of The Living Murray Initiative to enable the watering of the KPF. These structures were operated to water the forest for the first time from August to October 2014 and the fish response to the flooding was monitored (Duncan et al. 2015; Duncan et al. 2016). In the summer 2017, high rainfall in the catchments of the lower Basin resulted in a small flood in KPF. This presented an opportunity to monitor fish responses (movement and spawning) to a natural flood that could potentially inform management of the watering infrastructure to maximise benefits to native fish. Results showed that six common carp moved into KPF and all six progressed beyond Swan Lagoon. In contrast, only two large-bodied native (two golden perch and one Murray cod) moved into KPF. However, they did not move deeper into the forest beyond Swan

Lagoon. These results are supported by annual condition monitoring data that have rarely documented large-bodied native fish within KPF. It is recommended that the acoustic tagging component of the project be repeated when there is natural or managed flow into Barber Creek, Thule Creek and/or the return channel to confirm limited use of the site by large-bodied native species. Following confirmation of this, consideration should be given to managing the site exclusively for small bodied native fish in the short to medium term, starting with testing the feasibility of carp exclusions screens followed by potential use of the site as a release location for threatened species such as southern pygmy perch if carp can be successfully excluded.

Otolith daily ageing indicated most of the young-of-year carp gudgeon collected in late summer 2018 hatched after the flooding. Therefore, this species successfully spawned and recruited in KPF once flooding had ceased. In contrast, most common carp hatched before the flooding and thus their spawning location could have been the river or KPF. Common carp did not spawn in large numbers within KPF compared to previous years, potentially due to the small area of inundation reducing the availability of suitable spawning habitat. Nevertheless, common carp remain a limiting factor to a healthy fish community given their ability to rapidly recolonise KPF under suitable conditions.

Introduction

Koondrook–Perricoota Forest and The Living Murray initiative

The Koondrook–Perricoota Forest (KPF) is approximately 32,000ha in size and contains a mosaic of wetlands that are listed under the Ramsar convention. The KPF has been impacted by a change in the flow regime of the Murray River that has resulted in a decline in the flood frequency, magnitude and duration. Flows of approximately 18,000 ML/d in the Murray River at Torrumbarry Weir will result in water entering KPF at Swan Lagoon and the creeks will begin to flow at approximately 20,000 ML/d (Carson 2010). Pre-river regulation, flows of 20,000ML/d occurred in approximately 90% of years compared to 51% of post-river regulation (Carson 2010). More moderate floods of 40,000 ML/d historically occurred in 65% of years compared to only 28% of years at present (Carson 2010). Therefore, extremely dry periods in the KPF similar to that experienced from mid-2001 to mid-2010 where very little water entered the forest, were rare prior to river regulation. The significant changes in flood frequency and magnitude have negatively impacted on the health of the forest and the fish community within the forest.

Small-bodied fish species that utilise wetland habitat are particularly vulnerable to decreased flood frequency given that the KPF will largely dry out if a flood does not occur each year to refill the lagoons and wetlands. Some small-bodied species are able to quickly recolonise wetland habitat once it becomes available such as carp gudgeons (*Hypseleotris* spp.) and Australian smelt (*Retropinna semoni*) due to their ability to persist and reproduce in riverine environments. However, small-bodied wetland specialists that historically occupied these habitats including Murray hardyhead (*Craterocephalus fluviatilis*), southern pygmy perch (*Nannoperca australis*), purple spotted gudgeon (*Mogurnda adspersa*), flathead galaxias (*Galaxias rostratus*) and olive perchlet (*Ambassis agassizii*) have been completely lost from the KPF and surrounding areas given they are typically short lived (<10 years) and rely upon wetland habitat to complete their lifecycle.

There is very little known of natural movements of large-bodied native fish between the creeks and lagoons of KPF and the connecting rivers. Large-bodied fish such as golden perch (*Macquaria ambigua*) and silver perch (*Bidyanus bidyanus*) are known to utilise regulated and unregulated creeks in Barmah–Millewa Forest when it becomes available due to flooding (Jones & Stuart 2008). Historical data indicates juvenile golden perch were found in abundance in off-channel environments (Anderson 1920). This suggests juvenile stages may have a requirement to access this habitat. However these species are susceptible to being trapped behind regulators that control flooding to these environments in many areas, due to excessive turbulence from partially opened regulators, or because regulators are shut before fish can exit to the main channel (Jones & Stuart 2008).

In an attempt to mitigate some of the negative impacts of river regulation on fish, environmental flows are increasingly being utilised to increase habitat availability and to create conditions that are more suitable for fish spawning and subsequent recruitment. Furthermore, to improve the efficiency of water delivery and to protect neighbouring private interests, 'Environmental Works and Measures' (EWM) are being increasingly applied (MDBA 2011). EWM have been used at the KPF in order to allow flooding at times of lower river flow than would be required if these EWM were not in place (MDBA 2011). The structures were operated for the first time in August to October 2014 and the fish response was monitored (Duncan *et al.* 2015; Duncan *et al.* 2016) using the fish monitoring objectives outlined in the Koondrook–Perricoota Forest Monitoring Ecological Response Sub-plan (Anon 2012). While a number of objectives could not be assessed due to the flood being a relatively low volume (26,400ML), the data indicated the vertical-slot fishway was operating as expected for Australian smelt and that common carp and carp gudgeon spawned and recruited within KPF.

No further managed events have occurred in KPF since 2014; however a large natural event occurred between August and November 2016. This provided an opportunity to monitor the movements of native fish and common carp in response to a natural flood (Duncan *et al.* 2017b). In addition, the spawning of common carp within KPF and surrounding rivers was monitored, and otolith chemistry was used to determine if young-of-year (YOY) common carp captured in the Murray River and KPF following the flood originated from spawnings within KPF(Duncan *et al.* 2017a). Golden perch, silver perch and common carp caught outside KPF and in Swan Lagoon were fitted with acoustic tags prior to the flood. Their movements during the flood were recorded on an acoustic array inside and outside KPF. No tagged native fish moved into KPF during the flood, instead moving downstream or remaining at their tagging location. In contrast, most tagged common carp moved into KPF during the flooding and some then moved large distances upstream or downstream towards Barmah-Millewa Forest or Gunbower Creek (Duncan *et al.* 2017b). Common carp larvae were sampled in large numbers in many locations both within and outside KPF. However, otolith microchemistry analysis revealed that their survival rate within KPF was extremely low given most YOY within the Murray River at Torrumbarry and within KPF were traced back to natal locations outside KPF(Duncan *et al.* 2017a). These results contrasted with those from the 2014 managed event where common carp larval survival within KPF was high (Duncan *et al.* 2016). The low survival of common carp larvae following the 2016 flood was attributed to adverse water quality (acidic and anoxic water) during the flood event.

In December 2017 a small natural flood event resulted in inundation of some parts of KPF (Figure 1). Once the flooding was complete, there was no further connectivity between KPF and the Murray River at the time of writing (June 2018). This presented another opportunity to monitor fish responses to a natural flood. Three objectives in the ecological sub-plan (Anon 2012) were addressed (or partially addressed); objective 1 (the operation of the scheme will not result in dispersal of common carp spawned in KPF to the Murray River), objective 2 (there will be no impact of the operations on the free migration of native fish within the KPF that results in fish becoming stranded) and objective 8 (the operation of the scheme will result in a beneficial impact on the fish community in KPF).

Here we used otolith daily ageing to calculate the date of hatch of common carp and carp gudgeon to determine whether the flooding may have triggered a spawning event in KPF. If their date of hatch was after the inflows into KPF ceased, then these fish were considered to have originated from spawnings within KPF given no further inflows occurred in the months following the December flooding (objective 1). We also used acoustic telemetry to monitor the movement response of native large-bodied fish and common carp to the flooding (objective 2 and 8).

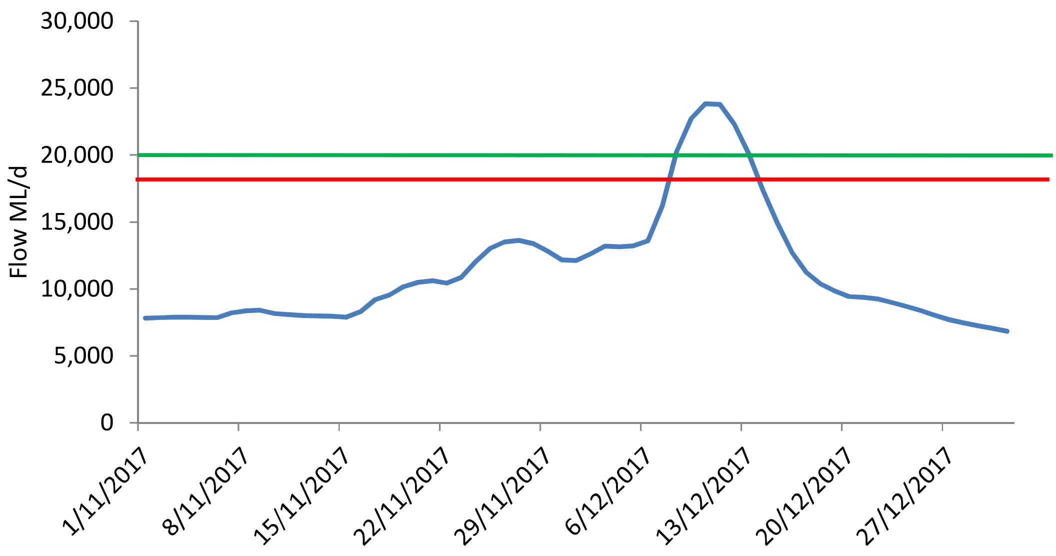


Figure 1: Hydrograph of Murray River flows at Torrumbarry from November 2017 to December 2017. The red line indicates the approximate* flow when water begins to enter the Koondrook–Perricoota Forest via Swan Lagoon and the green line indicates the approximate flow when the creeks begin to flow. (* Approximate as the commence to flow level at Swan Lagoon is variable as the silt in the mouth shifts around). Inflows into Koondrook–Perricoota Forest occurred from the 7th to 14th of December.

Methods

Acoustic telemetry

Two sites were selected to collect fish for acoustic tagging to provide the best chance that tagged fish were in the vicinity of entrance points to the KPF if natural or managed flooding occurred. These sites were Swan Lagoon (one of the locations where the Murray River will naturally enter KPF during high flows) and the Murray River adjacent to the inlet channel that is used to flood KPF during managed events. Intensive electrofishing was carried out in August 2017 in anticipation of either a natural or managed flood to collect large-bodied native fish and common carp suitable for acoustic tagging using the tagging methods in Butler *et al.* (2009). After capture, fish were held in 200 L oxygenated tanks before they were anaesthetised in 100 L oxygenated tanks containing 50 mg L-1 (95ml of 50mg/l stock solution added to 100L of water) benzocaine (ethyl-p-aminobenzoate) (Sigma Aldrich, Shanghai). Once the operculum rate slowed down (4-5 minutes), the fish were weighed and total length (golden perch and Murray cod, *Maccullochella peelii*) or fork length (common carp) were recorded. If the weight of the transmitter was below 2% of the fish's bodyweight (Winter 1996), they were placed in an operating cradle and prepared for surgery. The gills were continuously irrigated with water containing benzocaine (50 mgL^{-1}) and 25-30 mm incision for V13 tags or a 12-15mm for V9 tags was made through the body wall anterior to the anal vent and the tag inserted (Figure 2). The sex of the fish was determined if possible by examining the gonads prior to inserting the acoustic tag.

The acoustic tags (VEMCO V13 and V9) have a randomised nominal delay of 50-130 seconds between pulse trains and are projected to operate for 881 days. In addition to the acoustic tag, a Passive Integrated Transponder (PIT) tag was inserted into the cavity given there are numerous PIT reader systems in the nearby rivers (Edward-Wakool system and Murray River) that the fish could potentially encounter if they migrate away from the acoustic array. The wound was sutured with three absorbable sutures (Ethicon Monocryl 3-0) using a 2x1x1x1 surgeon's knot and the fish given an injection of a broad spectrum antibiotic, Oxytet 200 (Oxytetracycline, Troy Laboratories, Australia) before being allowed to recover in freshwater and being released back into the Murray River. All fish fitted with an acoustic tag from each monitored event (2014- 2017) are included in Appendix 3 given it is possible that the some of the fish tagged in the earlier years are still operational and therefore their movements could be detected by the present study.

An acoustic monitoring array of 21 VEMCO VR2W (VEMCO Ltd., Halifax, Nova Scotia, Canada) acoustic receivers was deployed within the forest in December 2017 prior to flooding to record the movements of individual tagged fish. Receivers were strategically located at entry/exit points to ensure the direction of fish movement could be determined and were also placed to minimise interference from instream structures (Figure 3 and 4, Appendix 1). Receivers were also deployed in the Murray River and Barber Creek to track movements of fish that exited the forest (Figure 4).

Figure 2: Surgery on an adult golden perch to insert a VEMCO V13 tag and PIT tag.

Receivers were tethered to a concrete anchor by a short length of 5mm stainless steel wire and a float was attached to allow the receiver to orientate upright in the water column. The concrete anchor was then attached to a nearby tree or star picket to ensure retrieval. Acoustic receivers were downloaded in January 2018 and June 2018 and the data was imported into a custom-built SQL database. Data from acoustic arrays managed in the Murray River, Gunbower Creek and Edward-Wakool Rivers (Figure 5) by other researchers was also included to document movements outside the current study's acoustic array.

Acoustic data analysis

Inflows into KPF occurred for approximately one week in December 2017 from the 7th to the 14th of December. Consequently, there was not enough data to perform a quantitative analysis similar to that undertaken in following the large natural flood in 2016 (Duncan *et al.* 2017b). Thus general observations of fish movement patterns were made.

Young-of-year fish collection

YOY common carp (all below 35 mm fork length) and carp gudgeon (all below 22 mm total length) were collected during the 2018 condition monitoring in January and February using a combination of boat and backpack electrofishing (Duncan *et al.* 2018). Fish were preserved in 100% ethanol and brought back to the laboratory for otolith processing.

Table 1. Young-of-year carp gudgeon, common carp and a silver perch used for otolith daily ageing.

Stream	Site	Latitude	Longitude	YOY carp gudgeon	YOY common carp	YOY Silver Perch
Barber Creek	Barbers Head	-35.6892	144.2625	3		
Burrumbury Creek	Boundary Lagoon	-35.7395	144.3360			
Burrumbury Creek	Evans Crossing Road	-35.8344	144.4221		15	
Clarkes Creek	Clarkes Lagoon	-35.7908	144.4243			
Burrumbury Creek	Corduroy Crossing	-35.8657	144.4348	6	16	1
Horseshoe Creek	Horseshoe Creek - Prices Road	-35.8201	144.4064			
Murray River	Lock Lagoon	-35.9397	144.4680			
Myloc Creek	Myloc 3	-35.7150	144.3212	1		
Penny Royal Creek	Penny Royal Actual	-35.7565	144.3630			
*	River Road No. 2	-35.83503	144.39273	14		
Murray River	Swan Lagoon	-35.9082	144.4410			
Total				**24**	**31**	**1**

*Site falls on an unnamed flood runner

Ageing carp gudgeon

The age of YOY carp gudgeon collected in KPF can be determined by extracting their otoliths and counting the number of rings to determine their age in days. The date of hatch can then be back-calculated by counting the number of rings from the date of capture . If the fish was confirmed to have been the result of a spawning after the completion of inflows, then it was considered to have successfully spawned and recruited (to YOY age) in KPF. In contrast, if the date of hatch was prior to the completion of flooding, the fish was potentially the result of a spawning outside of KPF.

Carp gudgeon were measured to the nearest millimetre and asteriscus otoliths were removed. Otoliths were mounted individually in CrystalbondTM, proximal surface downwards, and polished down to the primordium using a graded series of wetted lapping films (5 μm). Sections were examined using a compound microscope (x 400) fitted with a digital camera and CellSens image analysis software. Increments were counted blind with respect to fish length and capture date. The numbers of rings (usually an estimate of age in validated species) were determined by counting the number of increments from the primordium to the otolith edge. Two successive counts were made by two readers for one otolith from each fish. If these differed by more than 10% the otolith was rejected, but if not, the mean was used as an estimate of the number of increments. The daily formation of increments has not been validated for this species so data has been presented as an average number of rings. If increments are formed daily, spawn dates would be determined by subtracting the estimated age from the capture date. We propose to validate the daily formation of increments in carp gudgeon in the near future.

Ageing common carp

Common carp YOY were measured to the nearest millimetre and lapilli otoliths were removed. The same procedure to count the otolith increments was then followed as described for carp gudgeon. Increment counts were considered to represent true age of juvenile common carp (Vilizzi 1998) and spawn dates were determined by subtracting the estimated age from the capture date.

Figure 3: Typical deployment of VR2W receiver in a creek bed prior to inundation showing the concrete anchor and float.

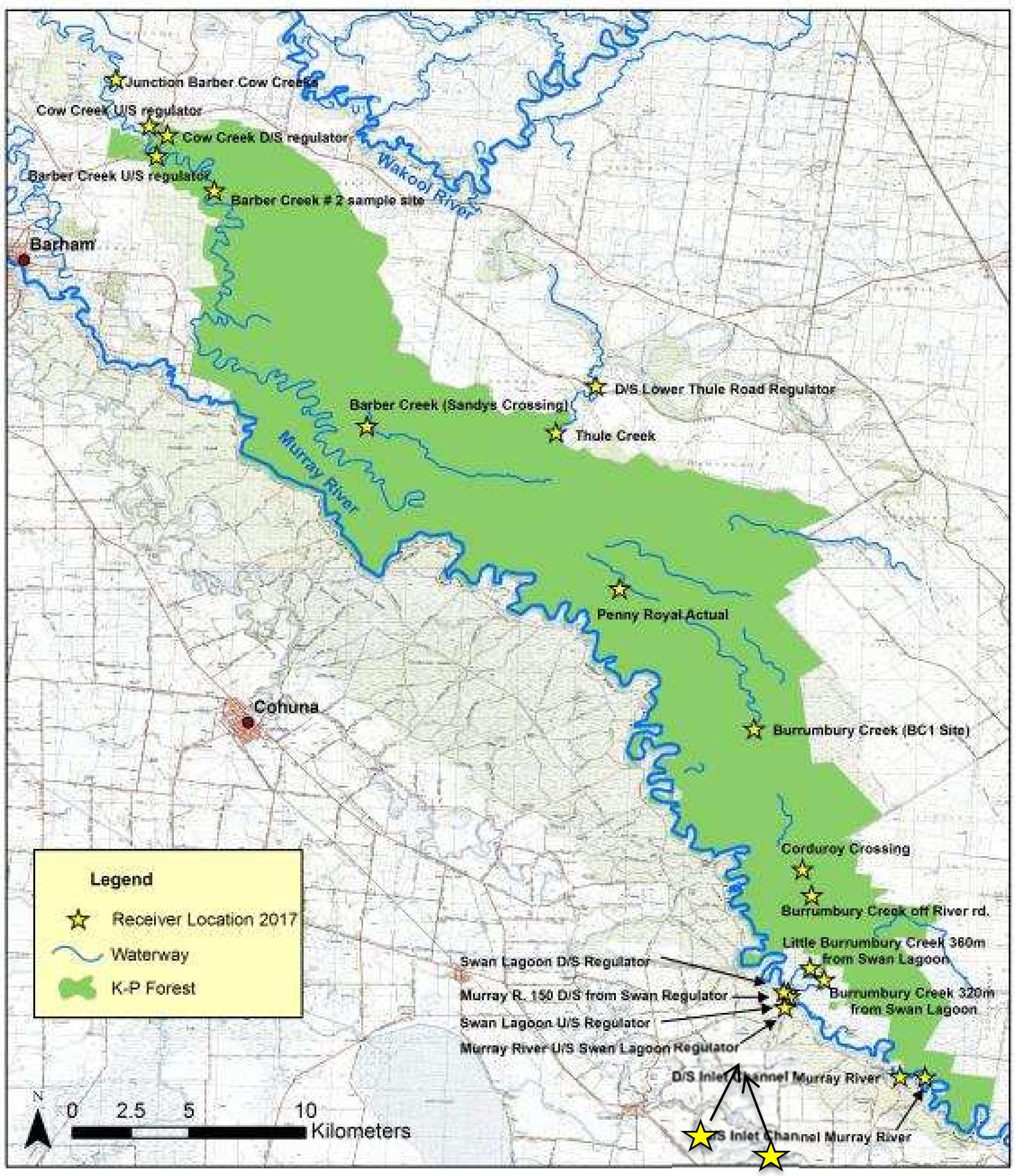


Figure 4: Location of acoustic telemetry receivers (yellow stars).

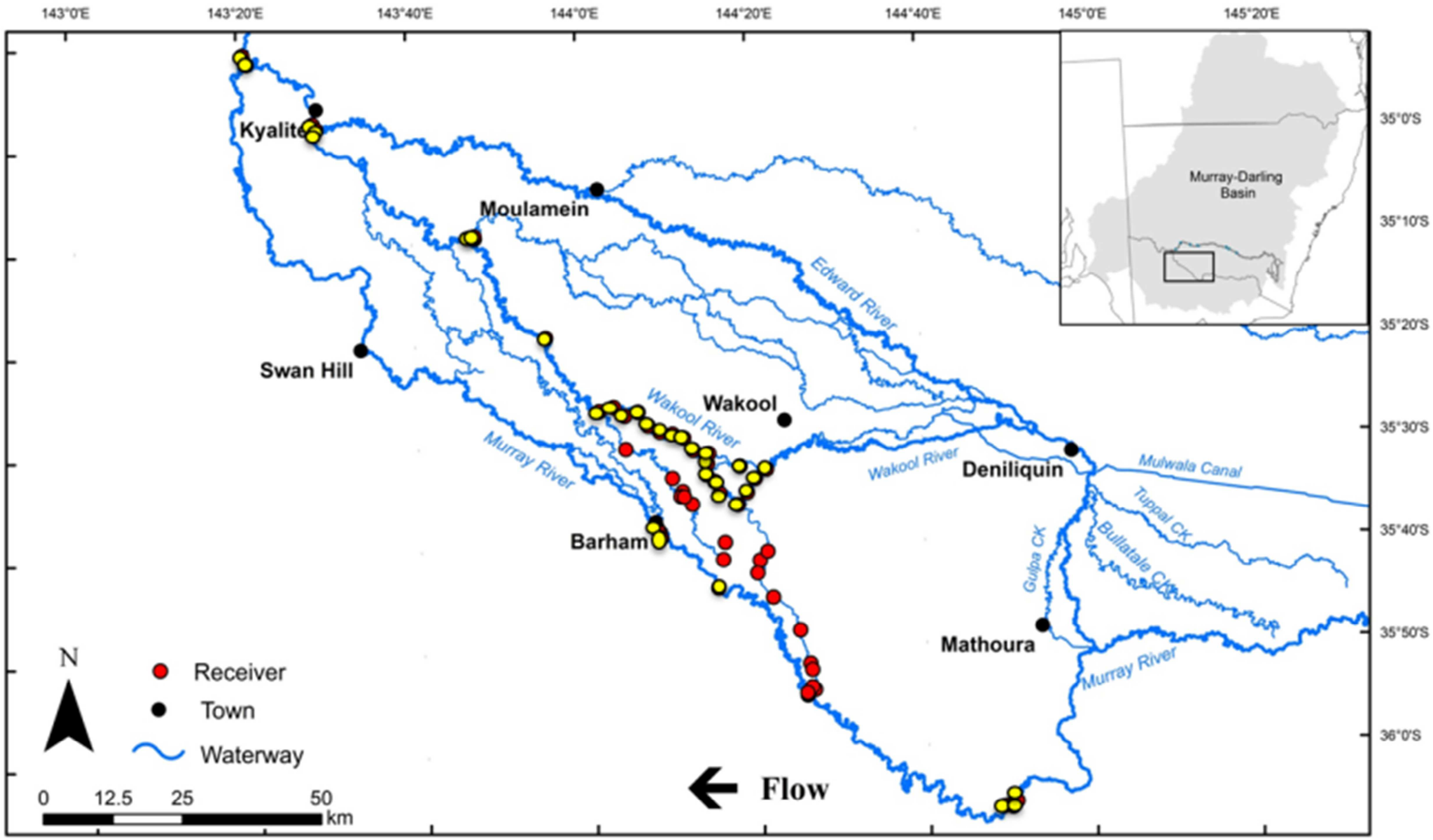


Figure 5: Location of acoustic telemetry receivers in Koondrook–Perricoota Forest (red dots) in and the surrounding region (yellow dots).

Results

Acoustic movements

Electrofishing at eight locations yielded twenty three golden perch, one silver perch, ten Murray cod and fifty four common carp that were suitable for acoustic tagging across 2014, 2016 and 2017 (Appendix 3). Of the 14 fish tagged in June 2014, no fish were detected on receivers in 2017/18. This could be due to either the batteries expiring on the transmitters, the death of the fish, the fish may not have moved beyond a receiver or it may have left the system undetected by a receiver. One golden perch tagged in 2016 and eleven tagged in 2017 were detected on the 2017 receivers and ten Murray cod tagged in 2017 were detected on acoustic receivers. Only two golden perch and one Murray cod moved into KPF, all via Swan Lagoon (Table 2, Figure 4). These fish were detected in Swan Lagoon, but did not proceed to the Burrumbury Creek receivers. One golden perch remained in Swan Lagoon for only a few minutes before leaving, the other stayed in Swan Lagoon for five hours before moving into the river. The Murray cod remained within Swan Lagoon for two days before exiting when the inflows had ceased. The final detection for the Murray cod and two golden perch was the Murray River in mid-June 2018 at their tagging location. Four native fish tagged at the Murray River inlet channel travelled downstream through Torrumbarry weir fishway and were detected by the Murray River receivers adjacent to Swan Lagoon (three Murray cod and one golden perch), whilst the remaining native fish stayed at their tagging locations.

Six common carp were detected moving into the forest via the Swan Lagoon regulators in 2017. All six fish were detected further into the forest past the Burrumbury Creek receivers located close to Swan Lagoon with three fish detected as far as Corduroy Crossing and Burrumbury Creek (BC1) receiver (Figure 4). Three fish weren't detected leaving the forest and are either still inside in the forest (dead or alive) or they left the forest without being detected, possibly via the Thule Cutting into the Murray River (Linda Broekman, pers comm.). Eight common carp were detected moving throughout the Edward-Wakool and Murray River acoustic array (Appendix 2, Figure 5).

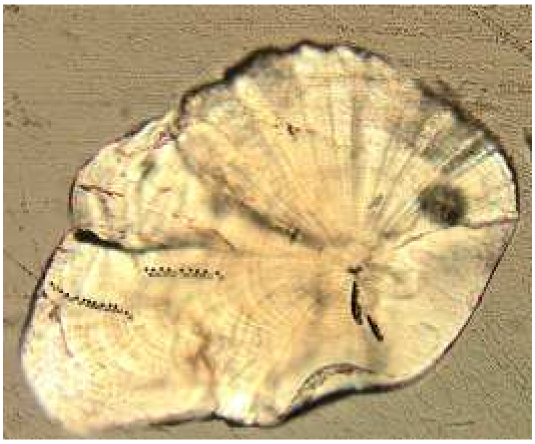
Table 2: Carp, golden perch and Murray cod movement summary for individuals entering Koondrook Perricoota Forest (only individuals with tag detections are presented).

Species	Transmitter	Tagging location (year)	Movement pattern	Final detection	Date of final detection
Common carp	A69-1601-27464	Thule Creek (2016)	Moved between Murray River into Swan Lagoon and Corduroy Crossing	Burrumbury Creek (BC1 Site)	13/12/17
Common carp	A69-1601-27523	Swan Lagoon Upstream Regulator (2016)	Moved between tagging location and the Murray River	Murray River	12/06/18
Common carp	A69-1601-27525	Barber Creek (2016)	Moved between Murray River into Swan Lagoon and Corduroy Crossing	Murray River	12/12/17
Common carp	A69-1601-27529	Barber Creek (2016)	Moved between Murray River into Swan Lagoon and Corduroy Crossing	Murray River	13/12/17
Common carp	A69-1602-2052	Murray River (2017)	Moved between Murray River into Swan Lagoon and Burrumbury Creek	Murray River	19/12/17
Common carp	A69-1602-2055	Murray River (2017)	Moved between Murray River into Swan Lagoon and Burrumbury Creek	Little Burrumbury Creek	15/12/17
Golden perch	A69-1602-2050	Murray River (2017)	Moved between Murray River into Swan Lagoon	Murray River	12/06/18
Golden perch	A69-1602-2059	Murray River (2017)	Moved between Murray River into Swan Lagoon	Murray River	11/12/17
Murray Cod	A69-1602-2053	Murray River (2017)	Moved between Murray River into Swan Lagoon	Murray River	11/06/18

Otolith ageing

Thirty common carp, 35 carp gudgeon and a single silver perch were aged by two individuals by counting daily increments (Figure 6a and 6b). The daily age of six common carp and four carp gudgeon varied by more than 10% and were excluded from the analysis. Twenty two common carp and seven carp gudgeon hatched either during or prior to the flooding and were therefore either spawned within KPF, or entered the forest with floodwaters (Tables 3 and 4). The single silver perch hatched prior to the flooding so could also have been the result of a spawning outside or inside KPF. All remaining fish (two carp and 24 carp gudgeon) hatched after the flood and were considered to have been the result of spawnings within KPF (Tables 3 and 4).

a)



b)

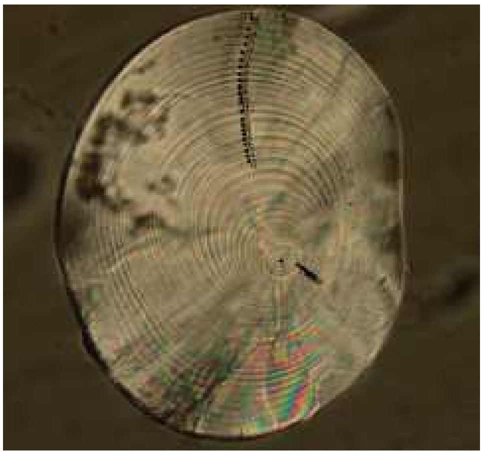


Figure 6a. Daily aged common carp with increment counts caught at Corduroy Crossing – estimated age 50 days old and b, carp gudgeon with increment counts caught at River Road No.2 – estimated age 35 days old.

Table 3. Young-of-year carp gudgeon and silver perch results for otolith daily ageing

Fish ID	Species	Date of Collection	Length FL (mm)	Length TL (mm)	Age (days)	Date of hatch
BIDS1_KPF_2018	Silver Perch	24/01/2018	34	36	52	3/12/2017
HYP2_KPF_2018	Carp Gudgeon	24/01/2018		20	58	27/11/2017
HYP4_KPF_2018	Carp Gudgeon	24/01/2018		18	48	7/12/2017
HYP5_KPF_2018	Carp Gudgeon	24/01/2018		16	35	20/12/2017
HYP7_KPF_2018	Carp Gudgeon	24/01/2018		17	37	18/12/2017
HYP8_KPF_2018	Carp Gudgeon	24/01/2018		16	37	18/12/2017
HYP9_KPF_2018	Carp Gudgeon	24/01/2018		18	44	11/12/2017
HYP10_KPF_2018	Carp Gudgeon	24/01/2018		19	47	8/12/2017
HYP11_KPF_2018	Carp Gudgeon	24/01/2018		18	36	19/12/2017
HYP13_KPF_2018	Carp Gudgeon	24/01/2018		16	32	23/12/2017
HYP14_KPF_2018	Carp Gudgeon	24/01/2018		18	44	11/12/2017
HYP15_KPF_2018	Carp Gudgeon	5/02/2018		23	51	16/12/2017
HYP17_KPF_2018	Carp Gudgeon	5/02/2018		21	59	8/12/2017
HYP18_KPF_2018	Carp Gudgeon	8/02/2018		18	62	8/12/2017
HYP19_KPF_2018	Carp Gudgeon	24/01/2018		15	30	25/12/2017
HYP20_KPF_2018	Carp Gudgeon	24/01/2018		17	36	19/12/2017
HYP21_KPF_2018	Carp Gudgeon	24/01/2018		19	38	17/12/2017
HYP22_KPF_2018	Carp Gudgeon	24/01/2018		19	32	23/12/2017
HYP23_KPF_2018	Carp Gudgeon	24/01/2018		20	32	23/12/2017
HYP24_KPF_2018	Carp Gudgeon	24/01/2018		21	37	18/12/2017

Table 4. Young-of-year common carp results for otolith daily ageing

Fish ID	Species	Date of Collection	Length FL (mm)	Age (days)	Date of Hatch
CYP4_KPF_2018	Common carp	24/01/2018	21	64	21/11/2017
CYP5_KPF_2018	Common carp	24/01/2018	20	68	17/11/2017
CYP6_KPF_2018	Common carp	24/01/2018	18	46	9/12/2017
CYP7_KPF_2018	Common carp	24/01/2018	21	64	21/11/2017
CYP8_KPF_2018	Common carp	24/01/2018	3	57	28/11/2017
CYP9_KPF_2018	Common carp	24/01/2018	24	50	5/12/2017
CYP10_KPF_2018	Common carp	24/01/2018	21	49	6/12/2017
CYP11_KPF_2018	Common carp	24/01/2018	20	41	14/12/2017
CYP13_KPF_2018	Common carp	24/01/2018	2	57	28/11/2017
CYP14_KPF_2018	Common carp	24/01/2018	23	65	20/11/2017
CYP16_KPF_2018	Common carp	24/01/2018	22	84	1/11/2017
CYP17_KPF_2018	Common carp	7/02/2018	25	61	8/12/2017
CYP18_KPF_2018	Common carp	7/02/2018	20	44	25/12/2017
CYP20_KPF_2018	Common carp	7/02/2018	21	75	24/11/2017
CYPS21_KPF_2018	Common carp	7/02/2018	19	79	20/11/2017
CYP22_KPF_2018	Common carp	7/02/2018	20	62	7/12/2017
CYP23_KPF_2018	Common carp	7/02/2018	23	73	26/11/2017
CYPS25_KPF_2018	Common carp	7/02/2018	16	69	30/11/2017
CYP27_KPF_2018	Common carp	7/02/2018	18	58	11/12/2017
CYP28_KPF_2018	Common carp	7/02/2018	21	66	3/12/2017
CYP29_KPF_2018	Common carp	7/02/2018	25	92	7/11/2017
CYP30_KPF_2018	Common carp	7/02/2018	26	66	3/12/2017
CYP31_KPF_2018	Common carp	7/02/2018	19	64	5/12/2017

Discussion

Higher Murray River flow in December 2017 resulted in approximately one week of inflows into KPF. This provided an opportunity for monitoring the movements of large-bodied fish in response to this flow. In addition, follow-up sampling of YOY common carp and carp gudgeon enabled an assessment of whether these species successfully spawned in KPF following the flood.

Acoustic tagging results showed two golden perch and one Murray cod tagged outside KPF moved into Swan Lagoon, but did not move further into the forest and none remained in the lagoon at the completion of inflows. These results are consistent with the movements recorded after the 2016 flood – which was of much greater volume and duration – where no native species moved into KPF beyond Swan Lagoon. However, for the first time in eight years of consecutive autumn condition monitoring on the KPF floodplain a single golden perch and a single silver perch YOY were sampled in KPF (Duncan *et al.* 2018). Only two adult natives have been sampled within KPF proper (not

Swan Lagoon or Lock Lagoon that are connected to the Murray River). While the combined data appears to show convincing evidence golden perch may not utilise KPF substantially at any life stage under current conditions, this may not be the case. The almost complete lack of YOY and adult fish could potentially be explained by these fish leaving the floodplain prior to connectivity with the Murray River being lost to avoid becoming stranded. It is important that golden perch and other native large-bodied fish continue to be considered when operating the regulators during future events. This will involve monitoring of fish accumulations at Barber Creek Regulator (if it is not fully open) and fishway trapping.

In contrast, common carp took advantage of the brief connectivity of the Murray River to KPF with six individuals moving into KPF. Three individuals stayed within KPF, possibly to spawn given that some of the YOY collected hatched soon after the flow flood concluded. Previous work has demonstrated that common carp tend to move upstream or downstream to suitable wetland habitats for spawning (Crook *et al.* 2013; Jones & Stuart 2009; Stuart & Jones 2006) and this is consistent with results that from the 2016 natural flood in KPF (Duncan *et al.* 2017a).

Following the inflows into KPF in December 2017 there was no subsequent connectivity to the Murray River. Consequently, if the estimated date of hatch of a fish was after the inflows ceased, then that individual was clearly the result of a spawning event within KPF. Daily ageing estimates determined that only two YOY common carp had a date of hatch after the flooding and were therefore confirmed to have been the result of a spawning within KPF. This contrasts to results following the 2014 winter-spring managed event where the date of hatch of the smallest YOY common carp was commonly in mid to late December and early January (Duncan *et al.* 2015). It is possible that the smaller area of inundation in 2017 compared to 2014 resulted in less suitable common carp spawning habitat and consequently reduced summer spawning activity. Alternatively a sudden drop in both the minimum overnight and day temperatures immediately after the rain event that resulted in the flood (Dind 2018) may have been a factor in reduced common carp spawning in December. In contrast, the majority of YOY carp gudgeon collected hatched after the completion of inflows, thus carp gudgeon successfully spawned and recruited within KPF following the flooding. Carp gudgeon are a generalist species – they are tolerant of a broad range of conditions and are capable of spawning and recruiting in isolated waterbodies (Gilligan *et al.* 2009). It would be useful to extend the ageing work to other species found in KPF that are not quite as abundant including Australian smelt (*Retropinna semoni*), Murray–Darling rainbowfish (*Melanotaenia fluviatlis*) and flathead gudgeon (*Philypnodon grandiceps*). This would then provide additional evidence of the value of flooding KPF to small-bodied native species.

Conclusion

The data presented here reiterate previous findings that large-bodied native fish do not substantially utilise KPF under current conditions. It is still not clear whether these native species may utilise KPF to a greater extent than detected by the current study and other related work. Nevertheless, striving to achieve a regular flow through the forest with as natural hydrograph as possible (i.e. allowing the water to pass through regulators unhindered rather than retaining the water in the forest) will provide the best opportunity to create suitable conditions for golden perch and other native fish species both within and downstream of the forest. We recommend that the acoustic tagging component of this research be repeated when there is a natural or managed flow of long duration that is passed unhindered into Barber Creek, Thule Creek and/or the return channel. If the results show large-bodied native species are still not substantially utilising KPF, then that would be considered as reasonable evidence to manage the forest primarily for small-bodied native species. This may open up new opportunities to trial the forest as a release location for threatened species such as southern pygmy perch given the infrastructure is available for providing a constant supply of water and common carp can potentially be excluded using screens (see below).

Acoustic monitoring of common carp during the 2017 natural flood at KPF provided further data that demonstrates that common carp will take any opportunity to move into the forest and that they will successfully spawn (albeit in small numbers on this occasion) and recruit to YOY stage in the forest. To minimise the number of YOY fish that are produced in KPF, it is recommended that the feasibility of common carp exclusion screens be investigated for all regulators where this species could enter the forest during both managed and natural events (Hillyard *et al.* 2010). While this will also prevent large-bodied native fish from entering, the evidence collected so far suggests these species rarely enter KPF. Thus the benefits to the small-bodied native fish community of excluding common carp may outweigh the risk of excluding the occasional large-bodied fish that may seek to enter KPF.

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Appendices

Appendix 1: Acoustic receiver locations and site status (water or no water) at the time of deployment.

Receiver No.	Location name	Stream	Latitude	Longitude
100723	Thule Creek	Thule Creek	-35.696290	144.338620
100726	Cow Creek U/S regulator	Cow Creek	-35.581460	144.188780
106958	Barber Creek U/S regulator	Barber Creek	-35.589380	144.184630
107536	Corduroy crossing	Burrumbury Creek	-35.865020	144.433850
109601[1]	McMahons Waterhole	McMahons Creek	-35.665630	144.270130
110478	Barber Creek Sandy Bridge	Barber Creek	-35.510940	144.078000
110481	Barber Creek # 2 sample site	Barber Creek	-35.602750	144.206920
110499	Burrumbury Creek (BC1 Site)	Burrumbury Creek	-35.810730	144.415230
110513	Burrumbury Creek 320m from Swan Lagoon	Burrumbury Creek	-35.907610	144.442170
110735	Swan Lagoon D/S Regulator	Swan Lagoon	-35.912680	144.428270
112154	Murray R. 260m U/S from Swan Regulator	Murray River	-35.916580	144.426850
112162[2]	Myloc Creek (Boysons)	Myloc Creek	-35.716620	144.333310
112172	Penny Royal Actual		-35.756590	144.363160
112180	D/S Lower Thule Road Regulator	Thule Creek	-35.405574	144.211558
112183	Burrumbury Creek off River rd.	Burrumbury Creek	-35.875020	144.437360
112729	Junction Barber Cow creeks	Barber Creek	-35.559700	144.168910
112732	Swan Lagoon U/S Regulator	Murray River	-35.914280	144.428700
115413	Little Burrumbury Creek 360m from Swan Lagoon	Little Burrumbury Creek	-35.903080	144.436720
115416	Barber Creek (Sandys Crossing)	Barber Creek	-35.693820	144.265870
115419[3]	Barber Creek #1	Barber Creek	-35.590190	144.191270
115426	Murray R. 150 D/S from Swan Regulator	Murray River	-35.912360	144.426470

[1] Relocated to Murray River – (U/S Inlet Channel Murray River -35.9452 144.48111)
[2] Relocated to Murray (D/S Inlet Channel Murray River – 35.94504 144.4715)
[3] Relocated to Murray (U/S Swan Lagoon Regulator Murray River -35.91832 144.42699)

Appendix 2. Carp, movement summary detected (only individuals with tag detections are presented).

Species	Transmitter	Tagging location (year)	Movement pattern	Final detection	Date of final detection
Carp	A69-1601-27467	Thule Creek (2016)	Moved between Cadell and Fashams (Wakool River)	Fashams (Wakool River)	18/05/18
Carp	A69-1601-27532	Barber Creek (2016)	Moved between Barham and Swan Hill U/S (Murray River)	Barham U/S Murray River	29/09/17
Carp	A69-1601-27537	Barber Creek (2016)	Moved between Murray River U/S Inlet Channel Barham U/S	Murray River	22/12/17
Carp	A69-1601-27540	Barber Creek (2016)	Moved between Murray River Barham and U/S Swan Lagoon Regulator (Murray River)	Murray River	03/12/17
Carp	A69-1601-27544	Barber Creek (2016)	Moved between Murray River Barham and U/S Inlet Channel (Murray River)	Murray River	06/01/17
Carp	A69-1602-2057	Murray River (2017)	Moved between Murray River Swan Hill D/S (Murray River)	Murray River	05/01/18
Carp	A69-1602-2060	Murray River (2017)	Moved between Murray River and Murray Wakool Junction	Murray River	25/11/17
Carp	A69-1602-2061	Murray River	Moved between Murray River and Murray Wakool Junction	Murray River	09/10/17

Appendix 3. **Fish tagged in August 2016, June 2014 and August 2017 their sex (if it could be determined), location and transmitter number.**

2014								
24/06/2014	Golden perch	455	F	Barber Creek	Sandy Bridge	-35.5082	144.0833	A69-1601-27446
24/06/2014	Golden perch	430	F	Barber Creek	Sandy Bridge	-35.5082	144.0833	A69-1601-27447
25/06/2014	Golden perch	403	M	Barber Creek	Craiglands	-35.5082	144.0833	A69-1601-27448
25/06/2014	Golden perch	410	M	Barber Creek	Craiglands	-35.5082	144.0772	A69-1601-27450
25/06/2014	Golden perch	409	F	Barber Creek	Craiglands	-35.5082	144.0772	A69-1601-27451
26/06/2014	Golden perch	486	F	Barber Creek	Sandy Bridge	-35.5082	144.0833	A69-1601-27453
26/06/2014	Golden perch	421	M	Barber Creek	Sandy Bridge	-35.5082	144.0833	A69-1601-27454
26/06/2014	Golden perch	380		Barber Creek	Sandy Bridge	-35.5082	144.0833	A69-1601-27455
25/06/2014	Common carp	469	M	Barber Creek	Craiglands	-35.5082	144.0772	A69-1601-27449
25/06/2014	Common carp	500	M	Barber Creek	Craiglands	-35.5082	144.0772	A69-1601-27452
24/06/2014	Common carp	647	F	Barber Creek	Sandy Bridge	-35.5082	144.0833	A69-1601-27442
24/06/2014	Common carp	609	F	Barber Creek	Sandy Bridge	-35.5082	144.0833	A69-1601-27443
24/06/2014	Common carp	455	M	Barber Creek	Sandy Bridge	-35.5082	144.0833	A69-1601-27444
24/06/2014	Common carp	593	M	Barber Creek	Sandy Bridge	-35.5082	144.0833	A69-1601-27445
2016								

10/08/2016	Golden perch	490	F	Burrumbury Creek	Burrumbury Creek exiting Swan L.	-35.9076	144.4422	A69-1601-27461
23/08/2016	Golden perch	485	F	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27462
24/08/2016	Golden perch	387	M	Barber Creek	MacDonalds	-35.4992	144.0657	A69-1601-27538
24/08/2016	Golden perch	479	F	Barber Creek	MacDonalds	-35.4992	144.0657	A69-1601-27539
23/08/2016	Silver perch	374	M	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27524
11/08/2016	Common carp	422	M	Barber Creek	Sandy Bridge	-35.5115	144.0839	A69-1601-27456
11/08/2016	Common carp	491	M	Barber Creek	Sandy Bridge	-35.5115	144.0839	A69-1601-27457
11/08/2016	Common carp	380		Barber Creek	Sandy Bridge	-35.5115	144.0839	A69-1601-27458
11/08/2016	Common carp	405	M	Barber Creek	Sandy Bridge	-35.5115	144.0839	A69-1601-27459
11/08/2016	Common carp	491	M	Barber Creek	Sandy Bridge	-35.5115	144.0839	A69-1601-27460
12/08/2016	Common carp	557	M	Thule Creek	Lower Thule Road bridge	-35.6783	144.3541	A69-1601-27463
12/08/2016	Common carp	310		Thule Creek	Lower Thule Road bridge	-35.6783	144.3541	A69-1601-27464
12/08/2016	Common carp	435	F	Thule Creek	Lower Thule Road bridge	-35.6783	144.3541	A69-1601-27465
10/08/2016	Common carp	526	F	Thule Creek	Deni Road bridge	-35.6085	144.3053	A69-1601-27467
10/08/2016	Common carp	390		Thule Creek	Deni Road bridge	-35.6085	144.3053	A69-1601-27468
10/08/2016	Common carp	450	M	Thule Creek	Deni Road bridge	-35.6085	144.3053	A69-1601-27469

10/08/2016	Common carp	464		Thule Creek	Deni Road bridge	-35.6085	144.3053	A69-1601-27470
10/08/2016	Common carp	405	M	Swan Lagoon	Swan L. below U/S reg.	-35.9143	144.4287	A69-1601-27523
23/08/2016	Common carp	515	M	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27525
23/08/2016	Common carp	382	M	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27526
23/08/2016	Common carp	485		Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27527
23/08/2016	Common carp	475		Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27528
23/08/2016	Common carp	436	F	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27529
23/08/2016	Common carp	410	F	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27530
23/08/2016	Common carp	388	M	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27531
23/08/2016	Common carp	425	M	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27532
23/08/2016	Common carp	468		Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27533
23/08/2016	Common carp	376	F	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27534
23/08/2016	Common carp	429	M	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27535
23/08/2016	Common carp	425	F	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27536
24/08/2016	Common carp	478	F	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27537
23/08/2016	Common carp	401		Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27540
23/08/2016	Common carp	395	M	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27541

24/08/2016	Common carp	505	F	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27542
24/08/2016	Common carp	383	M	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27543
24/08/2016	Common carp	399	M	Barber Creek	Sandy Bridge	-35.5073	144.0784	A69-1601-27544
25/08/2016	Common carp	424	F	Barber Creek	Avocado farm	-35.5183	144.1001	A69-1601-27545
25/08/2016	Common carp	435		Barber Creek	Avocado farm	-35.5183	144.1001	A69-1601-27546
25/08/2016	Common carp	475	M	Barber Creek	Avocado farm	-35.5183	144.1001	A69-1601-27547
25/08/2016	Common carp	408	M	Barber Creek	Avocado farm	-35.5183	144.1001	A69-1601-27548
25/08/2016	Common carp	378		Barber Creek	Avocado farm	-35.5183	144.1001	A69-1601-27549
25/08/2016	Common carp	538	F	Barber Creek	Avocado farm	-35.5183	144.1001	A69-1601-27550
10/08/2016	Common carp	200	J	Burrumbury Creek	Burrumbury Creek exiting Swan L.	-35.9076	144.4422	A69-1601-37228
2017								
8/08/2017	Murray Cod	890		Murray River	Inlet Channel	-35.5642	144.2832	A69-1602-2046
8/08/2017	Golden perch	492		Murray River	Inlet Channel	-35.5642	144.2832	A69-1602-2045
8/08/2017	Golden perch	512		Murray River	Inlet Channel	-35.5642	144.2832	A69-1602-2044
8/08/2017	Golden perch	459	F	Murray River	Inlet Channel	-35.5642	144.2832	A69-1602-2043
8/08/2017	Golden perch	460		Murray River	Inlet Channel	-35.5642	144.2832	A69-1602-30182

8/08/2017	Golden perch	471		Murray River	Inlet Channel	-35.5642	144.2832	A69-1602-30180
8/08/2017	Common carp	462		Murray River	Inlet Channel	-35.5642	144.2832	A69-1602-30181
8/08/2017	Common carp	445	M	Murray River	Inlet Channel	-35.5642	144.2832	A69-1602-30179
8/08/2017	Common carp	549	F	Murray River	Inlet Channel	-35.5642	144.2832	A69-1602-30176
8/08/2017	Common carp	534	F	Murray River	Inlet Channel	-35.5642	144.2832	A69-1602-30177
8/08/2017	Common carp	550	F	Murray River	Inlet Channel	-35.5642	144.2832	A69-1602-30178
9/08/2017	Golden perch	470		Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-2056
9/08/2017	Golden perch	356		Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-2054
9/08/2017	Golden perch	445	F	Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-2050
9/08/2017	Golden perch	422	F	Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-2049
9/08/2017	Golden perch	434		Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-2051
9/08/2017	Golden perch	441	F	Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-2059
9/08/2017	Common carp	362		Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-2057
9/08/2017	Common carp	430		Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-2052
9/08/2017	Common carp	540	F	Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-2055
9/08/2017	Common carp	593	F	Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-2060

9/08/2017	Common carp	523	M	Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-2061
9/08/2017	Murray Cod	519		Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-2058
9/08/2017	Murray Cod	542		Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-2053
9/08/2017	Murray Cod	854	M	Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-30184
9/08/2017	Murray Cod	981	F	Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-30183
9/08/2017	Murray Cod	462	M	Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-2047
9/08/2017	Murray Cod	470	M	Murray River	Swan Lagoon	-35.5447	144.2534	A69-1602-2048
10/08/2017	Murray Cod	428		Murray River	Inlet Channel	-35.5642	144.2832	A69-1602-2063
10/08/2017	Murray Cod	497		Murray River	Inlet Channel	-35.5642	144.2832	A69-1602-2062
10/08/2017	Murray Cod	935	F	Murray River	Inlet Channel	-35.5642	144.2832	A69-1602-30185