Fish movement in the Lindsay River and Mullaroo Creek in response to flow changes through Lindsay Island

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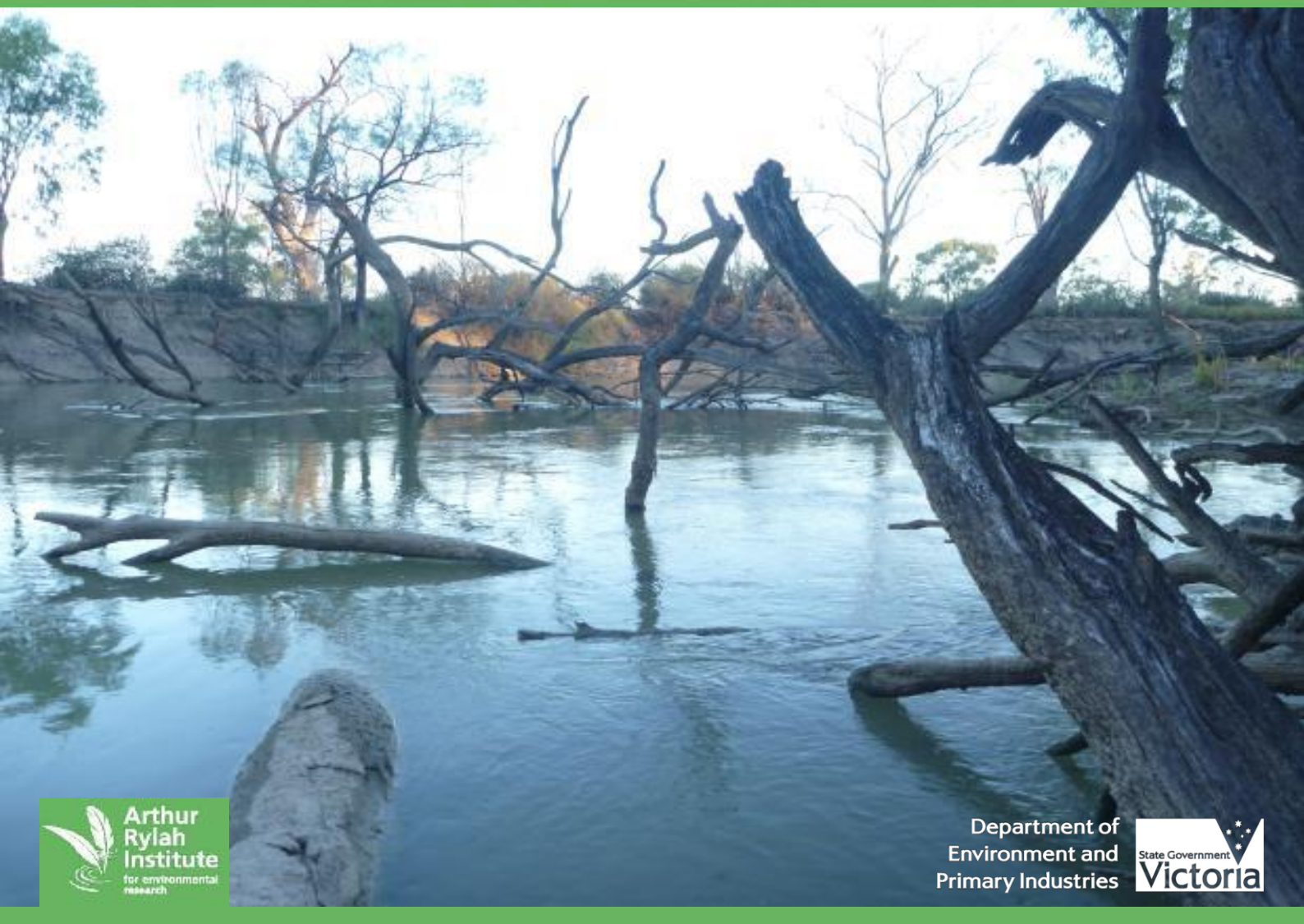

Arthur Rylah Institute for environmental research

Department of Environment and Primary Industries

State Government Victoria

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For the

Mallee Catchment Management Authority

In partnership with:

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Front cover photo: Mullaroo Creek, March 2014 (Photo: Scott Raymond, ARI)

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Executive summary

Regulation of the Murray River has negatively impacted the natural variability of hydrological regimes within the Mullaroo Creek/Lindsay River system through alterations to the frequency, duration and size of floodplain inundation (DSE 2010). The continued regulation of the Murray River poses a threat to the ecological integrity of the region including native fish populations. In an effort to mitigate this threat, the Murray-Darling Basin Authority, Victorian and South Australian state governments and the Mallee Catchment Management Authority have collaborated to construct a regulator on the upper Mullaroo Creek and Lower Lindsay River with the purpose of restoring natural flows and flooding.

Despite alterations to the systems flow regime, the region maintains numerous species and communities of conservation significance. Of particular note, is the importance of the upper Mullaroo Creek as a spawning area for Murray cod migrating from the Murray and Lindsay Rivers due to its unique hydrological regime and high density of instream habitat. Any flow modifications resulting from the operation of the new regulating structures must therefore, consider these important fish populations and their migration requirements in the system. This program establishes a tracking program to assess the movement of fish within the Lindsay River and Mullaroo Creek in response to flows and the operation of floodplain structures.

In March/April 2014, 80 large bodied-fish representing three native and one exotic species captured from the Mullaroo Creek and Lindsay River were fitted with radio transmitters (ranging in tag life from eight months to four years) to determine movement patterns. Transmitter fish included:

- 33 Murray cod
- 20 Freshwater catfish
- 21 Golden perch, and
- 6 European carp.

Five logger towers positioned throughout the Mullaroo Creek and Lindsay River system (used during previous movement studies) were restored to monitor the movement of tagged fish. This program is well positioned to monitor migration patterns and habitat use of fish under current and future water management of the system. Results will feed into management plans to address The Living Murray ecological objective to increase the abundance, diversity and distribution of native fish within the system.

Murray cod undergoing transmitter implant

Radio tower (receiver)

Native Freshwater catfish

Introduction

Lindsay Island and river regulation

Lindsay Island is part of the Chowilla-Lindsay-Wallpolla Icon Site, one of six icon sites identified under the Murray-Darling Basin Ministerial Council's The Living Murray initiative. Lindsay Island is situated within Murray Sunset National Park, which covers an area of 15,000 ha of floodplain to the south of the Murray River, between Lock 8 and Lock 6. Lindsay Island is listed in A Directory of Important Wetlands in Australia (Environment Australia 2001). The waterways, wetlands and floodplain provide refuge and resources for a range of flora and fauna, including threatened fish species, as well as important waterbird breeding habitat during flood events. The area also has high social and cultural significance.

River regulation is the key threatening process to the values of Lindsay Island, causing a reduction in the frequency, duration and size of floods and a reduction in the variability of natural hydrological regimes. This has negatively affected the health of riparian and wetland communities (Mallee CMA 2010). In order to meet the ecological objective of increasing abundance, diversity and distribution of native fish (MDBA 2010) (along with other objectives), The Living Murray initiative developed the Upper Lindsay Watercourse Enhancement project (DSE 2010). This project includes; lowering the sill in the southern Lindsay River, constructing regulators on the northern and southern Lindsay River inlets and replacing the degraded causeway in the Mullaroo Creek with a new regulator and fishway. A proposed regulator (Mullaroo Stage 2) on the lower Lindsay River outlet (upstream of the Lindsay and Murray rivers confluence) will further regulate hydrological regimes in the Lindsay/Mullaroo system.

The Mullaroo Creek regulator and fishway, together with the Lindsay River regulators are reported to 'increase the area and diversity of available aquatic habitat and contribute to the overall viability, abundance and extent of existing fish communities (Mallen-Cooper et al. 2010). However, there is also the potential for these (and future) regulators to restrict fish movement and alter the hydrological variability of the system. The impact of these regulators on fish is dependent on regulator operational procedures and movement dynamics and key life-history requirements of individual fish species. For example, creating flood conditions within the system may benefit Freshwater catfish as breeding grounds are increased but hinder the movement of Murray cod into the anabranch from downstream. Incorporation of ecological data to improve operational procedures will be an important component to facilitate future watering regimes within and through the Mullaroo Creek/Lindsay River system.

The upper Mullaroo Creek is an important refuge and breeding ground for a number of endangered native fish species, which are dependent on the systems unique hydraulic characteristics and high density of instream habitat (structural woody habitat) compared to sites within the lower Mullaroo Creek, Lindsay River and Murray River (Saddlier and O'Mahony 2009). In particular, Murray cod from surrounding reaches, including fish from both the Murray and Lindsay rivers showed a preference for the Mullaroo Creek during the spawning period (September to November) (Saddlier et al. 2008). Catch, length frequency, movement and habitat data show a Murray cod population with unique characteristics within the Murray-Darling Basin (Saddlier et al. 2009).

Changes to the hydraulics and flow regime within the Mullaroo Creek and Lindsay River system may alter existing migration and or habitat use of several fish species in the region (positively or negatively). As a result, a research program was initiated to assess migration and habitat use of fish within the Lindsay River and Mullaroo Creek in response to flows and the operation of floodplain structures. The program also has the ability to monitor other processes of interest to management, in particular the response of native 'sentinel fish' to threats such as blackwater events as well to investigate carp movements during and following flooding.

This report documents the establishment of a radio telemetry program on the Lindsay/Mullaroo system and sets a foundation for a longer-term investigation into the impacts of flow changes on the native fish community of the Lindsay River and Mullaroo Creek.

The 2014 program aims to:

- insert 80 radio-transmitters into three target native fish species and European carp
- record the response of 'transmitter fish' under varied flow conditions through the Lindsay River and Mullaroo Creek
- collect baseline data (including data obtained by Saddlier et al. 2009) to compare with future data following upgrades and operation of regulating structures.

In addition to the project aims this project provides the potential to:

- monitor 'sentinel fish' in response to blackwater events and flooding
- track European carp in response to floodplain inundation
- assess the timing of fish movement into, out of and through the Lindsay River system in response to environmental watering events

Methodology

Study location

The study was undertaken in Mullaroo Creek and the Lindsay River in north-western Victoria, approximately 450 km from Melbourne. These waterways form the Lindsay Island waterway system, an anabranch of the Murray River within the semi-arid Murray Sunset National Park. This anabranching system flows from upstream of Lock 7 in Victoria and re-enters the Murray River below Lock 7 in South Australia (Figure 1).

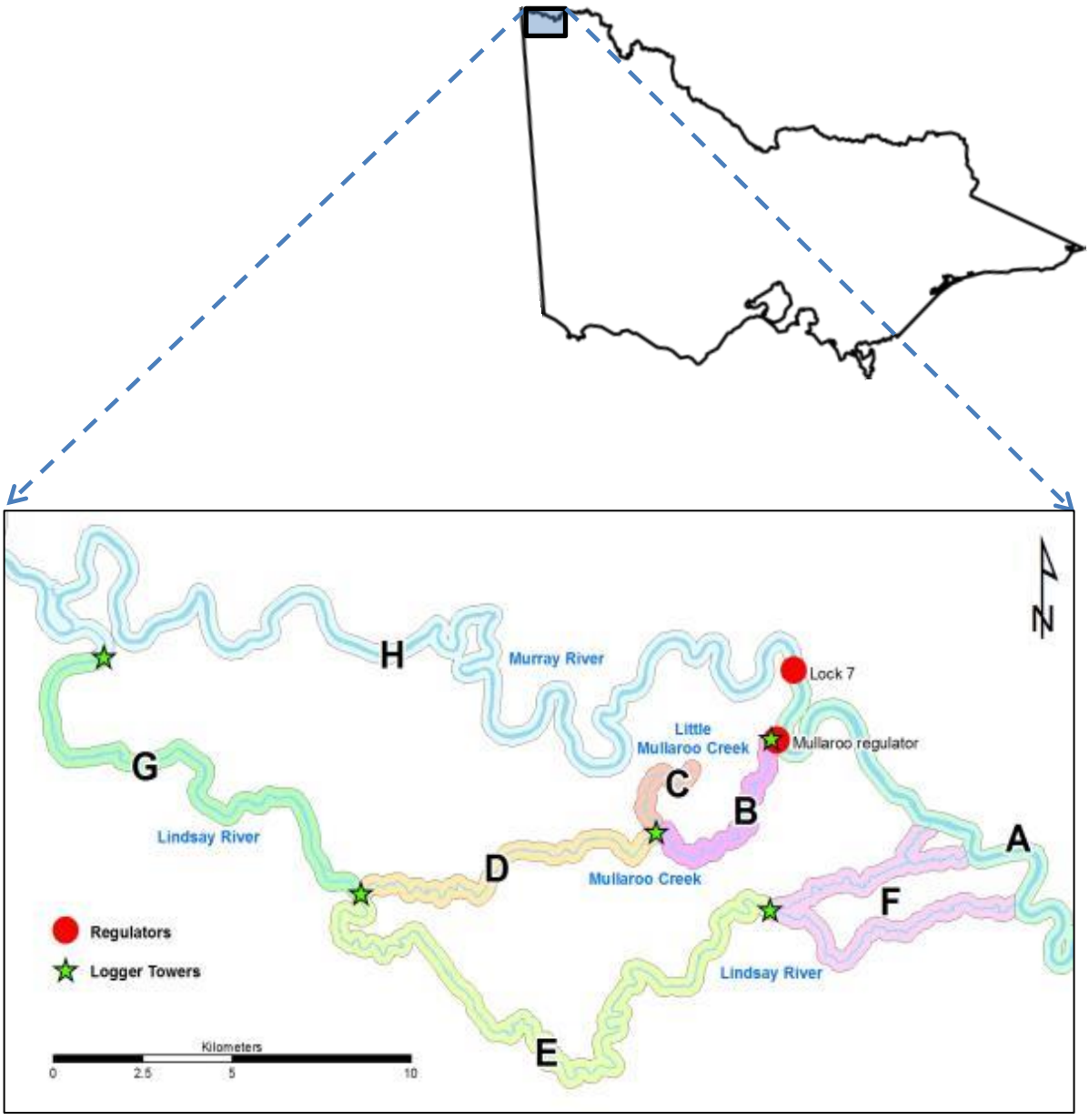


Figure 1. The Mullaroo Creek and Lindsay River study site. Green stars represent data logging stations and letters represent fish tagging and movement zones.

Target fish species

The iconic, large-bodied, native Murray cod is an endangered fish recorded to undertake annual upstream spawning migrations which can cover hundreds of kilometres. Once they have reached their spawning location, male and female cod exhibit paired courtship behaviour prior to egg laying and fertilization (Koehn and O'Connor 1990). Up to 2000,000 demersal adhesive eggs are deposited onto or within hollow logs, on other debris or within silt free nesting depressions on the river bed where they are immediately fertilized (Lake 1967; Cadwallader 1978; McDowell 1996; Koehn and O'Connor 1990; Rowland 1998). Most often, all eggs are released in one spawning event. Male Murray cod guard the eggs from predators and have been recorded to fan eggs, presumably as a means of reducing sediment deposition (Koehn and O'Connor 1990). Following egg hatching (6 to 10 days), larvae remain in groups until the yolk-sac is absorbed (McDowall 1996) then drift for 5-7 days (Humphries 2005). Following hatching, adult male Murray cod journey downstream to re-occupy their home range or territory (Koehn and O'Connor 1990). Murray cod spawning takes place in late Spring/early Summer and is associated with increasing water temperatures (Koehn and Harrington 2006).

Freshwater catfish, are a sedentary species that occupy small ranges (typically less than 300m), are not recorded to undertake spawning migrations (Davis 1975; Koster et al. 2010), have a preference for slow-moving waters and have restricted riverine populations within Victoria (Clunie and Koehn 2001). The species is listed as 'endangered' in Victoria, 'protected' in South Australia and as an 'endangered population' in the Murray-Darling Basin in New South Wales (Koster et al. 2010). Rising water temperatures (to 24^0C) induce spawning in this species and following courting behaviour, females lay demersal, non-adhesive eggs in a constructed 'nest' during October – March (Koehn and O'Connor 1990). The nest and eggs are attended (protected and fanned) by at least one adult until hatching takes place. River regulation, particularly flows and barriers to movement, are listed as processes likely to have played a key role in the decline of Freshwater catfish in the Murray-Darling Basin (Clunie and Koehn 2001). Sedimentation, competition with European carp and pesticides are also recorded threats to Freshwater catfish (Clunie and Koehn 2001).

Golden perch, are increasing flow and temperature induced, aggregate spawners reported to travel long distances to reach communal spawning grounds (Reynolds 1983; Koehn and O'Connor 1990; O'Connor et al. 2005; Koster et al. 2010). Under suitable conditions, spawning and fertilization of buoyant eggs occurs suddenly and collectively with eggs dispersed downstream (Lake 1967; King et al. 2005). Koster et al (2014) observed movement of Golden perch from the Goulburn River (tributary) into the Murray River during the spawning season, which in some years, coincided with the presence of Golden perch eggs/larvae in main-stem drift samples. Unlike Murray cod and Freshwater catfish, Golden perch do not exhibit parental care of eggs or young. Golden perch spawn from November to March.

European carp *Cyprinus carpio* migrate to suitable spawning grounds where they shed adhesive eggs over stream side and floodplain vegetation, with males fertilizing eggs as they fall. Development is rapid, with eggs hatching within two days at 25^0C (Koehn et al. 2000). Unlike our three native target species, European carp do not deposit their eggs at one time, indicating that each female may produce several batches of eggs (up to 1.5 million eggs in total) during a spawning season. Spawning in Australia has been reported to occur from September to December at temperatures as low as 13-14^0C (Koehn et al 2000).

Fish sampling

Sampling of Murray cod, Freshwater catfish and Golden perch focused on the upper reaches (zone B, Figure 1) of the Mullaroo Creek as previous studies showed this section contained the highest

abundances of native fish (Saddlier et al. 2008; Saddlier and O'Mahony 2009). The upper Lindsay River was targeted for European carp, due to larger individuals suitable for transmitter implantation being observed. Fish sampling was conducted in April/May 2014.

A Smith-Root 7.5 GPP boat-mounted electrofisher (settings: 500-1000 volts, 38 Hz, pulse DC) was used to capture fish for radio-transmitter implantation. The sampling strategy involved targeting habitat likely to support native fish. This involved sampling large woody debris such as fallen trees, logs and snag piles. When the electrofisher was within effective range (2–3 metres from target habitat) direct current was applied into the water to attract and over-ride the fishes' sensory system, resulting in the fish becoming temporarily stunned. Stunned fish were netted and transferred to a flow-through enclosed tank system on the vessel. Angling was also used to capture target fish species.

Fish tagging

Following capture, each fish was marked with an external identification tag (T-bar or Dart) adjacent to the dorsal fin (Figure 2). These tags display a telephone number for the reporting of fish capture data, which is incorporated into a fish database (Victorian fish tagging database; Arthur Rylah Institute). Each fish was also implanted with a PIT (passive integrated transponder) tag. These tags have an individual code which is read as fish pass PIT reading stations. PIT tag readers have been installed on most Locks along the Murray River to record fish movement data.

Figure 2. Golden perch showing position of external Dart tag

Radio-transmitters

Surgical procedures used to implant fish radio-transmitters follow those outlined in O'Connor et al. (2009). Fish were sedated with Aqui-S at a concentration of 1.5 ml per 50 litres of water in which they were immersed. After fish were adequately sedated (lack of observed movement) they were placed upside-down on an operating bench. Anaesthetic solution was poured directly over the gills to ensure fish remained sedated during surgery. Prior to incision, the underside of the fish was bathed with diluted (0.9% saline solution) Betadine solution to ensure the area was adequately sterile. A small incision (approximately one inch long) was made through the body wall on the lower left ventral side (parallel with the digestive tract) and the transmitter inserted into the body cavity of the fish. Transmitter size (7, 14, 23 or 56 g [Figure 3]) was determined as a proportion (<2%) of total fish body weight (Table 1). Once inserted, the transmitter was positioned so that the

external aerial could be passed through the body wall approximately 3–7 cm posterior of the incision, depending upon the size of the fish. Once the transmitter was positioned, the incision was again bathed in Betadine solution before internal sutures were used to close the body wall. External sutures were used to close the outer incision and the entire area bathed with Betadine solution before the fish was returned to an aerated recovery tank containing a 10 g/L salt solution to prevent infection. Careful observation of each fish was made to ensure it was able to maintain an upright swimming position prior to release into the same area from which it was captured. A pictorial flow chart outlining the sequence of events involved in radio-transmitter implantation is shown in Figure 4. Transmitters operated on 150 MHz and were manufactured by Advanced Telemetry Systems.

Table 1. Radio transmitter weight, minimum weight of fish and battery life of transmitters.

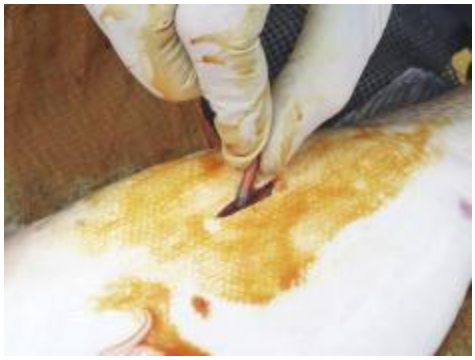
Transmitter weight (g)	Minimum fish weight-2% (g)	Radio Battery life (days)
7	350	245
14	700	528
23	1150	1142
56	2800	1460

Figure 3. Radio transmitters

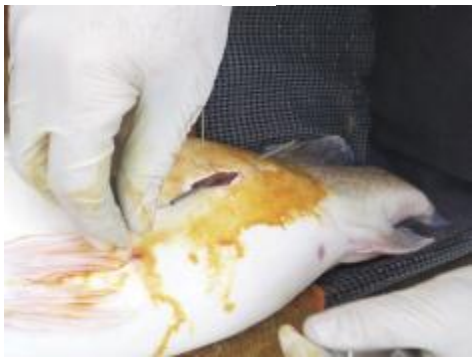
Fish holding tanks and surgey bench on boats

Incision in fish

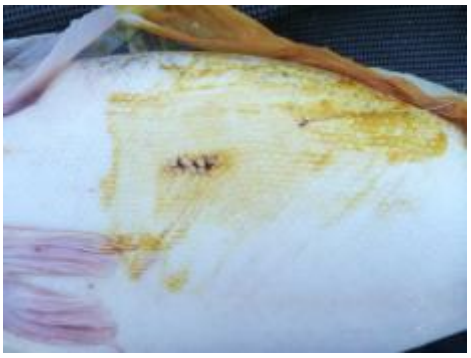
Insertion of transmitter



Insertion of PIT tag



Inserting transmitter antenna



Suturing of incision

Releasing cod at capture site

Figure 4.Pictorial sequence for implanting PIT tag and radio-transmitter into Murray cod

Data loggers

Five data logging stations (Figure 5) were installed at strategic locations along the Mullaroo Creek and Lindsay River study site (Figure 1, Table 2). This repeated the array of Saddlier and O'Mahony (2009), with an additional logging station erected at a fork in the Upper Lindsay River. The data loggers receive radio signals (via antennae) from transmitters up to 300 metres away. As the antennas are directional (i.e. an antenna picks up its strongest signal when pointed directly at the transmitter), each antenna receives and records a signal of different strength. The antennas are positioned in either an upstream or downstream direction on the river/creek, and if a tributary exists, a third antenna is directed towards the inflowing tributary. Because signal strength and detection time are recorded for each antenna, the position and direction of movement for each fish within the range of the logger can be determined.

Figure 5. Upper Mullaroo data logger, showing logger box, solar panel and antennae.

Table 2. Mullaroo Creek and Lindsay River data logger locations, 2014

Logger	Location	GPS (Map-East-North)
1	Junction of upstream end of Mullaroo Ck. And Murray R.	54-522014-6228484
2	Confluence of Mullaroo Ck. and Little Mullaroo Ck.	54-518797-6225985
3	Confluence of Mullaroo Ck. and Lindsay R.	54-510551-6224342
4	Lindsay R. just upstream of confluence with Murray R.	54-503379-6230655
5	Upper Lindsay R. where river divides in two	54-521983-6223892

As data loggers are subject to theft and vandalism, recording equipment was housed in 8 mm thick steel plate boxes set on 4 m poles secured into the ground with concrete. Ventilation holes and shade cloth were provided to protect the equipment from high summer temperatures. An articulated pole was hinged off the back plate of the logger box for ease of installing and maintaining antennae.

Each four-element Yagi antenna (supplied by Advanced Telemetry Systems) was attached by a

1.5 m coaxial cable to a three-way switch box (supplied by Advanced Telemetry Systems). A 40 W solar panel was attached to the roof or the antenna pole and connected to a 12 volt, 100 amp hour lead-acid battery via a regulator. The data logger was connected to the battery to allow continuous, uninterrupted power to the unit.

Results

A total of 80 fish were implanted with radio transmitters during the preliminary survey: 33 adult Murray cod, ranging in size from 519 – 1210 mm total length (TL mm); 20 freshwater catfish ranging in size from 348 – 520 mm total length; 21 golden perch ranging in size from 310 – 493 mm total length; and 6 European carp ranging in size from 440 – 640 mm fork length (Tables 2, 3, 4 and 5).

Table 3. Size and tag details of Murray cod implanted with radio telemetry tags in Mullaroo Creek and Lindsay River April/May, 2014.

Common name	Scientific name	Capture Zone	Length (mm)	Weight (g)	External Tag No.
Murray cod	*Maccullochella peelii*	d	519	1908	129170
Murray cod	*Maccullochella peelii*	b	527	2100	21058
Murray cod	*Maccullochella peelii*	b	550	2700	21059
Murray cod	*Maccullochella peelii*	b	579	2826	128645
Murray cod	*Maccullochella peelii*	b	588	3130	21056
Murray cod	*Maccullochella peelii*	b	611	3408	129168
Murray cod	*Maccullochella peelii*	b	625	3542	129179
Murray cod	*Maccullochella peelii*	b	637	3940	129186
Murray cod	*Maccullochella peelii*	b	640	4100	123543
Murray cod	*Maccullochella peelii*	b	640	4256	21057
Murray cod	*Maccullochella peelii*	d	660	5190	129176
Murray cod	*Maccullochella peelii*	d	680	5150	129189
Murray cod	*Maccullochella peelii*	d	720	5976	128639
Murray cod	*Maccullochella peelii*	b	760	8200	128643
Murray cod	*Maccullochella peelii*	d	815	10400	128638
Murray cod	*Maccullochella peelii*	b	825	9000	21075
Murray cod	*Maccullochella peelii*	b	835	11000	21060
Murray cod	*Maccullochella peelii*	b	835	10000	128650
Murray cod	*Maccullochella peelii*	b	855	9900	21061
Murray cod	*Maccullochella peelii*	d	870	14200	128637
Murray cod	*Maccullochella peelii*	b	885	12500	123542
Murray cod	*Maccullochella peelii*	b	885	14000	128646
Murray cod	*Maccullochella peelii*	d	890	12900	128648
Murray cod	*Maccullochella peelii*	b	900	13400	128647
Murray cod	*Maccullochella peelii*	d	955	16400	128636
Murray cod	*Maccullochella peelii*	b	980	17000	12562
Murray cod	*Maccullochella peelii*	d	980	15500	23485
Murray cod	*Maccullochella peelii*	b	990	18500	123520
Murray cod	*Maccullochella peelii*	b	1080	25400	100126
Murray cod	*Maccullochella peelii*	b	1100	26900	100113
Murray cod	*Maccullochella peelii*	b	1140	24000	128645
Murray cod	*Maccullochella peelii*	b	1160	35000	100125
Murray cod	*Maccullochella peelii*	b	1210	34800	100124

- Eight small (≈ 150mm total length) Murray cod were captured/observed during the 2014 monitoring study

Table 4. Size and tag details of Golden perch implanted with radio telemetry tags in Mullaroo Creek and Lindsay River April/May, 2014.

Common name	Scientific name	Capture Zone	Length (mm)	Weight (g)	External Tag No.
Golden perch	*Macquaria ambigua*	b	310	402	128632
Golden perch	*Macquaria ambigua*	b	310	430	128634
Golden perch	*Macquaria ambigua*	d	335	532	129187
Golden perch	*Macquaria ambigua*	b	350	522	128633
Golden perch	*Macquaria ambigua*	d	357	644	128640
Golden perch	*Macquaria ambigua*	b	359	750	129167
Golden perch	*Macquaria ambigua*	b	360	666	128635
Golden perch	*Macquaria ambigua*	b	374	740	129169
Golden perch	*Macquaria ambigua*	b	375	718	129182
Golden perch	*Macquaria ambigua*	b	376	802	129155
Golden perch	*Macquaria ambigua*	b	376	784	129165
Golden perch	*Macquaria ambigua*	b	395	826	129166
Golden perch	*Macquaria ambigua*	d	397	894	129188
Golden perch	*Macquaria ambigua*	b	402	940	129156
Golden perch	*Macquaria ambigua*	d	402	974	129190
Golden perch	*Macquaria ambigua*	d	403	660	129184
Golden perch	*Macquaria ambigua*	d	404	948	129196
Golden perch	*Macquaria ambigua*	b	413	1038	129180
Golden perch	*Macquaria ambigua*	b	436	1202	129160
Golden perch	*Macquaria ambigua*	d	478	1508	129171
Golden perch	*Macquaria ambigua*	b	493	1242	129161

- Twelve small (≈ 150mm total length) Golden perch cod were captured/observed during the 2014 monitoring study

Table 5. Size and tag details of Freshwater catfish implanted with radio telemetry tags in Mullaroo Creek and Lindsay River April/May, 2014.

Common name	Scientific name	Capture Zone	Length (mm)	Weight (g)	External Tag No.
Freshwater catfish	*Tandanus tandanus*	d	348	366	129172
Freshwater catfish	*Tandanus tandanus*	d	361	372	129174
Freshwater catfish	*Tandanus tandanus*	b	380	438	129183
Freshwater catfish	*Tandanus tandanus*	b	398	550	129153
Freshwater catfish	*Tandanus tandanus*	b	398	516	129157
Freshwater catfish	*Tandanus tandanus*	b	405	640	129194
Freshwater catfish	*Tandanus tandanus*	b	407	624	129177
Freshwater catfish	*Tandanus tandanus*	b	426	610	129163
Freshwater catfish	*Tandanus tandanus*	b	430	714	129159
Freshwater catfish	*Tandanus tandanus*	b	432	622	129181
Freshwater catfish	*Tandanus tandanus*	d	435	696	129185
Freshwater catfish	*Tandanus tandanus*	b	438	824	129178
Freshwater catfish	*Tandanus tandanus*	d	450	728	128641
Freshwater catfish	*Tandanus tandanus*	d	450	806	129195
Freshwater catfish	*Tandanus tandanus*	b	457	894	129164
Freshwater catfish	*Tandanus tandanus*	b	458	900	129154
Freshwater catfish	*Tandanus tandanus*	b	465	902	129158
Freshwater catfish	*Tandanus tandanus*	d	465	682	129191
Freshwater catfish	*Tandanus tandanus*	b	470	902	129192
Freshwater catfish	*Tandanus tandanus*	b	520	1234	129162

Table 6. Size and tag details of European carp implanted with radio telemetry tags in Mullaroo Creek and Lindsay River April/May, 2014.

Common name	Scientific name	Capture Zone	Length (mm)	Weight (g)	External Tag No.
European carp	*Cyprinus carpio*	e	440	1320	129199
European carp	*Cyprinus carpio*	b	502	1772	128664
European carp	*Cyprinus carpio*	e	603	3290	129198
European carp	*Cyprinus carpio*	e	608	3680	129197
European carp	*Cyprinus carpio*	b	640	2896	128642
European carp	*Cyprinus carpio*	e	640	3444	129200

Program direction and recommendations

This project has successfully established a telemetry program enabling the monitoring of fish movement throughout the Lindsay Creek/Mullaroo Creek system in response to a range of events including blackwater, flooding and variable flows. Eighty transmitters were successfully inserted into four large- fish species to monitor their movements within the Lindsay River and Mullaroo Creek systems. This data will provide the basis of assessing migration and habitat use of fish within the Lindsay River and Mullaroo Creek in response to flows and the operation of new floodplain structures. The program also has the ability to monitor other processes of interest to management, in particular the response of native 'sentinel fish' to threats such as blackwater events as well as to investigate carp movements during and following flooding.

The collection of this data is now reliant on bi-annual site visits. Specifically, data stored in the logging stations should be downloaded in;

- August 2014, and again in
- early December 2014.

The August download will ensure that the loggers are able to record the large volume of data expected to be stored during the Spring/Summer fish breeding period while the December download will free up the loggers to record fish movement over the following six month period. This trip will also enable us to manually track Freshwater catfish before their transmitters run out as their small size only allows for the insertion of transmitters with a limited battery life (up to 8 months). In conjunction with the logger downloads, battery, reference transmitters and logger integrity shall be maintained. These bi-annual downloading trips will allow staff to track and determine the location of individual fish within sample zones, determine post spawning mortality (if any) and provide additional information on the association of fish with preferred habitats.

In addition, limitations associated with battery life of transmitters (8 months to four years) dictate that an annual tagging trip be undertaken to ensure sufficient replicates for each fish species are present for effective monitoring and data analysis. This is particularly important for catfish.

While radio-tracking of target fish species shall provide information on fish movement patterns and habitat use under current and future management of water throughout the system, with a particular emphasis on the establishment and operation of regulating structures in the region, (both the Mullaroo and Lindsay regulators and the proposed regulator (Mullaroo Stage 2) on the Lindsay/Murray River confluence. Specific questions this program can investigate include:

- Are the fishways on the Lindsay River and Mullaroo Creek effective when regulator gates are closed/open?
- Will current Murray cod migration from the Murray River and Lindsay River continue when the Mullaroo/Lindsay system acts as a watering site (under simulated flooding)?
- What habitats will the re-invigorated freshwater catfish population use, and can this habitat be expanded under new floodplain operations?
- Will or can other anabranch systems be created to replicate the Mullaroo Creek through weir pool manipulations using the new regulating structures? and
- How will data from this and additional studies feed into management and operation of regulators?

There is a clear need to understand fish movement during floodplain inundation. Research into fish utilization of wetland and floodplain habitats, the response of fish to increased nutrient loads (ecosystem productivity) and the impact of floodplain inundation on key components of life-history traits, population structure of fish and movement into and through the system is unknown but vital to the long-term sustainability of the fish community. Furthermore, the impact of

floodplain inundation on linkages (connectivity, productivity, spawning grounds and dispersal) between the Lindsay/Mullaroo and Chowilla systems are unknown.

Collection and incorporation of ecological data into regulator operational procedures will be an important component in the management of future watering regimes (and response to environmental events such as blackwater) within and through the Mullaroo Creek/Lindsay River system. Establishment of a steering committee to facilitate regulator operations in the region would perpetuate the ecological objectives for the Lindsay River/Mullaroo Creek system outlined in The Living Murray initiative.

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