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Charles Sturt University

Commonwealth Environmental Water Office Monitoring, Evaluation and Research Project: Edward/Kolety-Wakool River System Selected Area Summary Report 2020-21

FLOW Monitoring Evaluation Research

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Cover photos:

Left: Adult female Murray River short-necked turtle (Photo: James Van Dyke)
Right: Low water levels in Stevens Weir, 7th June 2021 (Photo: Paul Frazier)

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1. Monitoring and evaluation of environmental water in the Edward/Kolety-Wakool Selected Area

Background

The Commonwealth Environmental Water Office (CEWO) Monitoring, Evaluation and Research (Flow-MER) Program (2019 to 2022) is an extension of the Long-Term Intervention Monitoring (LTIM) and Murray-Darling Basin Environmental Water Knowledge and Research Project (EWKR) projects, with monitoring, evaluation and research activities undertaken within a single integrated program.

The Flow-MER Program provides the critical evidence that is required to understand how water for the environment is helping maintain, protect, and restore the ecosystems and native species across the Murray–Darling Basin (MDB) and informs management of Commonwealth water for the environment. The Flow-MER Program consists of evaluation, research and engagement at a Basin-scale and monitoring, evaluation, research and engagement across seven Selected Areas within the MDB.

This report summarises the key outcomes of monitoring and evaluation, research, communications and engagement that were undertaken in the Edward/Kolety-Wakool (EKW) Selected Area in 2020-21. Further details are available in a Technical Report (Watts et al. 2021). This project was undertaken as a collaboration between Charles Sturt University, NSW DPI (Fisheries), NSW Department of Planning, Industry and Environment, and La Trobe University. The turtle research was undertaken in partnership with Yarkuwa Indigenous Knowledge Centre Aboriginal Corporation.

Edward/Kolety-Wakool Selected Area

The EKW system is a large anabranch system of the Murray River in the southern MDB. The system begins in the Millewa Forest and travels north and northwest before discharging back into the Murray River (Figure 1). It is a complex network of interconnected streams, ephemeral creeks, flood-runners, wetlands and floodplain forests and woodlands. Under regulated conditions flows in the Edward/Kolety River and tributaries remain within the channel, whereas during high flows there is connectivity between the river channels, floodplains and several large forests including the Barmah-Millewa Forest, Koondrook-Perricoota Forest and Werai Forest.

The area has a rich and diverse Indigenous history and supports a productive agricultural community and supports recreational uses such as fishing, birdwatching and bushwalking. First Nations including the Wamba Wamba (Wemba Wemba) and Perrepa Perrepa (Barapa Barapa), and Yorta Yorta, maintain strong connections to Country.

The Barmah-Millewa Forest, Koondrook-Perricoota Forest and Werai Forest (Figure 1) make up the NSW Central Murray Forests Ramsar site (NSW Office of Environment and Heritage 2018), being one of the matters of national environmental significance to which the EPBC Act applies. Werai Forest has great cultural significance to the Wamba Wamba and Perrepa Perrepa Traditional Owners. Land use and occupancy mapping has identified over 12,000 sites of cultural significance to First Nations people in the Werai Forest (Weir et al 2013). Traditional Owners have been working towards having Werai Forest established an Indigenous Protected Area to be cared for through an Indigenous Land Use Agreement.

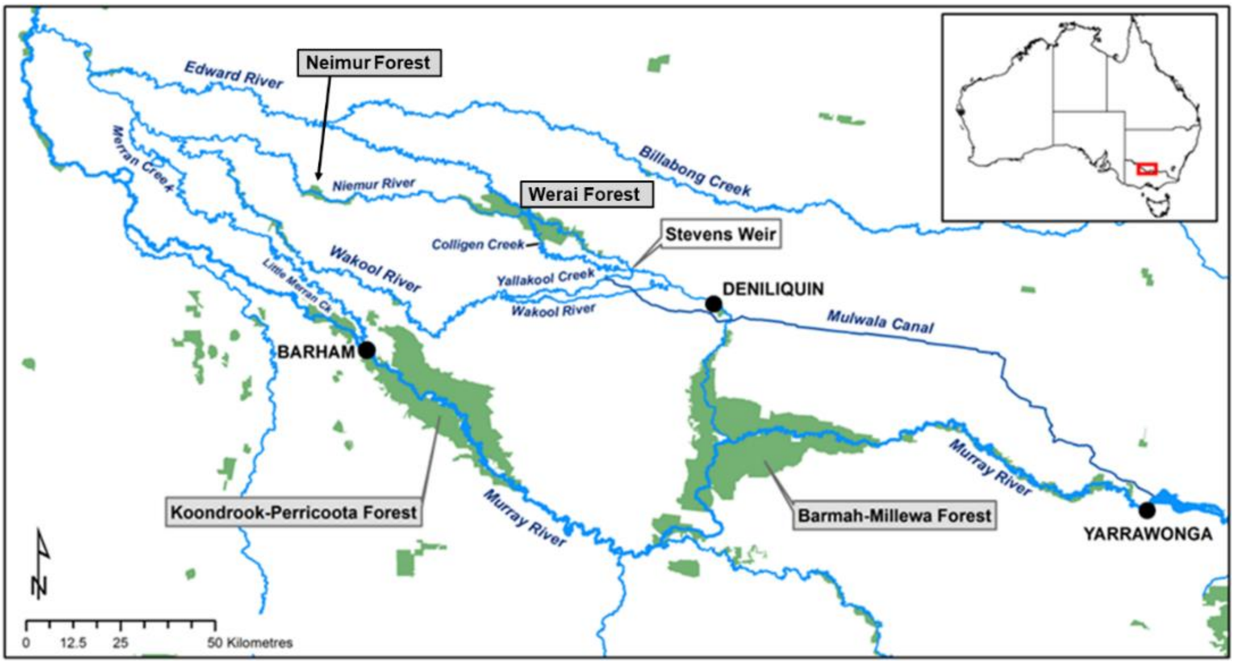

Figure 1. Map showing the main rivers in the Edward/Kolety-Wakool system.

The EKW system is important for its high native species richness and diversity including threatened and endangered fish, frogs, mammals, and riparian plants. It is listed as an endangered ecosystem, as part of the 'aquatic ecological community in the natural drainage system of the lower Murray River catchment' in New South Wales (NSW Fisheries Management Act 1994).

The multiple streams and creeks in the EKW system provide important refuge and nursery areas for fish and other aquatic organisms, and adult fish regularly move between this system and other parts of the Murray River. The EKW system includes three broad aquatic ecosystem types (Figure 2):

- *Permanently flowing Edward/Kolety River and semi-permanent Colligen-Niemur, Yallakool Creek and Wakool River.* These systems support biodiversity and provide drought refugia for aquatic biota.
- *Floodplain forests and woodlands.* These ecosystems are culturally significant and are important habitats for fish, support breeding colonies of birds, and are a source of carbon for the river system.
- *Ephemeral and intermittent creeks including Tuppal, Jimaringle, Cockran and Gwynnes Creeks.* These creeks provide habitat connectivity and support threatened and vulnerable species.

Figure 2. Photos showing the diversity of aquatic ecosystem types in the Edward/Kolety-Wakool system. Left: A permanent section of the Wakool River. Middle: Flood runner in Werai Forest. Right: Tuppal Creek.

Water management in the Edward/Kolety-Wakool system

The EKW system plays a key role in the operations and ecosystem function of the Murray River, connecting upstream and downstream ecosystems. Like many rivers of the MDB, the hydrology of rivers in the EKW system has been significantly altered by river regulation (Green 2001; Hale and SKM 2011). Natural flows in this system are strongly seasonal, with high flows typically occurring from July to November. Analysis of long-term modelled flow data show that flow regulation has resulted in a marked reduction in winter high flows, including extreme high flow events and average daily flows during the winter period. In the modelled natural discharge models for the 2020-21 water year there were three freshes in spring/early summer in July 2020, Sept 2020, Nov/Dec 2021, and a late summer smaller fresh in February 2021. These four modelled natural events were highly regulated, so in 2020-21 the observed flow peaks were considerably less than the modelled flow peaks (Figure 3).

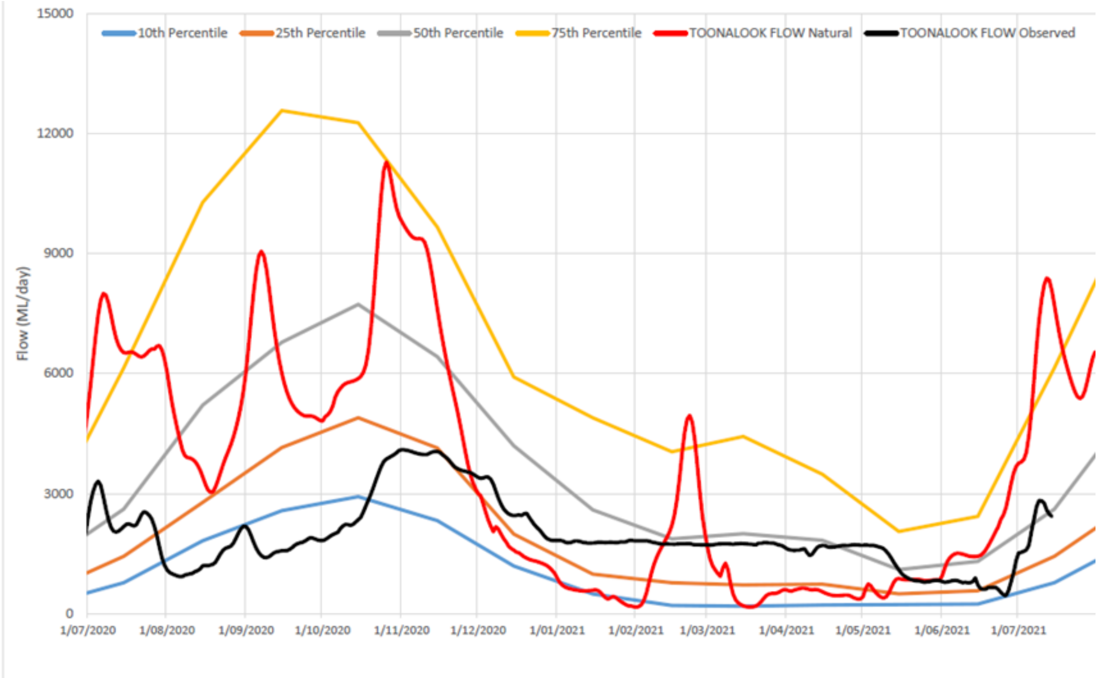

Figure 3 Hydrograph showing observed and modelled natural daily discharge in the Edward/Kolety River from 1/6/2020 to 1/8/2021 at the Toonalook gauge. (Source: MDBA).

The main source of Commonwealth environmental water for the EKW system is from the Murray River, with flows entering the system via the Edward River offtake, Gulpa offtake, Tuppal and Bullatale Creek. Stevens Weir, the main flow regulating structure within the system, creates a weir pool that enables environmental water to be delivered to the Colligen-Niemur system, Yallakool Creek, Wakool River, Edward/Kolety River and Werai Forest. Water is also diverted from Lake Mulwala into the Mulwala Canal can also be delivered into the system through 'escapes' or outfalls managed by the irrigator-owned company Murray Irrigation Limited. Delivery of regulated instream flows to the EKW system are managed within regular operating ranges, as advised by river operators to avoid third party impacts. Regulated flows remain within the channel, with small freshes connecting low-lying in-channel features such as backwaters. This limits the types of flows that can be achieved under current operating ranges to in-channel base flows and freshes. During higher unregulated flows there is connectivity between the river channels, floodplains and the forests.

2. ENVIRONMENTAL WATERING IN THE EDWARD/KOLETY-WAKOOL SELECTED AREA IN 2020-21

Since 2009 Commonwealth environmental water has been delivered to the EKW system as base flows and freshes, contributed to flow recession, and contributed to flows in ephemeral watercourses. Water has also been delivered from irrigation canal escapes to create local refuges during hypoxic blackwater events. To date it has not been possible to deliver large within channel freshes or overbank flows due to operational constraints in the system. In addition to watering actions specifically targeted for the EKW system, in some years Commonwealth environmental watering actions from Hume Dam and actions that are targeted for downstream watering actions transit through the EKW system.

Eight Commonwealth environmental watering actions were delivered in 2020-21 in the Wakool-Yallakool system and the Colligen-Niemur system (Table 1). All eight actions are incorporated under Watering Action Reference number WUM10105-01 (CEWO 2021). Some of the water during these actions was sourced as return flows from the Southern Spring Flow in the Murray River.

Table 1 Commonwealth environmental watering actions in 2020-21 in the Edward/Kolety-Wakool system.

Action	System	Name	Objectives (from CEWO)	Dates
1	Yallakool-Wakool system	Spring fresh	800 ML/day flow trial to test inundation extent, coordinated with wider Murray River actions to maximise benefit. Slow recession for instream water plants to elevated base flow of 380 ML/d. To provide early season rise in river level to contribute to connectivity, water quality, stimulate early growth of in-stream aquatic vegetation, pre-spawning condition of native fish and/or spawning in early spawning native fish	20/10/20-30/11/20 *(Yallakool)* 23/10/20 - 27/11/20 *(Wakool)*
2	Yallakool	Elevated base flow	To maintain nesting habitat for Murray Cod, and inundation for aquatic vegetation growth	30/11/20 - 15/12/20
3	Yallakool	Summer freshes	To influence and encourage silver perch breeding and fish movement, may also assist with dispersal of larvae and juveniles of a number of fish species. Slow recession to support instream water plants. Two freshes: 15/12/20 start peak 1/4.01/21 finish peak 1 start peak 2. 15/2/21 finish peak 2, and recession down to operational base levels of 170 ML/d	15/12/20 – 15/2/21
4	Yallakool	Autumn fresh	To influence/encourage fish movement. May also assist with dispersal of juveniles of a number of fish species.	30/3/21 - 6/5/21
5	Colligen-Niemur	Spring fresh	To provide early season rise in river level to contribute to connectivity, water quality, stimulating early growth of in-stream aquatic vegetation, pre-spawning condition of native fish and/or spawning in early spawning native fish	21/10/20 - 6/12/20
6	Colligen-Niemur	Elevated base flow	To maintain nesting habitat for Murray Cod, and inundation for aquatic vegetation growth.	6/12/20 - 8/1/21
7	Colligen-Niemur	Summer fresh	Summer fresh to influence and encourage fish movement, may be coordinated with wider Murray River actions to maximise benefit. May also assist with dispersal of larvae and juveniles of a number of fish species.	8/1/21 - 26/1/21
8	Upper Wakool	Variable base flows	To provide a proactive, longer-term approach to preventing a potential hypoxic water event. Longitudinal connectivity, flow variability and potential refuge. Variable cycling for WQ Ranging from 50 ML/d to 120 ML/d	23/1/21 - 9/6/21

Due to the lack of forecast rainfall eventuating and reduced outflows from Yarrawonga, the 800 ML/day early season fresh was delayed until the required flow rates at Yarrawonga were achieved so the watering actions could be delivered as part of the planned Murray Southern Spring Flow. There were no Commonwealth environmental watering actions between July and September 2020.

Watering action number 1 (Table 1, Figure 4) was an 800 ML/day flow trial coordinated with wider Murray River actions to maximise benefit. Instead of commencing in mid-July, the spring flow in the Yallakool-Wakool commenced on 20 October 2020, with environmental water delivered via the Yallakool offtake, Wakool offtake and the Wakool escape from Mulwala Canal to create a combined flow pulse with a peak of approximately 781 ML/day in the Wakool River at Barham-Moulamein Road (zone 4).

Actions 1, 2, 3 in Yallakool-Wakool system and actions 5, 6 and 7 in the Colligen-Niemur system (Table 1, Figure 4) were a sequence of spring fresh/elevated base flows/summer freshes that in combination aimed to contribute to connectivity, water quality, stimulate early growth of in-stream aquatic vegetation, and support pre-spawning condition of native fish and/or spawning in early spawning native fish. Watering action 4 was an autumn fresh in Yallakool-Wakool system. Action 8 was a period of variable base flows in the upper Wakool River to improve water quality and connectivity.

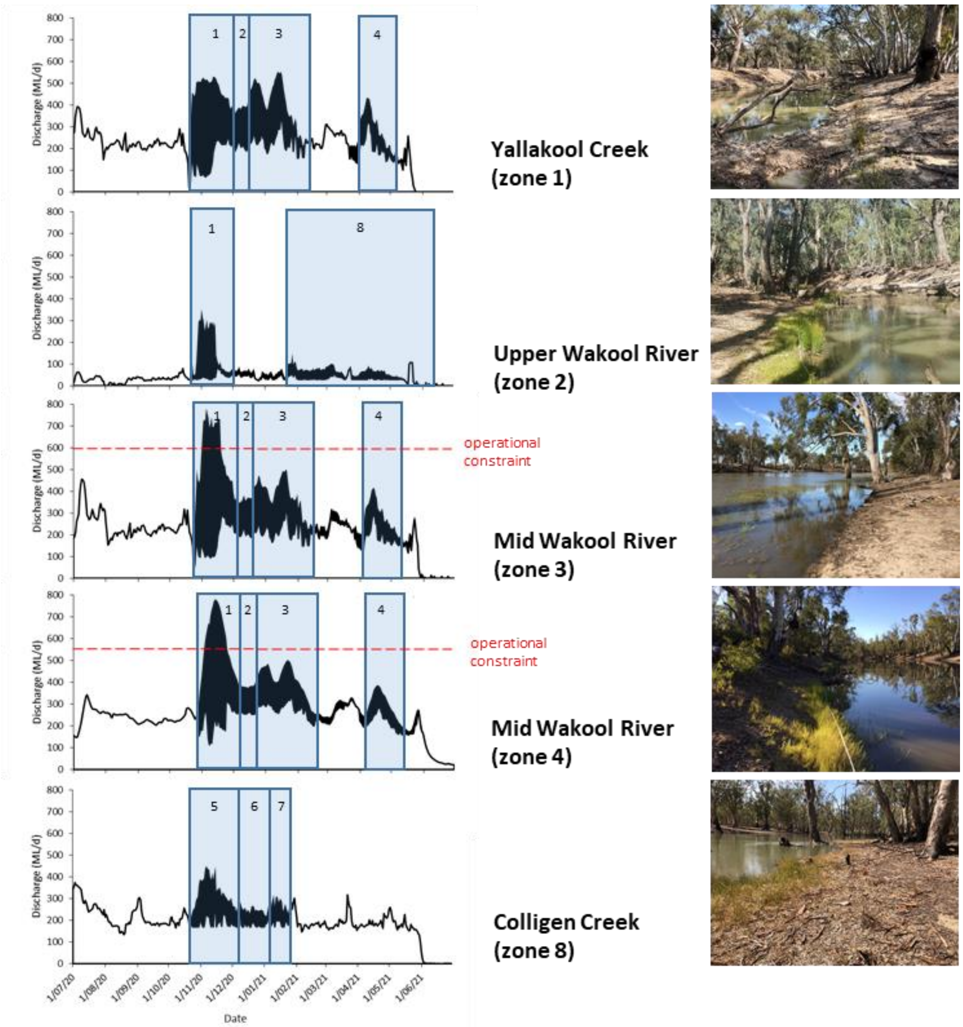

Figure 4. Hydrographs of zone 1 Yallakool Creek, zones 2, 3 and 4 in the Wakool River, and zone 8 Colligen Creek from 1 July 2020 to 30 June 2021. The portion of the hydrographs coloured black is attributed to the delivery of CEW. The blue shaded sections indicate environmental watering actions.

3. KEY OUTCOMES FROM ENVIRONMENTAL WATER USE

Monitoring

The monitoring of the environmental watering actions was undertaken using methods and approaches described in the Edward/Kolety-Wakool Flow-MER Plan (Watts et al 2019). An evaluation of the outcomes of Commonwealth environmental watering actions in 2020-21 was undertaken for the following indicators: Hydrology, water quality and carbon, stream metabolism, aquatic and riverbank vegetation, fish reproduction, fish recruitment, and fish community.

Responses to Commonwealth environmental water were evaluated in two ways:

i) Indicators that respond quickly to flow (e.g., water quality, stream metabolism, fish spawning) were evaluated for their response to individual watering actions. When possible, indicators were modelled to compare responses with and without environmental water.

ii) Indicators that respond over longer time frames (e.g., riverbank and aquatic vegetation, fish recruitment, fish community) were evaluated for their long-term response to environmental watering regimes over eight years of the LTIM/Flow-MER Program (2014-2021). This was undertaken by evaluating responses over multiple years, and/or comparing responses in reaches that received environmental water to reaches that received none or minimal environmental water.

Responses to the 800 ML/day flow trial in Yallakool-Wakool (Watering action 1)

Commonwealth environmental watering action 1 (800 ML/day flow trial) was coordinated with the Murray River Southern Spring Flow. It aimed to provide early season rise in river level to contribute to connectivity, water quality, stimulate early growth of in-stream aquatic vegetation, pre-spawning condition of native fish and/or spawning in early spawning native fish.

Watering action 1 had the following outcomes:

- **Increased the maximum discharge compared to operational flows**. The discharge peaked at 781 ML/d in zone 4 compared to operational flow of 225 ML/d on this date (Figure 4).
- **Increased the variability of flows**. In the absence of the watering actions there would have been extended periods of low variability flows.
- **Increased longitudinal connectivity** by initiating flow in Black Dog Creek, connecting the upper Wakool River and Yallakool Creek (Figure 5).

Figure 5 Changes in water level in Black Dog Creek during the 800 ML/d flow trial in 2020. Black Dog Creek is a runner that flows from the Wakool River near 'Widgee" across to Yallakool Creek.

- **Watering action 1 increased lateral connectivity and hydraulic diversity.** A comparison of the modelled inundated area for a 170 ML/day operational flow and a 750 ML/day environmental flow in a reach of the mid-Wakool River (Figure 6), shows the increase in inundated area and connectivity during the environmental flow. Results of hydraulic modelling for other reaches in the EKW system are presented in Watts et al. (2015). A 750 ML/d flow in this reach increased lateral connectivity by inundating low lying wetlands and other in-channel features, and increasing the total wetted area of riverbank compared to operational flows. Increasing the extent and duration of lateral connectivity can play an important role in river productivity, increasing dissolved carbon released from the sediment, leaves, and vegetation. Increased inundation of the riverbank can also trigger germination and growth of aquatic and riverbank plants, which provide habitat for invertebrates, frogs and fish.

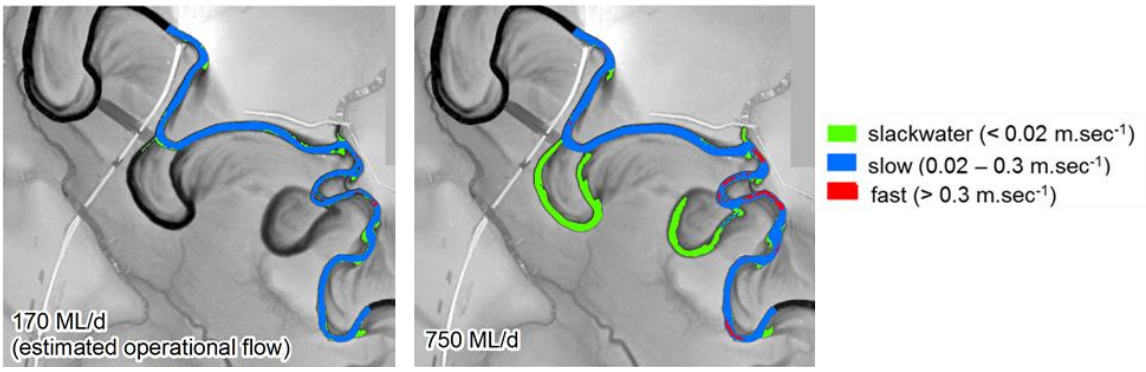

Figure 6. Results of hydraulic modelling for a 4 km reach of the Wakool River near the Wakool-Barham Road showing difference in inundated area modelled for 170 ML/day operational flow (left) and 750 ML/day environmental flow (right) that was similar discharge to the peak of the watering action 1 in Oct/Nov 2020.

- **Watering action 1 did not result in any adverse water quality outcomes**. Dissolved oxygen concentration remained normal for the period of watering action.
- **Watering action 1 created a pulse of dissolved organic carbon (DOC**) in the Wakool-Yallakool system. The concentration of DOC in the mid- Wakool River was outside the normal range observed in the system and almost reached a similar level to that observed during 2016-17 floods. This pulse of DOC may have been influenced by return flows from MIllewa Forest during the Southern Spring Flow.
- **Watering action 1 increased production and consumption of carbon** (Figure 7). Healthy aquatic ecosystems need key ecological processes of photosynthesis and respiration to occur to generate new biomass (which becomes food for organisms higher up the food chain), and to break down plant and animal detritus and to recycle nutrients to enable growth to occur.
- **Watering action 1 stimulated germination (Figure 8) and early growth (Figure 9) of riverbank and aquatic vegetation** on the lower part of the riverbank that was wetted during the watering action.

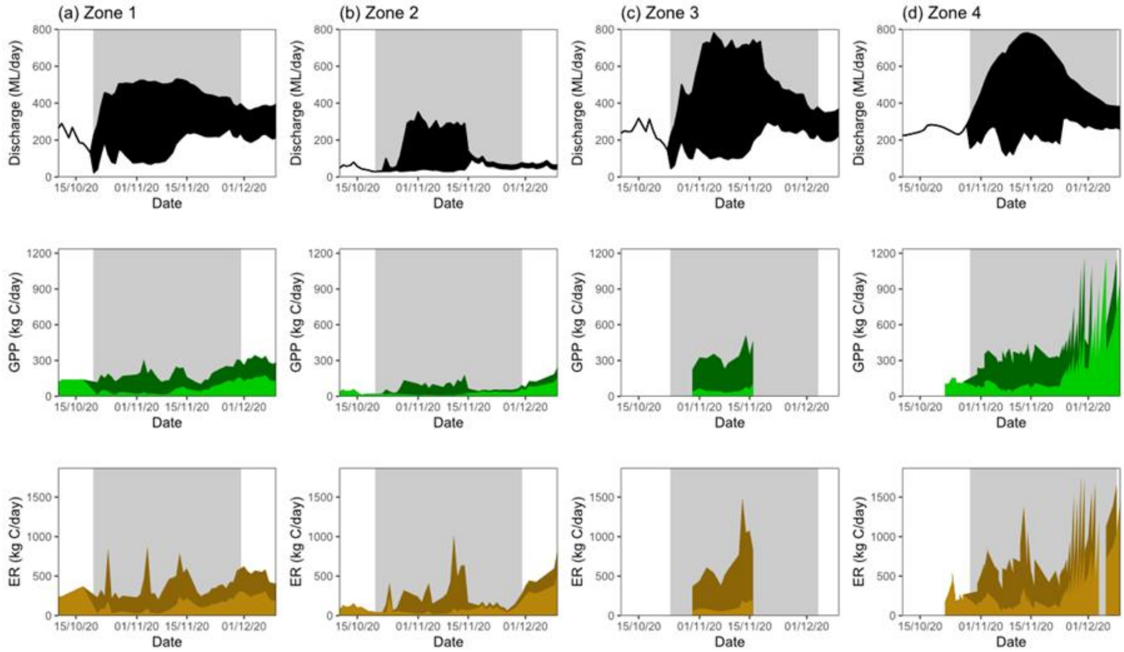

Figure 7. Plots of discharge (ML/day) and carbon production (GPP, kg C/day) and consumption (ER, kg C/day) during watering action 1, zones 1-4, showing the component attributed to Commonwealth environmental water (CEW). Duration of action is grey shaded area. Discharge plot: CEW black, operational water white. GPP plot: CEW dark green, operational water light green. ER plot: CEW dark brown, operational water light brown.

Figure 8 Riverbank plant seedlings emerging after the recession of the spring flow (watering action 1).

Figure 9 Photo showing extent of germination of riverbank plants following the spring flow (watering action 1). The plants evident in December 2020 at zone 4 site 2 have germinated in the location where there were visibly damp banks in November 2020 following the recession of the environmental watering action.

Responses to the sequence of spring/summer watering actions over spring/summer (Actions 1 to 3 Yallakool-Wakool and actions 5-7 in Colligen-Niemur)

- The spring/summer sequence of watering actions **increased the variation of discharge in all monitored zones** compared to operational flows. In the absence of the watering actions there would have been extended periods of low variability flows.
- The spring/summer watering actions **increased lateral connectivity** compared to the modelled connectivity under operational flows.
- **The sequence of watering actions maintained good water quality** and resulted in no adverse outcomes.
- The sequence of watering actions in Yallakool-Wakool and Colligen-Niemur systems **stimulated germination and early growth of riverbank** and aquatic plants. The summer freshes that followed this **provided opportunities for the persistence and growth of seedlings, flowering and the dispersal of seeds.**
- There was **strong spawning and recruitment in flathead gudgeon** in 2020-21, with higher catches of both larval and juvenile stages (Category 1 adult surveys) recorded compared to all previous years of monitoring.
- Pre-spawning and nesting behaviour of Murray cod is likely to take commence between September and October. In 2018-19 nest-building and spawning would have taken place under 200 ML/day flows, resulting in good spawning outcomes for Murray cod. In 2020-21 flows were at base levels (50 ML/day) in September and the elevated base flow did not commence until November. **The delay in starting the spring fresh and subsequent establishment of elevated base flow may have contributed to the lower catch rates of Murray cod larvae in the upper Wakool in 2020-21 compared to 2018-19.**

Responses to the variable base flows in the-Wakool River (Action 8)

- Commonwealth environmental watering action 8 resulted in higher discharge than other years and the variable base flows and **maintained good dissolved oxygen concentrations in the Wakool River.** This demonstrates that using Commonwealth environmental water in upper Wakool during the hotter months could provide a proactive, longer-term approach to improve water quality and prevent potential hypoxic water events.
- Watering action 8 **increased the variation of discharge** in the upper Wakool River compared to operational flows. In the absence of the watering actions there would have been extended periods of low variability flows.

Responses over multiple years of environmental watering

- **Environmental watering is supporting long-term recovery of aquatic and riverbank plants.** Aquatic and riverbank plants play an important role in the functioning of aquatic ecosystems, supporting riverine food webs and providing habitat for waterbugs, frogs, birds and fish. The water regime in a river can affect the survival, growth and maintenance of plants, particularly those that live under the water (submerged), or those that live on the lower part of the riverbank and tolerate wetting and drying (amphibious plants).

- The 2016 flood significantly reduced the number of aquatic and riverbank plant taxa across all study sites. Since the flood there has been a partial recovery, with more taxa present in zones that have received environmental water. However, the number of species has not yet recovered to the same levels as prior to the flood. **The number of plant taxa has been consistently higher in zones 1, 3, 4 and 8 that have received more environmental watering actions than the zone 2 (upper Wakool).**
- The 2016 flood decimated submerged plants and macroalgae, and there has been recovery of these groups since 2017-18 (Figure 10). In 2020-21 **the percent cover of submerged taxa was maintained in zones that received environmental water,** but submerged taxa were no longer present at the four monitored sites in the upper Wakool River that has received fewer environmental watering actions over the 7 years.

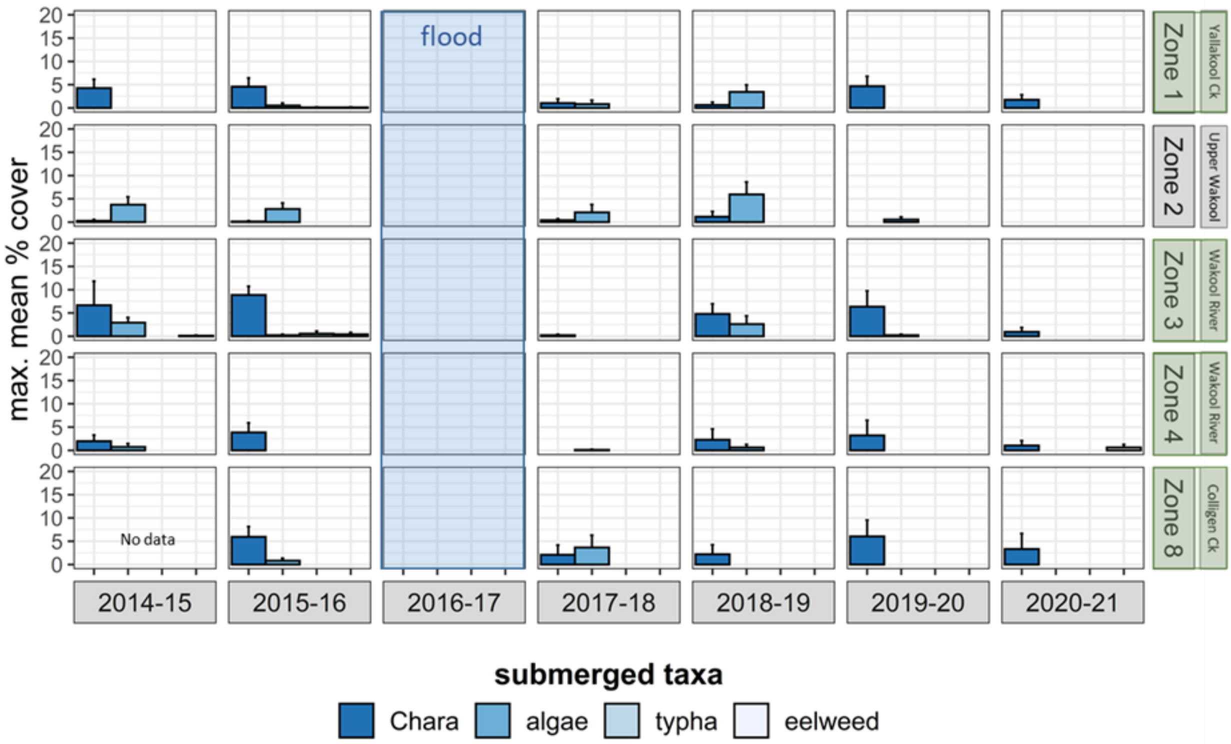

Figure 10 Mean percent cover of four submerged plant taxa monitored monthly across five hydrological zones in the Edward/Kolety-Wakool system between 2014 and 2021. Blue shading indicates the year of the flood in 2016. Green shading of zone names indicates that zones 1, 3, 4 and 8 received environmental water every year. Zone 2 received fewer environmental watering actions.

- Amphibious plants have begun to recover in all river zones since the 2016 flood. The response has not been uniform across river zones or taxa and taxa have responded in different ways. The common spikerush (*Eleocharis sp.)* tolerated the flooding and has maintained a similar percent cover across all years with no strong relationship to watering regime. In contrast, floating pondweed (*Potamogeton tricarinatus*), milfoil (*Myriophyllum sp.*) and other amphibious responder plants that were abundant in the mid-Wakool River in 2015 (Figure 14) but were killed by the flooding in 2016, are recovering very slowly, with some slow recovery evident in zones that have received environmental water (Figure 11). **More amphibious responder taxa have re-established in zones 1, 3, 4, and 8 that have received more environmental watering actions than zone 2** (Figure 12).

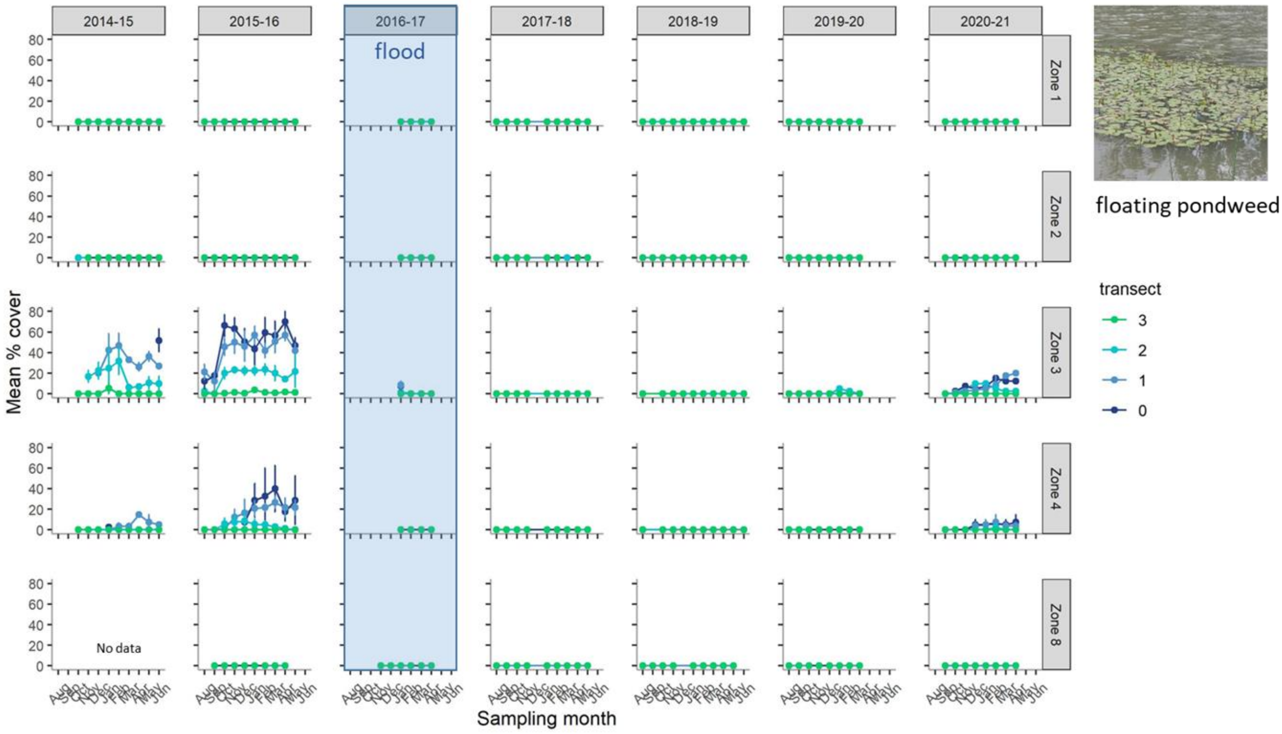

Figure 11 Mean percent cover of floating pondweed (*Potamogeton tricarinatus*) monitored monthly across five hydrological zones in the Edward/Kolety-Wakool system between 2014 and 2021. Transect zero is lowest on the riverbank and transects are labelled consecutively up to transect 5 highest on the riverbank. Zone 2 received minimal no environmental water, with the exception being in 2018-19 and variable base flows in 2020-21.

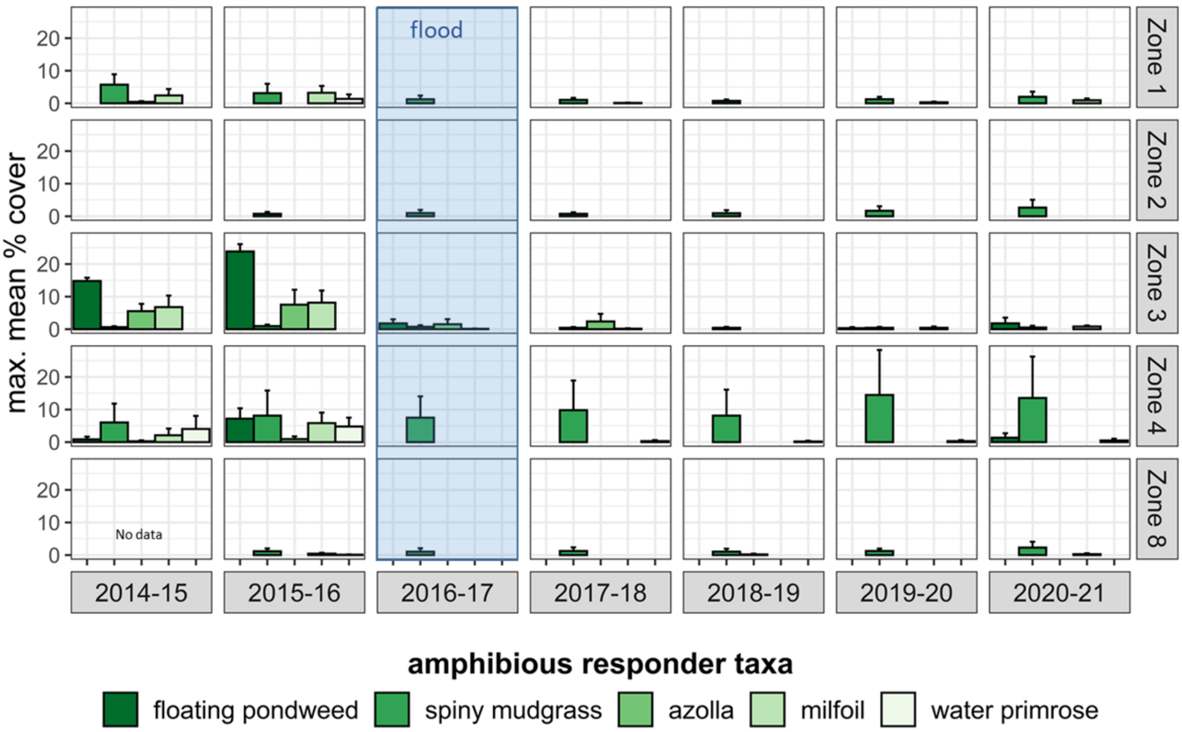

Figure 12 Mean percent cover of the five most abundant amphibious responder vegetation taxa monitored monthly across five hydrological zones in the Edward/Kolety-Wakool system between 2014 and 2021. Zones 1, 3, 4 and 8 received environmental water each year. Zone 2 received minimal no environmental water, with the exception being in 2018-19 and variable base flows in 2020-21.

- **Environmental watering is supporting fish recruitment.** Fish recruitment monitoring in the EKW system is focused on juvenile Murray cod, silver perch and golden perch. Juveniles include both young-of-year (YOY) and 1 year old (1+) fish. This monitoring enables comparison of the abundance and growth rates of juvenile of these three species from four river zones in response to environmental watering. In 2020-21 Murray cod recruits were detected in the mid Wakool River (zones 3 and 4) for the second consecutive year since 2015-16 (Figure 13). **In both 2019-20 and 2020-21 there were more Murray cod 1+ age class recruits (Figure 14) in zones 1, 3 and 4 that have received more environmental watering actions than in zone 2**. In addition, five silver perch (*Bidyanus bidyanus*) age-class 1 (1+) recruits (Figure 14) were detected in the mid-Wakool River (zone 4) and trout cod recruits were detected in Yallakool Creek (zone 1) for the first time during annual recruitment sampling (Figure 14).

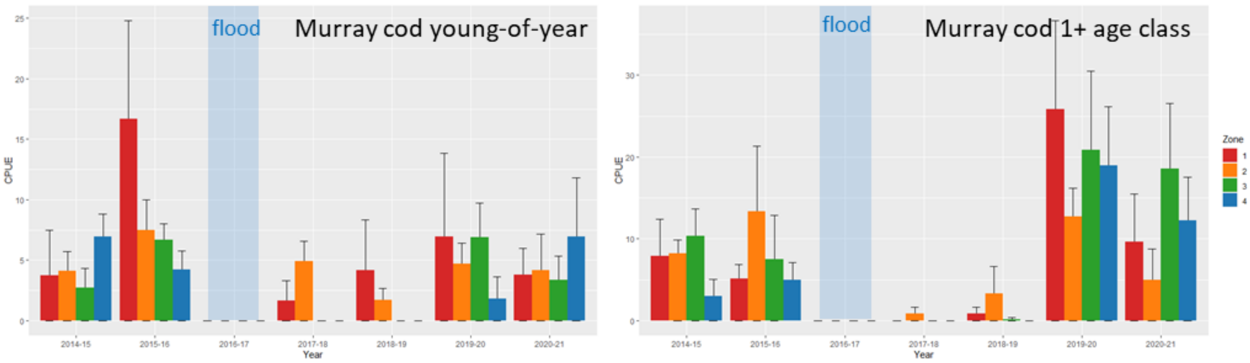

Figure 13 Mean (+SE) catch per unit effort (CPUE; number of Murray cod caught per 10 000 seconds of electrofishing) in the Edward/Kolety-Wakool river zones from 2014-21. Left: Results for Murray cod young-of-year. Right: Results for Murray cod 1+ age cohort.

Figure 14 Images of fish surveyed during February 2021 Recruitment surveys.

Environmental watering is supporting recovery of the fish community: Monitoring of the fish community was undertaken only in the mid Wakool River in 2021. System-wide fish community surveys were undertaken in year 1 (2014-15) and year 5 (2018-19) of the LTIM program and will take place in 2021-22 of the Flow-MER Program. Nine native species and three alien fish species of fish were captured during fish community sampling in the mid Wakool River in 2019-20 (Figure 15).

- **Murray cod, silver perch and golden perch increased in abundance and biomass in 2021 compared to the previous year.**
- **Strong spawning and recruitment in flathead gudgeon were recorded in 2020-21**, with higher catches of both larvae and juveniles recorded compared to previous years (Figure 15).
- **A higher abundance of silver perch, of all sizes except for YOY, were present in 2021 compared with previous years.**
- Typical annual fluctuations were observed in small-bodied generalist species.

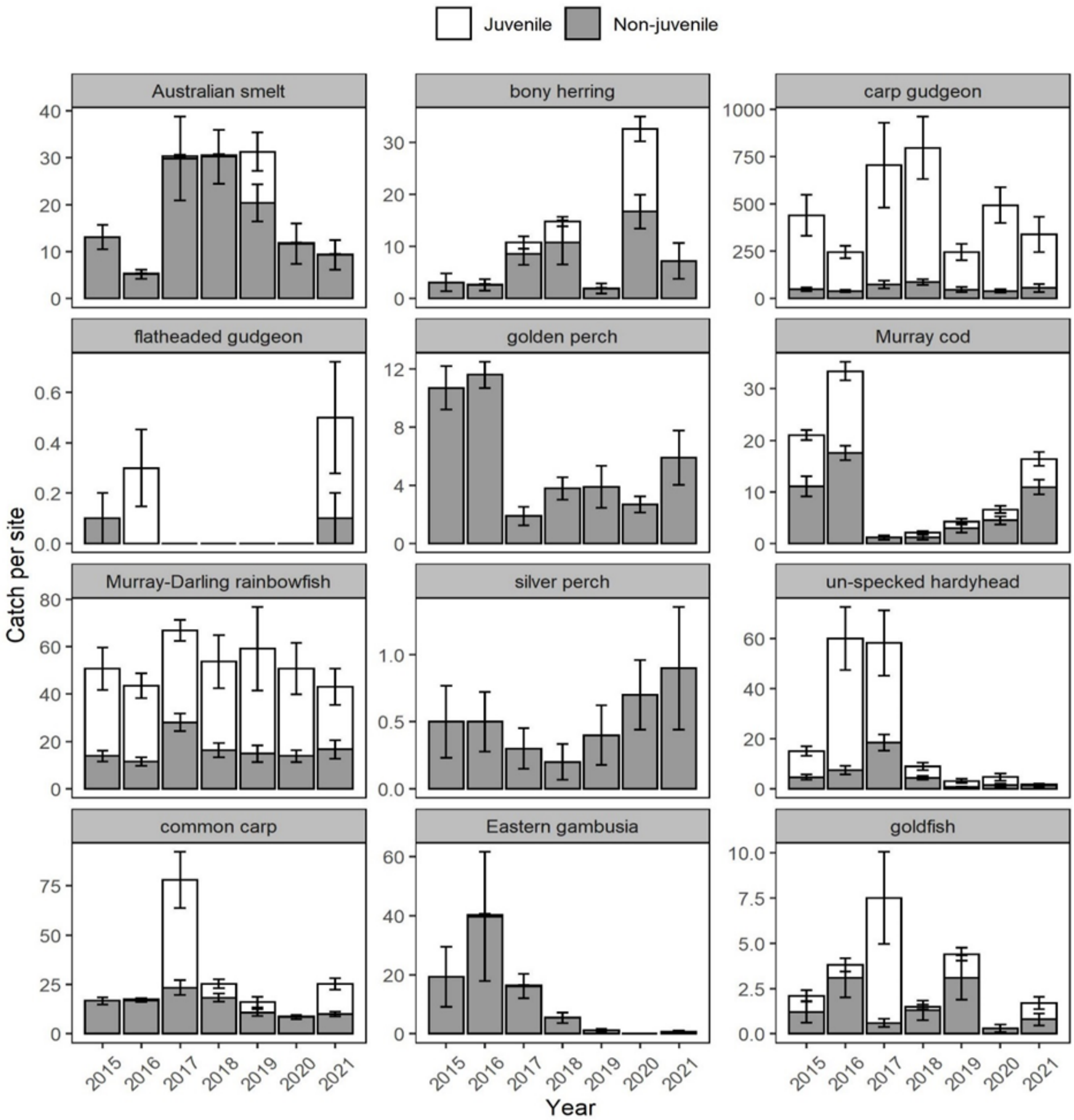

Figure 15 Catch per site (number of fish; mean ± SE) for each fish species within the Edward/Kolety-Wakool River system target reach, sampled from 2015–2021. Cumulative stacked bars separate the catch of juveniles (white bars) and non-juveniles (grey bars).

Research outcomes

As part of the Edward/Kolety-Wakool Flow-MER Program there are several research projects undertaken through contingency funding. The research projects aim to address knowledge gaps and improve the delivery, monitoring and evaluation of environmental water in the EKW system. Two research projects were completed in 2020-21 are results are included in this 2020-21 report. The first project examined turtle movement and condition to answer the question How does connectivity of wetlands along the Edward/Kolety River affect turtle distribution, movement and body condition? In addition, social research was undertaken in 2020-21 to examine stakeholder attitudes to, and acceptance of, the concept and use of Commonwealth environmental water.

Turtle research: How does connectivity of wetlands along the Edward/Kolety River affect turtle distribution, movement and body condition?

Freshwater turtles are an important component of Australian river ecosystems, and are culturally important to local Traditional Owners. As major scavengers, they are likely to be important regulators of nutrient cycling in river systems, at least at their historic densities. Despite their importance, about half of all Australian turtle species are currently listed as vulnerable, threatened, or endangered. Freshwater turtle populations may be threatened by winter drying of wetlands. As aquatic ectotherms (ie, cold-blooded), freshwater turtles substantially reduce their activity rates during the cold of winter. Thus, if they overwinter at a site that dries completely, they are likely to be exposed to mortality both as a result of environmental exposure and greater susceptibility to predators that they cannot escape.

Three freshwater turtle species are found in the Edward/Kolety River: the broadshelled turtle, *Chelodina expansa*, eastern long-necked turtle, *Chelodina longicollis*, and the Macquarie River, *Emydura macquarii* (Figure 16). In this project, we examined how winter drying affects turtle populations in the Edward/Kolety River in two ways: i) We used repeated trapping surveys to compare turtle community, body condition and population structures among disconnected wetlands that were more likely to experience winter drying and connected wetlands that were unlikely to experience winter drying, and ii) We used acoustic telemetry to track a subset of tagged individual *E. macquarii* to determine individual movement patterns in relation to the wetting/drying regime of 6 wetlands.

Figure 16 Turtles of the Edward/Kolety-Wakool River system. Left: broadshelled turtle (*Chelodina expansa*). Middle: eastern long-necked turtle (*Chelodina longicollis*). Right: Macquarie River turtle (*Emydura macquarii*).

Three of the study wetlands (Horseshoe, Moonahcullah, and Billabong) were disconnected, meaning that there was at least a small area of dry land between them and the Edward/Kolety River at normal flows during this study. Three wetlands (Barratta, Yallakool, ad Dahwilly) all had a continuous open connection to the river, and their levels fluctuated with river levels.

During the study, we caught 195 *C. expansa*, with 37 recaptures; 265 *C. longicollis*, with 62 recaptures; and 303 *E. macquarii*, with 33 recaptures. Catch-per-unit-effort did not differ between disconnected and connected wetlands for any of the three turtle species present. Demographics of all three species followed similar trends at the six wetlands. We detected very few juveniles of all three species, and all populations were dominated by older, larger adults. This trend is widespread in the Murray-Darling Basin, and indicates that turtles suffer from low recruitment rates.

During the study, we detected 121 exit events, where tagged *E. macquarii* exited a wetland into the adjacent river. We also detected 107 entry events, where tagged *E. macquarii* entered a wetland from the adjacent river. Female turtles tended to stay close to 'home' (wetlands in which they were initially tagged) even if they exited their home wetland, whereas males tended to either disappear completely, leave their wetland and reappear in the river adjacent to a different wetland, or re-appear at their home wetland weeks to months after disappearance (Figure 17).

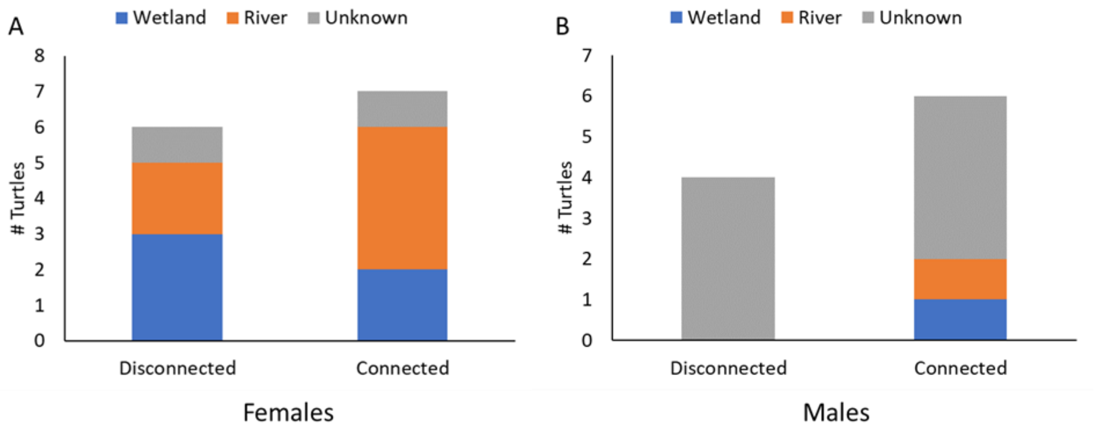

Figure 17 Locations where tagged female (**A**) and male (**B**) *E. macquarii* overwintered during the study. 'Wetland' indicates the turtle spent the winter in its home wetland. 'River' indicates the turtle spent the winter in the river adjacent to its home wetland. 'Unknown' indicates that the tagged turtle exited its home wetland into the Edward/Kolety River and disappeared for winter.

Tagged *E. macquarii* typically exited temporary wetlands prior to winter and overwintered in the adjoining Edward/Kolety River. The majority of females spent the winter in the river adjacent to their home wetlands and returned to their home wetlands by the start of spring. Most males had disappeared from the receiver network by the start of winter so we cannot state whether they overwintered in the river or in other wetlands.

Turtles from connected wetlands exited and re-entered their home wetlands much more frequently than turtles from disconnected wetlands (Figure 18). At disconnected wetlands, females had low exit rates because they exited once (at most), but re-entered their home wetland. Males had low exit rates because they never returned after exiting. At connected wetlands, females exited and re-entered their home wetlands repeatedly throughout the year. Males exited and re-entered their home wetlands several times.

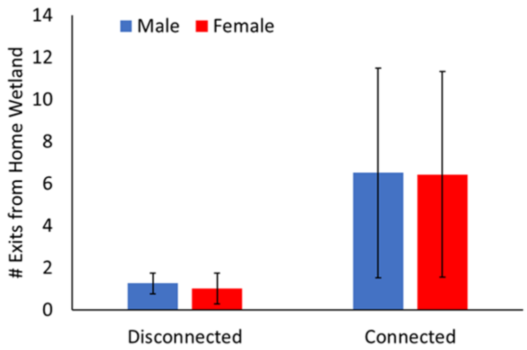

Figure 18 Left: Mean number of times turtles exited and re-entered home wetland per turtle. Tagged *E. macquarii* in connected wetlands exited and re-entered their home wetlands more frequently than those in disconnected wetlands. Right: Joseph Briggs and James Van Dyke check a trap for turtles. (Photo: Tracy Hamilton)

Our results indicate that turtles that utilise wetlands on the floodplains of permanent river systems may be protected from winter wetland drying due to their behaviour of moving to the adjacent river to hibernate. By spending the winter in the river channel, they avoid the risks of being exposed in a drying wetland as temperatures drop in winter. Our research indicates that turtles can survive in wetlands susceptible to winter drying if a nearby waterway retains water and can act as a winter refuge.

This project was undertaken in collaboration with Wamba Wamba and Perrepa Perrepa Traditional Owners, via the Yarkuwa Indigenous Knowledge Centre. Through this project provided Traditional Owners were provided training and experience in turtle ecology and conservation methods that they will be able to apply in their own future conservation work in Werai forest. The project facilitated reciprocal learning, as the Traditional Owners also shared their perspectives and knowledge about turtles, wetlands, and conservation.

Edward/Kolety River Social Research

This research considered the knowledge, values and opinions of people with a 'stake' in the EKW system in relation to environmental water and its use in that river system, specifically to address the following questions:

1. How are knowledge, information and learning (i.e., acting, adapting and accepting) understood and experienced by stakeholders in the EKW River system?
2. What are the current EKW River system stakeholder attitudes to, and acceptance of, the concept and use of Commonwealth environmental water?
3. What institutional, social and/or cultural interventions could improve the acceptance and impact of Commonwealth environmental water for this and other sites?

An online questionnaire was developed that used a semi-standardised format that included pre-structured choices and opportunity for respondents to formulate their own responses. A list of themes, topic areas and potential questions were developed in consultation with willing stakeholders, and piloted. Sections related to: the respondent population and their involvement in the EKW River system; their knowledge and understanding of water in the EKW River system;

their understanding and perceptions of environmental water planning and management and their forms of communication and information sources.

Survey respondents were predominately men over 40 years of age who have lived in the area, either on the river or in the towns, for most or all of their lives. All of the respondents, whatever age or gender, were well connected to the river system. They are interested in all of the river system, and they are concerned not only about the health of the river but also with its relationship to personal livelihood and the local community.

All of the respondents agreed that healthy rivers are necessary for healthy societies (Figure 19). It is rare to have 100% agreement to a value statement in such a contested area of activity, and this could, perhaps should, be a pivot point for information exchange in the future. What health means in each in instance will vary for each individual, group and organisation, but the common shared agreement of purpose can provide a solid foundation for working with those variances. Some, but not all, agree that water for the environment can play a role in achieving river health.

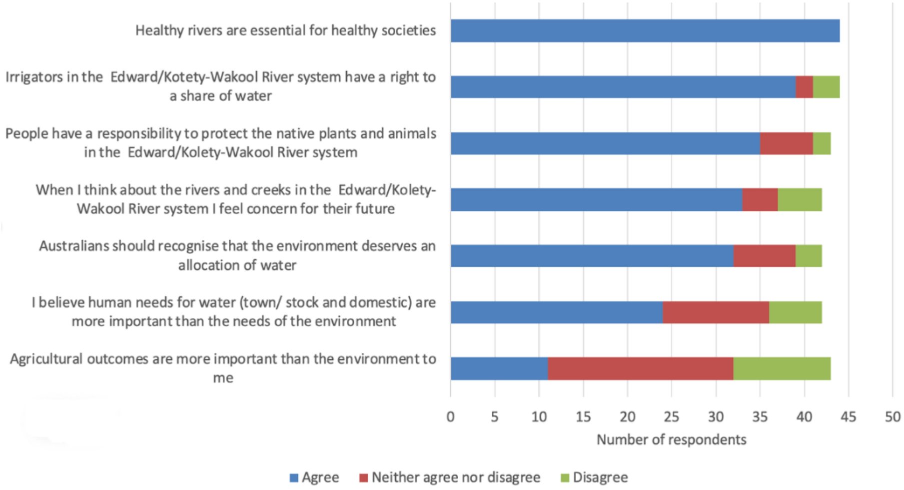

Figure 19 Responses of respondents in the Edward/Kolety-Wakool social survey when asked to respond to statements about their values and beliefs.

The respondents have a good understanding of the roles of various government agencies and groups that have a role in water management in the EKW system, while the trust in those groups is more varied. The qualitative data indicate that dissatisfaction relates to perceptions of low consultation and poor accountability around environmental water, and water in general.

This group of respondents want to know about the responses of animals, plants and water quality to the used of environmental water. They support the focus of existing monitoring programs. The data from the survey suggests:

1. There is potential to use the results of this survey as an object for conversations within the communities (including scientists) associated with this river system and Flow-MER.
2. There is a need to reduce the narrow scientific focus on water for the environment, because the river system communities relate to all of the water.
3. More information about river health and water quality should be available in locally relevant and accessible ways.
4. Continue to work with the expertise and passion that at local people have for the river system.

This survey instrument appears to be valuable, and we recommend that it is used for further exploration of the social acceptability of the use of water for the environment in the EKW system. Involving specific social groups that were under-represented in this report would be valuable. This includes women, Traditional Owners, and water planners/ water managers. Mitchell and Allan (2018) found that over one-third of respondent groups in their NSW based survey took up the recommendation of completing a survey as a group exercise, and this may be needed to increase the number and range of responses if the survey is administered again. Engagement of these groups may also require paper-based survey, offers to assist in group settings, and targeted use of social media.

Communications and engagement

The EKW Environmental Flows Team is committed to undertaking collaborative projects and sharing the findings of monitoring and research with others. Information about the EKW Flow-MER Program is shared through reports, newsletters, the Flow-MER website, the Charles Sturt University Edward/Kolety-Wakool website, and refereed scientific journal publications. We organise and participate in events to share the project findings to managers and the local community. Presentations on the monitoring and research are given to the EKW Environmental Water Reference Group twice per year. Through collaboration with managers and other stakeholders the results from the EKW Flow-MER Program are used to inform the adaptive management of environmental water. Findings from this project have contributed to annual and long-term watering plans for the system.

A key aspect of our engagement strategy is to partner with community organisations on collaborative projects. The research project on turtle populations in the Edward/Kolety River was undertaken in partnership with the Yarkuwa Indigenous Knowledge Centre (Figure 20) (see also section 3, research outcomes). Stories on this turtle research project have featured in newsletters and other publications.

Figure 20 Left: The turtle research team (Photo: Liticia Ross). Right: Measuring the length of a turtle shell (Photo: Graham Stockfeld)

In December 2020 six workshops were held at the Western Murray Land Improvement Group centre in Barham to give primary and secondary students hands-on experience of environmental science and to learn about river monitoring (Figure 21). The workshops were led by Robyn Watts, Nicole McCasker, Xiaoying (Sha sha) Liu and Roseanne Farrant from Charles Sturt University, with wonderful assistance from WMLIG staff. Approximately 150 students from Barham High School, Barham Public School, Moulamein Public School, and Wakool Burraboi Public School attended the workshops. Each session included some short talks as well as some activities so students could use microscopes from Charles Sturt University to look at aquatic bugs and plants and preserved fish larvae. Students also used water quality meters to test water collected from the Murray River, a local wetland and farm dam.

Figure 21 Left Students from Wakool Burraboi Public School looking at aquatic bugs. Right: Students from Barham Public School really enjoyed learning about aquatic bugs and using the microscopes (Photos: R Watts)

In March 2021 a meeting of the EKW Environmental Water Reference Group was held at the Western Murray Land Improvement Group centre in Barham. The members of the Reference Group include local community members and representatives of local organisations with an interest in the delivery of environmental water in the EKW River system. The group provides an opportunity for community representatives, staff of the CEWO and NSW Department of Planning, Industry and Environment (DPIE), and scientists to work collaboratively towards the implementation of environmental watering actions and related monitoring and evaluation activities that will benefit the EKW River system. A highlight of the meeting was a field trip to Pollack Swamp (Figure 22) led by Dan Hutton, Roger Knight, Anthony Jones and Tyrone Jones who have been monitoring outcomes of environmental watering in the swamp.

Figure 22 Members of the Edward/Kolety-Wakool Environmental Water Reference Group visiting Pollack Swamp (Photo: Robyn Watts)

4. Implications for management of environmental water

The Edward/Kolety-Wakool system plays an important role in the mid-Murray River system. The complex network of interconnected streams, ephemeral creeks, flood-runners, wetlands and floodplain forests in the EKW system provide a wide variety of habitats for aquatic life including aquatic plants, waterbugs, tadpoles and frogs, fish and waterbirds. Due to the geomorphological complexity of the system, relatively small volumes of environmental water (compared to Murray River flows) can create flow pulses that inundate low lying areas, providing food and creating newly inundated habitats.

The results from the LTIM and Flow-MER Program have demonstrated that there have been many positive outcomes of environmental watering actions in the EKW system. The watering actions have increased longitudinal and lateral connectivity, increased variability of discharge, maintained water quality, and increased primary productivity, increased germination, flowering and dispersal of riverbank plants, and increased spawning in some fish species. In addition, the sequence of watering actions over several years have contributed to the ongoing fish recruitment outcomes, fish population outcomes, and aquatic plant recovery observed in 2020-21. These outcomes support the long-term recovery of the ecosystem and make the ecosystem resilient to endure future disturbances, such as drought or floods.

There have been some notable outcomes that have not yet been observed in the EKW system in response to environmental watering. Eggs or larvae of golden perch have not been detected over the 8 years of LTIM/Flow-MER, and there has been only a very small number of silver perch eggs and larvae found. The presence of juvenile silver perch in the EKW system does, however, indicate that successful spawning and recruitment of this species is occurring in the southern MDB, but most likely at a much broader geographic scale than the Edward/Kolety Selected Area (see Tonkin et al. 2019). The life cycle of golden and silver perch is considered to require unimpeded flowing water habitats encompassing at least 100's of kilometres. Therefore, delivering environmental water to maintain connectivity within the EKW system and between the EKW system and the mid-Murray River will ensure that bi-directional movement of juveniles and adults of both species will continue to help support recovery of fish populations in the EKW system (Thiem et al. 2017). The CEWO's overarching objective for environmental watering for fish populations in the EKW system was to provide flows to "support habitat (including longitudinal connectivity and bench inundation), food sources and promote increase movement/dispersal, recruitment and survival/condition of native fish". The strategy of maintaining connectivity with the Murray is consistent with objectives.

Recommendations from previous annual reports (2014-2020)

A summary of recommendations from previous Edward/Kolety-Wakool LTIM annual reports (Watts et al. 2015, 2016, 2017b, 2018, 2019) and the 2019-20 Edward/Kolety-Wakool Flow-MER annual report (Watts et al 2020) is provided in Appendix 1 of the 2020-21 Technical Report. These recommendations relate to the use and/or contribution of Commonwealth environmental water to different types of watering actions including:

- Base flows
- Small freshes
- Medium and larger in- channel freshes
- Recession flows

- Winter flows
- Mitigate issues arising during hypoxic blackwater events
- Mitigate issues associated with managed flows operations, including constant regulated flows, (low variability), rapid recession of flows, and winter cease to flow.

Some of the previous flow recommendations refer to specific targeted ecological objectives, such as fish movement, spawning of Murray cod, or river productivity. In previous LTIM/Flow-MER reports there are also some recommendations that have addressed more general aspects of environmental water management, such as the need to implement flow trials, the setting of flow objectives, and the need to improve sources of hydrological data to facilitate the evaluation of environmental watering actions.

Recommendations for management of environmental water

The following ten recommendations are based on findings from this 2020-21 annual report, with some reference made to recommendations and findings in previous reports.

Recommendation 1:

Environmental water delivery in 2020-21 was the closest yet (since the LTIM/Flow-MER Program commenced in 2014) to achieving environmental flows that included the timing, magnitude, duration and extent and provided longitudinal connectivity with other flow freshes in the mid-Murray region required for spawning, recruitment and movement of juvenile golden perch and silver perch. The sequence of flows over spring/summer in 2020-21 also supported the germination and survivorship of riverbank plants that play an important role in stabilising riverbanks, riverine productivity and food webs, and provides habitat for fish, frogs, birds and invertebrates.

Recommendation: Deliver a sequence of flows over the period from late winter/spring/early summer to support the spawning, recruitment and movement of juvenile perch, support aquatic and riverbanks plants, riverine productivity, and provide habitat and food for other aquatic animals.

Recommendation 2:

Although small watering actions have provided a beneficial outcome for the riverine ecosystem productivity, the findings of the stream metabolism evaluation suggest that reconnecting backwaters and the floodplain to the river channel would result in much larger positive productivity outcomes.

Recommendation: Consideration be given to providing a more variable flow regime that reconnects low lying parts of the floodplain to the river channel.

Recommendation 3:

Positive spawning responses of Murray cod during elevated flows in the upper Wakool River were observed in 2018-19, and record numbers of larvae were associated with the delivery of sustained 200 ML/day flows, which commenced from late September 2018 through to January 2019. In 2020-21, a similar increase from base flows was delivered, however this did not commence until 30 November 2020. Monitoring results have shown that the number of Murray cod larvae caught in 2020-21 was the second lowest since monitoring commenced in 2014-15 (second lowest to the 2016-17 during the 2016 flood).

Pre-spawning and nesting behaviour of Murray cod is likely to commence between September and October. In 2018-19 nest-building and spawning would have taken place under 200 ML/day flows, while in 2020-21 flows were still at base levels (50 ML/day) in September. The lower catch rates of Murray cod in the upper Wakool in 2020-21 compared to 2018-19 may have been due to difference in the timing of the two watering actions. The timing of watering action 2 (elevated base flow) in late November 2020 may have been too late for achieving the flow objective.

Consideration of future water delivery to tributaries of the Edward/Kolety-Wakool system that commences in September may be more successful in maximising the availability of suitable nesting areas during the Murray cod breeding season. As trout cod spawn at cooler water temperatures than Murray cod, it may be worth considering introducing an elevated baseflow through the Yallakool and Wakool systems as early as August to support nesting in this species. Consideration of future water delivery of elevated base flows (200 ML/day) to the Upper Wakool River from start of September to maximise nesting and spawning opportunities for Murray cod.

Recommendation: Deliver elevated base flows from the start of September to maximise nesting and spawning opportunities for Murray cod. Record catches of larvae have been recorded in 2018-19 when this type of watering action was delivered.

Recommendation 4:

The ‘2020 Southern Spring Flow’ (SSF) was a river pulse in the Murray River that was designed by timing releases of water for the environment in the Murray, Goulburn and Murrumbidgee rivers to deliver water to five wetlands of international significance, to provide a system-wide productivity boost and improve connectivity down the river to the Coorong and Murray Mouth (SCBEWC, 2021). CEWO (2020) states “Where possible, water for the environment will be managed to benefit multiple sites enroute and will be coordinated with other sources of water”.

Instead of commencing in mid-July, the water delivery for the SSF in 2020 was delayed until October 2020. Due to this delay, all of the planned watering actions in the Edward/Kolety-Wakool were also delayed, because there was an aspiration in CEWO to gain maximum benefit of water from the SSF returning from Millewa Forest to deliver the planned watering actions in the Edward/Kolety-Wakool system. Thus, watering action #1 (spring fresh) in Yallakool-Wakool commenced on 20 October 2020, and watering action #2 (elevated base flow in Wakool-Yallakool system that aimed to maintain nesting habitat for Murray cod) was delayed until 30 Nov to 15th

December. The lower catch rates of Murray cod larvae in the upper Wakool in 2020-21 may have been due to the delayed timing of this watering action (see recommendation 3).

As environmental water delivery from Hume Dam to the Murray River can strongly influence outcomes in the anabranches and distributaries of the Murray River (e.g., the Edward/Kolety-Wakool system) there is a need for a more integrated, system-wide approach to the planning of environmental watering in the Murray River. The watering actions from Hume Dam need to be designed in a holistic manner, with expected outcomes for the anabranches and distributaries included in the planning, with consideration of the benefits and risks of coordinated actions. The planning should include options to enable watering actions to be 'un-linked' if circumstances change and the integrated actions cannot be delivered to achieve the planned outcomes. This would enable environmental watering actions to be independently implemented in parts of the river system, if necessary, to achieve outcomes. This holistic approach will require more complex and integrated planning than has been implemented in previous water years.

Recommendation: Undertake integrated, system wide planning of environmental water actions for the Murray River that includes watering of anabranches and distributaries, such as the Edward/Kolety-Wakool system. Planning should include options to 'un-link' watering actions in different parts of the Murray system if circumstances arise that prevent the integrated actions from being delivered in the way they were initially planned.

Recommendation 5:

In 2020-21 watering action 8 delivered variable base flows to the upper Wakool River to prevent a potential hypoxic water event, provide longitudinal connectivity, flow variability and potential refuge. This watering action produced positive outcomes.

Recommendation: Undertake watering actions to improve the connectivity and aquatic and riverbank vegetation outcomes in the Upper Wakool River. Deliver larger freshes with increased variability to enable riverbank vegetation to establish and be maintained.

Recommendation 6:

Some fish (e.g., flathead gudgeon) and plants may benefit from water delivery in the Edward/Kolety-Wakool system that targets inundation of a greater diversity of creek systems, including distributary ephemeral and intermittent creeks.

Recommendation: Undertake watering actions to improve the connectivity and other outcomes in intermittent and ephemeral streams and flood runners in the Edward/Kolety-Wakool system. Consideration of timing of delivery that reduces opportunities for carp spawning whilst minimising hypoxic blackwater may need to also be taken in account.

Recommendations for future monitoring and research

We make the following four recommendation about communications, monitoring and research in the Edward/Kolety-Wakool system.

Recommendation 7:

The Southern Spring Flow in the Murray River in 2019-20 and 2020-21 resulted in flows returning from Millewa Forest to the Edward/Kolety-Wakool system. Results from 2020-21 monitoring suggest that these return flows had an impact on water quality, productivity and fish outcomes in the Edward/Kolety-Wakool system. At present there is no hydrological model that can provide estimates of daily discharge returns from the Murray watering actions.

Recommendation: Hydrological models be developed that will enable daily returns from Murray River environmental watering actions to be estimated in the Edward/Kolety River, so it is possible to evaluate all sources of environmental water that influence the Edward/Kolety hydrology.

Recommendation 8:

The social research found that more information and research about the social and cultural impacts of using water for the environment would be welcomed by the community. The research also suggested that more information about river health and water quality is sought that is presented in locally relevant and accessible ways. Detailed information about the Flow-MER Program is currently available on websites, but locally focused, locally accessible, and even locally verified or voiced information is also needed. The social research also found that community members considered that the information available about water delivery is disjointed.

Recommendation: Share more information with the community about social and cultural impacts of using water for the environment and present it in locally relevant and accessible ways. When developing communication products about environmental water for the non-technical community, present Information about environmental water in the context of all water in the system.

Recommendation 9:

Several social groups were underrepresented in the social research project undertaken in 2020-21. The under-represented groups were women, Traditional Owners, young people, and water planners/water managers. The current research was undertaken by online survey, and a paper option was available but not taken up. Future social research may require implementation of a different survey options survey, such as offers to assist in group settings, and targeted use of social media to engage these under-represented groups. The research should be co-designed with the community.

Recommendation: Undertake more social research about the social and cultural impacts of using water for the environment, and in particular co-design the research with the community to facilitate the engagement of previously under-represented groups in the community.

Recommendation 10:

The turtle research project was undertaken in collaboration with Wamba Wamba and Perrepa Perrepa Traditional Owners, via the Yarkuwa Indigenous Knowledge Centre. Through this project Traditional Owners were provided training and experience in turtle ecology and conservation methods that they will be able to apply in their own future conservation work in Werai forest. The project facilitated reciprocal learning, as the Traditional Owners also shared their perspectives and knowledge about turtles, wetlands, and conservation.

Recommendation: Future monitoring and research projects should, where possible, be undertaken in collaboration with Traditional Owners and other community groups to facilitate co-learning and engagement of the community in water planning, management, monitoring and research.

5. Acknowledgements

Core monitoring

The authors of this report as well as the Commonwealth Environmental Water Office respectfully acknowledge the Traditional Owners of the Murray-Darling Basin, their Elders past and present, their Nations, and their cultural, social, environmental, spiritual and economic connection to their lands and waters. We are honoured to work on the ancestral lands of the Wamba Wamba or Wemba Wemba, and Perrepa Perrepa or Barapa Barapa People. We recognise their unique ability to care for Country and their deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices. We are committed to genuinely partner and meaningfully engage with Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.

This project was funded by the Commonwealth Environmental Water Office with in-kind contributions from Charles Sturt University, NSW Department of Primary Industries, NSW Office of Environment and Heritage and La Trobe UNiversity. Project partners: Charles Sturt University, NSW Fisheries, NSW Department of Planning, Industry and Environment, La Trobe University, Streamology, Yarkuwa Indigenous Knowledge Centre, Edward-Wakool Anglers Association, Western Murray Land Improvement Group.

We extend our thanks to the Edward/Kolety-Wakool Environmental Water Reference Group, Wakool River Association, Edward/Kolety-Wakool Angling Association, Yarkuwa Indigenous Knowledge Centre Aboriginal Corporation, the Colligen and Niemur Group, Western Murray Land Improvement Group, and landholders in the Edward/Kolety-Wakool River system for their keen interest in this project and for providing access to monitoring sites on their properties.

Thanks to staff from Commonwealth Environmental Water Office, NSW Department of Planning, Industry and Environment, Murray Local Land Services, WaterNSW, Murray-Darling Basin Authority, Murray Irrigation Limited for providing water planning information and access to hydrological and water use data.

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Maps were prepared by Simon McDonald and Deanna Duffy (Charles Sturt University Spatial Analysis Unit). John Pengelly (CSIRO) processed carbon and nutrient samples. Larval and juvenile fish sampling was carried out under NSW Fisheries license (larval fish P19/0006-1.0, juvenile fish P19/0051). Projects were approved by the CSU Animal Care and Ethics Committee (larval fish surveys: A19260, recruitment surveys: A19384). Sampling in the Murray Valley National Park was permitted under the National Parks and Wildlife Act 1974 (Scientific License: SL101403). Adult fish surveys were conducted by DPI Fisheries under Fisheries NSW Animal Care and Ethics permit 14/10.

Turtle research

We acknowledge the Traditional Owners of the lands in which the study took place, and pay respect to Elders past, present, and future. The wetlands and areas researched in this project are the on the lands of the Wamba Wamba and Perrepa Perrepa people.

We are grateful to Jeanette and David Crew and Yarkuwa Indigenous Knowledge Centre for their support of the project. We thank Jason Thiem and the La Trobe Centre for Freshwater Ecosystems for lending the acoustic receivers used in this project. We thank Katie Howard for helping to establish the telemetry network, and Joseph Briggs, John Trethewie, Emma Kynaston, and Angela Simms for fieldwork assistance. We thank Josh Campbell and Jamie Hearn from Murray LLS for additional troubleshooting and assistance. We are grateful to the following people for allowing us to access wetlands via their properties and work sites: Chris McBurnie (Billabong), Barry Doidge (Barratta Farm), Peter Landale (Dahwilly Farm), Ken and Jill Hooper (Moonahcullah property), and Mark Jeffery (Water NSW).

Social Research

We acknowledge the many people who assisted with the research including: Gail Fuller from Charles Sturt University' Spatial Data Analysis Network for creating and managing the on-line survey instrument; Everyone who contributed comments and ideas on early versions of the draft survey; The Murrumbidgee Field Naturalists for piloting the survey; Dr John Xie from Charles Sturt University' Qualitative Consulting Unit for assistance with statistical analysis; And especially everyone who answered the survey; we appreciate you spending your time and sharing your thoughts with us.

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