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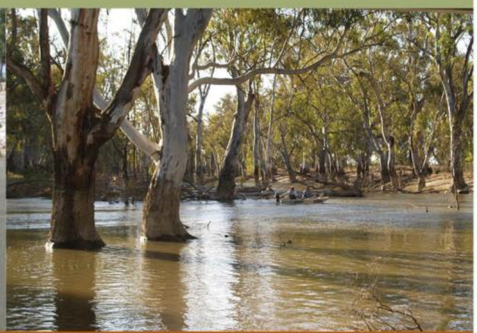

Commonwealth Environmental Water Office Long term Intervention Monitoring project: Edward-Wakool Selected Area Synthesis Report 2014-15

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Executive summary

Background

This synthesis report documents the monitoring and evaluation of ecosystem responses to Commonwealth environmental watering in the Edward-Wakool system in 2014-15. It is the first annual report of the Long Term Intervention Monitoring (LTIM) Project funded by the Commonwealth Environmental Watering Office. This project was undertaken as a collaboration among Charles Sturt University, NSW DPI (Fisheries), Monash University, NSW Office of Environment and Heritage, Griffith University and Murray Local Land Services. Field sampling for this project was undertaken by staff from Charles Sturt University, NSW DPI (Fisheries), NSW Office of Environment and Heritage, and Murray Local Land Services. Murray Local Land Services coordinated several community activities so community members were informed about this project and had the opportunity to provide input to the project.

This report provides details of the watering actions, indicators, methodology, and an assessment of short-term ecosystem responses to environmental watering in 2014-15 with respect to the objectives set by the Commonwealth Environmental Water Office. Evaluation of responses across multiple years will be undertaken in subsequent reports. The findings underpin recommendations on the timing, duration and magnitude of flow to help inform the adaptive management of future environmental flows in this system. A detailed analysis and presentation of results from the monitoring is presented in the Edward-Wakool LTIM Project Technical Report 2014-15 (Watts et al. 2015).

Commonwealth environmental watering actions in the Edward-Wakool system in 2014-15

Three Commonwealth environmental watering actions were undertaken in the Edward-Wakool System in 2014-15:

- Yallakool Creek-Wakool River watering action between August 2014 and January 2015. The watering action objectives for this action, as defined by CEWO, were that It was expected that this action will i) support inundation of Murray cod nesting sites and contribute to maximising Murray cod recruitment, ii) contribute to improved opportunities for movement, condition, reproduction and recruitment of native fish, iii) increase hydrological connectivity, including inundation of slackwater habitats areas downstream of the Yallakool-Wakool confluence, providing opportunities for recruitment of small bodied native fish, frogs and shrimp, iv) maintain/improve vegetation condition, including fringing vegetation and emergent/submerged aquatic plants, v) maintain/improve water quality within the system, particularly dissolved oxygen, salinity and pH, and vi) contribute to maximising outcomes in the Wakool from outflows from Koondrook-Perricoota and provide greater volume of receiving water.

- Tuppal Creek watering action (partnered with NSW environmental water) in spring (October to November 2014) and autumn (March to April 2015) to contribute to providing habitat for native fish and frogs, improving water quality and providing connectivity between the remnant pools, and
- Colligen Creek watering action in January 2015 which used contingency flows to provide a slow recession to a high flow peak caused by a rain rejection event for native fish and vegetation outcomes.

The Tuppal Creek and Colligen Creek watering actions were not monitored as part of the Edward-Wakool LTIM Project, and hence have not been described or evaluated in this report. The Yallakool Creek-Wakool River environmental watering action is the focus of this synthesis report and the technical report (Watts et al. 2015).

The monitoring for the Edward-Wakool LTIM Selected Area Evaluation focussed on four hydrological zones: Yallakool Creek (zone 1), the upper Wakool River (zone 2) and mid reaches of the Wakool River (zones 3 and 4). Indicators monitored in 2014-15 were: river hydrology, riverbank inundation by 2D-hydraulic modelling, stream metabolism and instream primary productivity, water quality and carbon, riverbank and aquatic vegetation, fish reproduction, fish recruitment, and fish community.

Outcomes of Commonwealth environmental watering

Commonwealth environmental water delivered to the Edward-Wakool system had the following positive outcomes in river reaches receiving environmental water (Table i):

- increased variation in discharge,
- maintained dissolved oxygen levels and ecosystem respiration,
- increased in-channel longitudinal connectivity
- Increased lateral connectivity - there was an increase in wetted benthic area and area of slackwater and slow water in Wakool River zones 3 and 4 but not in Yallakool Creek zone 1
- increased cover and diversity of instream aquatic vegetation, particularly in Wakool River zones 3 and 4, but not consistently in Yallakool Creek zone 1.
- Increased the diversity of native fish with one new species, *Galaxias oliros* (obscure galaxias) recorded in Yallakool Creek.

There was one negative response observed in 2014-15, being a reduction in the area of slackwater in Yallakool Creek during watering actions compared to area of available slackwater during base flows (Table i). This finding was consistent with observations in 2013-14 (Watts et al 2014) of a lower abundance of shrimp larvae in Yallakool Creek during the environmental watering. Shrimp were not monitored as part of the LTIM Project, but it is expected that the increased area of fast flows in Yallakool Creek will have had a negative effect on larval shrimp, and the the increase in slack water and slow water in zones 3 and 4 will have had a positive outcome for shrimp and other taxa in those zones that require slow flowing water for recruitment and survival.

There were a number of indicators where there was no detectable response to environmental watering (Table i). Although hydraulic modelling demonstrated that environmental watering increased wetted benthic area in some reaches, this increase was not sufficient to trigger an increase in gross primary productivity. Fish spawning, and recruitment indicators assessed in 2014-15 did not respond to environmental watering action. Although there is good evidence that fish reproduction occurs in this system, the spawning response could not be attributed to the watering action because a similar level of reproduction occurred in the Wakool River (zone 2) that did not receive environmental water. Although there is evidence of some recovery in the fish community in areas impacted by the blackwater events in 2010-2012, some of the improvement in the fish community is likely to be due to other factors, such as immigration of fish into the system.

The responses to Commonwealth environmental watering observed in 2014-15 were consistent with those observed previously in this system. The good outcomes for dissolved oxygen and aquatic vegetation will help to improve the system for longer term benefits to be realised, providing habitat for invertebrates and small bodied fish and potentially improving riverine productivity. Good dissolved oxygen levels and increased instream habitat are essential for the long-term health of this system and could lead to improved outcomes for fish in the longer term.

The environmental watering that was implemented during the blackwater events of 2010 to 2012 mitigated extreme low dissolved oxygen concentrations (Watts et al. 2013) and created an area of refuge habitat and water quality conditions to avoid critical loss of fish in the upper reaches of the Wakool River and Yallakool Creek. The benefits of those watering actions area still evident, with fish populations in the upper reaches of the system having higher biomass than the populations in the lower reaches. The long-term recovery of fish populations in this system is ongoing. Some of the benefits of the Commonwealth environmental watering actions are expected to be realised over a much longer time frame and should not be expected to eventuate from a single flow action.

Table i. Summary of ecosystem responses to Commonwealth environmental watering in the Edward-Wakool system in 2014-15. Green shading indicates positive response, red shading indicates negative response, grey shading indicates no detectable response (either positive or negative) to environmental watering. White boxes indicate no evaluation was undertaken. N/A = not evaluated. (Source: Watts et al 2015)

Indicators	Dependant variable	Short-term response to Yallakool Creek e-watering event (Aug 2014-Jan 2015) (< 1 year)	Response to e-watering assessed across 2014-15 watering year (1 year)	Longer-term response to e-watering (assessed across 1-5 years)
Hydrology	Hydrological connectivity			N/A TO BE ASSESSED IN YEARS 2 TO 5 OF THE LONG-TERM INTERVENTION MONITORING PROJECT
	Coefficient of variation of discharge	N/A	Zone 3 and 4 only	
Hydraulic modelling	In-channel wetted benthic area		N/A	
	Area of slackwater	Zone 3 and 4 only	N/A	
	Area of slow flowing water	Zone 3 and 4 only	N/A	
	Area of fast flowing water	Zone 1		
Stream metabolism, water quality, and organic matter characterisation	Rates of gross primary productivity			
	Rates of ecosystem respiration			
	Rates of primary productivity			
	Dissolved organic matter			
	Dissolved oxygen			
	Temperature			
	Nutrient concentration			
	Modification of type and amount of DOM			
Riverbank and aquatic vegetation	Percent cover of riverbank and aquatic vegetation	N/A		
	Diversity of riverbank and aquatic vegetation	N/A		
Fish movement	Native fish survival, dispersal and synchronised movement	N/A	N/A	
Fish spawning and reproduction	Diversity of native fish	N/A		
	Abundance of 'Opportunistic' (e.g. small bodied fish) species	N/A		
	Abundance of 'flow-dependent' spawning species (e.g. golden and silver perch)	N/A		
Fish recruitment	Growth rate of young-of-year (YOY) and age-class 1 (1+) Murray cod	N/A		
	Recruitment of young-of-year (YOY) and age-class 1 (1+) Murray cod	N/A		
Fish community	Fish condition	N/A	N/A	
	Fish recovery	N/A	N/A	

Assessment of outcomes against the Commonwealth environmental watering objectives

An assessment of the outcomes against the ecological objectives for 2014-15 in the Edward-Wakool system outlined in the Water Use Minute 10008 (CEWO, 2014) is presented in Table ii and an assessment of outcomes against the specific objectives for the Yallakool Creek environmental watering action in 2014-15 is provided in Table iii. Some of the watering objectives were achieved, some were not achieved and some were not assessed in the Edward-Wakool system in 2014-15. In both of these assessments the water quality and vegetation objectives were met. The lateral and longitudinal connectivity objectives were met at some sites, but not consistently throughout all zones. The objectives for reproduction and recruitment of native fish were not achieved by the Yallakool Creek environmental watering action in 2014-15.

Table ii. Assessment of outcomes of Commonwealth environmental watering in the Edward-Wakool system in 2014-15 against the broad environmental watering objectives outlined in water use Minute 10008. Green shading indicates positive response, red shading indicates negative response, grey shading indicates no detectable response (either positive or negative) to environmental watering. White boxes indicate no evaluation was undertaken.

Commonwealth environmental watering objective from Water Use Minute 10008	Objective achieved or not achieved
Improve the diversity and condition of native fish and other native species including frogs, turtles and invertebrates through maintaining suitable habitat and providing/supporting opportunities to move, breed and recruit	Improved diversity of native fish, with one new species detected
	Diversity and condition of frogs, turtles and invertebrates not assessed
	Improvement in reproduction and recruitment of native fish not achieved
Improve habitat quality in ephemeral watercourses	Ephemeral watercourses not assessed
Support mobilisation, transport and dispersal of biotic and abiotic material (e.g. sediment, nutrients and organic matter) through longitudinal and lateral hydrological connectivity	Mobilisation, transport and dispersal not assessed
	Increased longitudinal connectivity. Increased lateral connectivity at some sites
Support inundation of low-lying wetlands/floodplains habitats within the system	Inundation of low lying in-channel features at some sites
Maintain health of riparian, floodplain and wetland native vegetation communities	Floodplain and wetland vegetation not assessed.
	Cover and diversity of riverbank and aquatic vegetation was improved at most sites
Contribute to a more natural wetting-drying cycle for ephemeral wetlands and watercourses	Not assessed
Maintain/improve water quality within the system, particularly dissolved oxygen, salinity and pH	Concentration of dissolved oxygen and rates of ecosystem respiration was maintained in reaches receiving environmental water
Improve ecosystem and population resilience through supporting ecological recovery and maintaining aquatic habitat	Aquatic habitat (aquatic vegetation, slackwater) was maintained at most sites receiving environmental water
	Reduced area of slackwater in Yallakool Creek

Table iii. Assessment of outcomes of Commonwealth environmental watering against the environmental watering objectives defined for the Yallakool Creek environmental watering action in 2014-15. Green shading indicates positive response, red shading indicates negative response, grey shading indicates no detectable response (either positive or negative) to environmental watering. White boxes indicate no evaluation was undertaken.

Commonwealth environmental watering objective for the Yallakool Creek environmental watering action	**Objective achieved or not achieved**
Support inundation of Murray cod nesting sites and contribute to maximising Murray cod recruitment	Extent of inundation of Murray cod nesting sites not assessed, but it is expected that the environmental flow inundated nests
	No detectible improvement in Murray cod recruitment
Contribute to improved opportunities for movement, condition, reproduction and recruitment of native fish	Fish movement not assessed in 2014-15
	No detectible improvement in reproduction or recruitment of native fish
Increase hydrological connectivity, including inundation of slackwater habitats areas downstream of the Yallakool-Wakool confluence, providing opportunities for recruitment of small bodied native fish, frogs and shrimp	There was increased longitudinal connectivity. There was increased lateral hydrological connectivity at some sites
	Reduced area of slackwater in Yallakool Creek
Maintain/improve vegetation condition, including fringing vegetation and emergent/submerged aquatic plants	Cover and diversity of riverbank and aquatic vegetation was improved at most sites
Maintain/improve water quality within the system, particularly dissolved oxygen, salinity and pH	Concentration of dissolved oxygen and rates of ecosystem respiration was maintained in reaches receiving environmental water
Contribute to maximising outcomes in the Wakool from outflows from Koondrook-Perricoota and provide greater volume of receiving water	Not assessed, because a planned outflow from Koondrook-Perricoota by NSW Forestry did not occur

Recommendations and application through adaptive management into 2015-16 use of Commonwealth environmental water

The ten recommendations listed below include, where applicable, a note to indicate if the recommendation has been applied (as at 31 October 2015) in the 2015-16 use of Commonwealth environmental water in the Edward-Wakool system (commenced on 4 September 2015). A detailed explanation of these recommendations is provided in Watts et al. (2015).

Recommendation 1. Increase the duration of the recession of Commonwealth environmental watering actions relative to the Yallakool Creek environmental watering actions in 2012-13 and 2013-14.

Adaptive management response in 2015-16: This recommendation has been applied in the 2015-16 use of Commonwealth environmental water in the Yallakool Creek and Colligen Creek-Niemur River watering actions, particularly to maximise outcomes for instream aquatic vegetation. For example, the recession period for 2015-16 flows in Yallakool Creek was over nine weeks compared to four weeks in 2014-15.

Recommendation 2. Avoid long periods of constant flows by commencing the recession of environmental watering actions earlier and introducing flow variability into environmental watering actions.

Adaptive management response in 2015-16: This recommendation has been applied in the 2015-16 use of Commonwealth environmental water in the Yallakool Creek, Wakool River and Colligen Creek-Niemur River watering actions. For example, in 2015-16 the River Operator (Water NSW) was provided with an 'operating range' during the period when constant flows were most likely to occur. This trialled the use of the 'operating range' to improve flow variability at a small scale whilst not risking the ability to achieve other targeted outcomes, such as providing nesting habitat for Murray cod. Colligen Creek is likely to have increased levels of variability compared to other systems due to the River Operator passing rain rejection or other operational flows through the creek. Monitoring and evaluation of 2015-16 watering actions will inform the development of the 'operating range' in future watering actions.

Recommendation 3. Consider a trial of shifting the focus of the delivery of environmental water from Yallakool Creek to the Wakool River to achieve ecosystem outcomes and at the same time facilitate learning about the system.

Adaptive management response in 2015-16: During 2015-16 environmental water planning this recommendation was considered, and a small volume of Commonwealth environmental water was delivered to the upper Wakool River to maximise outcomes for instream aquatic vegetation and the potential movement of native fish. However, the full recommendation of shifting the focus of environmental watering from Yallakool Creek to the upper Wakool River has not yet been trialled.

Recommendation 4. Consider the delivery of base environmental flows during autumn and winter to promote the temporal availability and continuity of instream habitat.

Recommendation 5. Continue to include a water use option in environmental water planning that enables Commonwealth environmental water to be used to mitigate adverse water quality events.

Adaptive management response in 2015-16: This recommendation has been applied in the 2015-16 planning for the use of Commonwealth environmental water in the Edward-Wakool River system, especially to contribute to contingency responses to hypoxic blackwater events should they occur.

Recommendation 6. Set watering action objectives that identify the temporal and spatial scale at which the response is expected and are realistic given the magnitude of environmental watering actions proposed.

Adaptive management response in 2015-16: This recommendation has been applied in the setting of objectives for the planned use of Commonwealth environmental water in the Edward-Wakool River system during 2015-16. Objectives now reflect the maintaining/supporting role from the use of Commonwealth environmental water in the Edward-Wakool River system.

Recommendation 7. Consider the implementation of a short duration environmental flow trial in late winter/spring 2016 at a higher discharge than the current constraint of 600 ML/day (possibly up to 1000 to 1200 ML/day). This would facilitate a test of the hypothesis that larger in-channel environmental watering action will result in increased river productivity.

Recommendation 8: Consider the implementation of an environmental watering action in the Edward River to target golden perch and silver perch spawning, as this is a larger system that does not have the same level of delivery constraints as the Wakool-Yallakool system.

Recommendation 9. Undertake comprehensive flows assessment for the smaller creeks and rivers of the Edward-Wakool system.

Recommendation 10. Collaborate with other management agencies and the community to maximise the benefits of Commonwealth environmental watering actions

Adaptive management response in 2015-16: This recommendation has been applied in the use of Commonwealth environmental water in the Edward-Wakool River system during 2015-16. The use of Commonwealth environmental water to provide slower, more natural rates of recessions to high flow events (e.g. rain rejections and other operational flows) is an example of this.

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1. BACKGROUND

1.1 Purpose of this report

This is the first annual report of the five year Long Term Intervention Monitoring (LTIM) Project in the Edward-Wakool system. Being the first year of this program, this report provides a synthesis and summary of short-term responses to environmental watering in 2014-15. A detailed evaluation is available in the 2014-14 Edward-Wakool LTIM Technical Report (Watts et al. 2015). Evaluation of ecosystem responses to Commonwealth environmental watering across multiple years will be undertaken in subsequent years. This report builds on previous short-term monitoring projects undertaken in the Edward-Wakool system since 2010 (Watts et al. 2013a, Watts et al. 2013b, Watts et al. 2014).

1.2 The Edward-Wakool system

The Edward-Wakool system is a large anabranch system of the Murray River main channel in the southern Murray-Darling Basin, Australia. It is a complex network of interconnected streams, ephemeral creeks, flood-runners and wetlands including the Edward River, Wakool River, Yallakool Creek, Colligen-Niemur Creek and Merran Creek. The Edward-Wakool system 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 Edward-Wakool river ecosystem is recovering from the impact of the Millenium drought in south-eastern Australia when flows in the Murray-Darling Basin were at record low levels. The regulators controlling flows from the Edward River into tributary rivers, such as Yallakool Creek and the Wakool River, were closed between February 2006 and September 2010. In 2007-08 there was a blackwater event that resulted in the loss of many thousands of native fish. At the break of the drought a number of unregulated flow events occurred in the Edward-Wakool system between September 2010 and March 2011 resulting in another backwater event.

1.3. Hydrological regime of the Edward-Wakool system

Like many rivers of the Murray-Darling Basin, the flow regimes of the Edward-Wakool system has been significantly altered by river regulation (Green 2001; Hale and SKM 2011). The hydrology of the Edward-Wakool system is tightly linked with the hydrology of the River Murray and the management of flows at Yarrawonga Weir. Comparison of long-term modelled flow data for pre-development and post development scenarios for the Edward River shows that natural flows in this system are strongly seasonal, with high flows occurring typically from July to November (Figure 1). Flow regulation has resulted in a marked reduction in winter high flows, including both extreme high flow events, but also average daily flows during the winter period. In addition, there has been an increase in daily flows during the low-flow months (January to March).

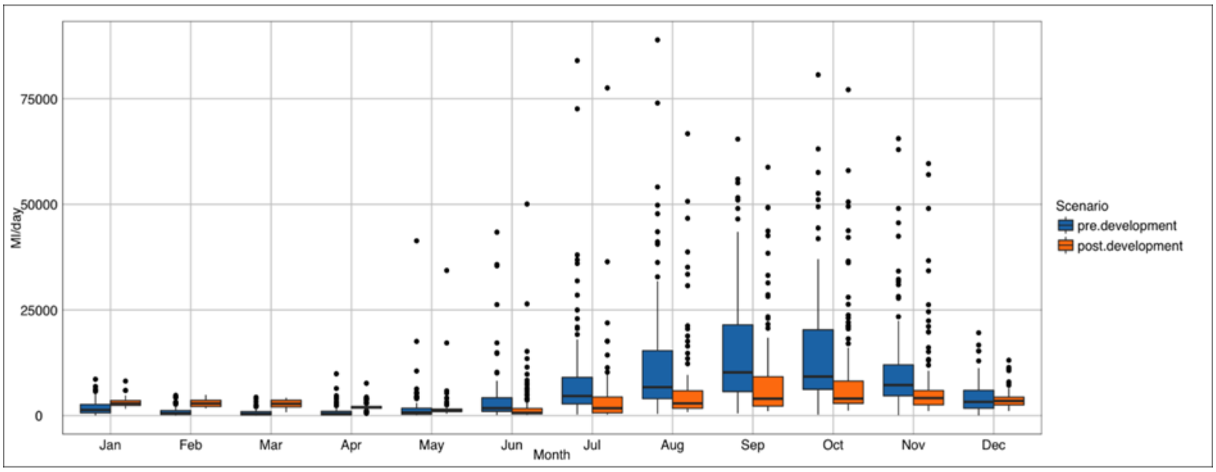


Figure 1. Boxplots of mean daily flow by month for the Edward River at Deniliquin. (Source: Watts et al 2015).

2. Commonwealth environmental water use objectives for the Edward-Wakool system, 2014-15

The 2014-15 Commonwealth environmental watering action objectives for the Edward-Wakool system, as outlined in the Water Use Minute 10008, were as follows:

- improve the diversity and condition of native fish and other native species including frogs, turtles and invertebrates through maintaining suitable habitat and providing/supporting opportunities to move, breed and recruit
- improve habitat quality in ephemeral watercourses
- support mobilisation, transport and dispersal of biotic and abiotic material (e.g. sediment, nutrients and organic matter) through longitudinal and lateral hydrological connectivity
- support inundation of low-lying wetlands/floodplains habitats within the system
- maintain health of riparian, floodplain and wetland native vegetation communities
- contribute to a more natural wetting-drying cycle for ephemeral wetlands and watercourses
- maintain/improve water quality within the system, particularly dissolved oxygen, salinity and pH
- improve ecosystem and population resilience through supporting ecological recovery and maintaining aquatic habitat.

3. Commonwealth environmental watering actions in the Edward-Wakool system in 2014-15

Commonwealth environmental water has been delivered to rivers in the Edward-Wakool system since 2010. Over that time instream freshes were delivered to Yallakool Creek and Colligen Creek in 2011-12, 2012-13 and 2013-14 (Watts et al. 2013a; 2013b, 2014a). In addition, Commonwealth environmental water was delivered from the Edward River and/or from irrigation escapes on several occasions to improve water quality and create refuge during poor water quality events.

Three Commonwealth environmental watering actions were undertaken for the Edward-Wakool System in 2014-15; i) Yallakool Creek-Wakool River watering action between August 2014 and January 2015, ii) Tuppal Creek watering action (partnered with NSW environmental water) in spring (October to November 2014) and autumn (March to April 2015), and iii) Colligen Creek watering action in January 2015. The Tuppal Creek and Colligen Creek watering actions were not monitored as part of the Edward-Wakool LTIM Project, and hence have not been described or evaluated in this report. The effects of the Yallakool Creek environmental watering action will be the focus of this report.

Yallakool Creek Environmental Watering Action (Aug 2014 – January 2015)

A cod maintenance watering option was developed for Yallakool Creek for 2014-15 (Figure 2.1, CEWO 2014) that was similar to a watering action undertaken in 2013-14 in this system. It was planned that Commonwealth environmental water would contribute about 500 ML/day in Yallakool Creek through to the end of the cod spawning season. In the absence of natural high inflows, it was planned that environmental water would be delivered to provide an early season pulse to 'prime' the channel and contribute to a more natural flow regime (CEWO 2014)(Figure 2.2).

The watering action objectives for this action were defined by CEWO on 22 July. It was expected that this action will:

- support inundation of Murray cod nesting sites and contribute to maximising Murray cod recruitment
- contribute to improved opportunities for movement, condition, reproduction and recruitment of native fish
- increase hydrological connectivity, including inundation of slackwater habitats areas downstream of the Yallakool-Wakool confluence, providing opportunities for recruitment of small bodied native fish, frogs and shrimp

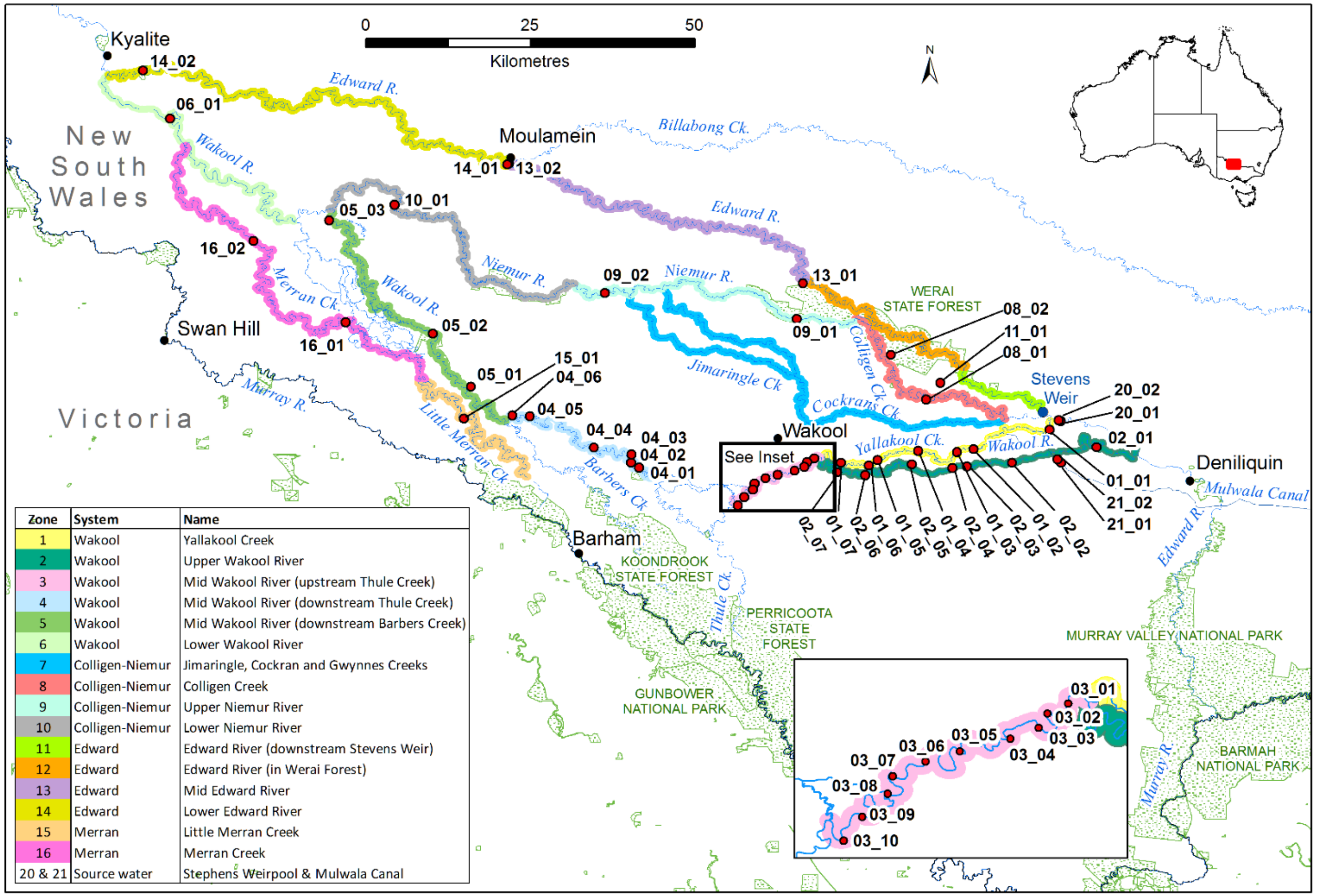
- maintain/improve vegetation condition, including fringing vegetation and emergent/submerged aquatic plants
- maintain/improve water quality within the system, particularly dissolved oxygen, salinity and pH
- contribute to maximising outcomes in the Wakool from outflows from Koondrook-Perricoota and provide greater volume of receiving water.

Following a series of high unregulated inflow events in July 2014, flows started to pass through the Edward-Wakool system, including overbank flows into Werai and flows to both Colligen and Yallakool Creeks. On the back of these tributary inflows, use of Commonwealth environmental water commenced earlier than planned to synchronise with naturally occurring high flows and the potential that, despite low water temperatures, large bodied native fish may have commenced moving into breeding habitat and nesting sites. The watering action in Yallakool Creek (zone 1) commenced on 12 August 2014 and there was an extended in-channel fresh of approximately 500 ML/day from August until 16 December 2014, followed by a recession of about 40cm over 30 days until it reached operational flows in the range of 200 to 240 ML/day. The action was completed on 15 January 2015. The total Commonwealth environmental water delivery for this action was 34,561 ML.

4. Monitoring and Evaluation

The monitoring of ecosystem responses to environmental watering in the Edward-Wakool system in 2014-15 was undertaken as outlined in the Edward-Wakool Long-Term Intervention Monitoring and Evaluation Plan (Watts et al 2014b). The majority of the monitoring is focussed on four hydrological zones: Yallakool Creek (zone 1), the upper Wakool River (zone 2) and mid reaches of the Wakool River (zones 3 and 4)(Figures 2, 3). In addition to the fish population surveys undertaken annually in these four zones, a further 15 sites throughout the Edward-Wakool system will be surveyed for fish populations in years 1 and 5 (Figure 2, Table 1).

Indicators were monitored to contribute to the Edward-Wakool Selected Area Evaluation and/or the Whole of Basin scale evaluation that is being undertaken by the Murray-Darling Freshwater Research Centre (Hale et al 2014). Indicators monitored in the Edward-Wakool for the LTIM Project are described in Watts et al (2014b) and include: river hydrology, riverbank inundation by 2D-hydraulic modelling, stream metabolism, water quality and carbon, riverbank and aquatic vegetation, fish reproduction, fish recruitment, fish community, and fish movement (not monitored in 2014-15 but will be monitored from July 2015). Many of the indicators are expected to respond to environmental watering in short time frames (< 1 year), but others (e.g. the fish community) are included as longer term indicators that are expected to respond over 2 to 5 year time frame.



Created by Spatial Data Analysis Network, Charles Sturt University, May, 2015

Data Source: NSW "Place Point" & "Hydroline" spatial data: Digital Cadastral Database [CD-ROM]. LPMA, 2008, New South Wales; Australian Reserves GEODATA TOPO 250K Series 3, 2006, OEH NSW National Parks 2012

Figure 2. Location of monitoring sites for the Edward-Wakool Selected Area for the Long-Term Intervention Monitoring (LTIM) Project. Zones one to four are referred to as the focal zone for the Edward-Wakool project. Hydrological gauges are located in Yallakool Creek just upstream of site 01_01 (gauge 409020, Yallakool Creek at offtake), Wakool River zone 2 just upstream of site 02_01 (gauge 409019, Wakool River offtake), and in the Wakool River zone 4 at site 04_01 (gauge 409045, Wakool River at Wakool-Barham Road). The Wakool escape is located close to site 21_01. Site names are listed in Table 1.

Table 1. List of site codes and site names for sites monitored for the Long term Intervention Monitoring (LTIM) Project in the Edward-Wakool Selected Area.

Zone Name	Zone	Site Code	Site Name
Yallakool Creek	01	EDWK01_01	Yallakool/Back Ck Junction
Yallakool Creek	01	EDWK01_02	Hopwood
Yallakool Creek	01	EDWK01_03	Cumnock
Yallakool Creek	01	EDWK01_04	Cumnock Park
Yallakool Creek	01	EDWK01_05	Mascott
Yallakool Creek	01	EDWK01_06	Widgee, Yallakool Ck
Yallakool Creek	01	EDWK01_07	Windra Vale
Upper Wakool River	02	EDWK02_01	Fallonville
Upper Wakool River	02	EDWK02_02	Yaloke
Upper Wakool River	02	EDWK02_03	Carmathon Reserve
Upper Wakool River	02	EDWK02_04	Emu Park
Upper Wakool River	02	EDWK02_05	Homeleigh
Upper Wakool River	02	EDWK02_06	Widgee, Wakool River1
Upper Wakool River	02	EDWK02_07	Widgee, Wakool River2
Mid Wakool River (upstream Thule Creek)	03	EDWK03_01	Talkook
Mid Wakool River (upstream Thule Creek)	03	EDWK03_02	Tralee1
Mid Wakool River (upstream Thule Creek)	03	EDWK03_03	Tralee2
Mid Wakool River (upstream Thule Creek)	03	EDWK03_04	Rail Bridge DS
Mid Wakool River (upstream Thule Creek)	03	EDWK03_05	Cummins
Mid Wakool River (upstream Thule Creek)	03	EDWK03_06	Ramley1
Mid Wakool River (upstream Thule Creek)	03	EDWK03_07	Ramley2
Mid Wakool River (upstream Thule Creek)	03	EDWK03_08	Yancoola
Mid Wakool River (upstream Thule Creek)	03	EDWK03_09	Llanos Park1
Mid Wakool River (upstream Thule Creek)	03	EDWK03_10	Llanos Park2
Mid Wakool River (downstream Thule Creek)	04	EDWK04_01	Barham Bridge
Mid Wakool River (downstream Thule Creek)	04	EDWK04_02	Possum Reserve
Mid Wakool River (downstream Thule Creek)	04	EDWK04_03	Whymoul National Park
Mid Wakool River (downstream Thule Creek)	04	EDWK04_04	Yarranvale
Mid Wakool River (downstream Thule Creek)	04	EDWK04_05	Noorong1
Mid Wakool River (downstream Thule Creek)	04	EDWK04_06	Noorong2
Mid Wakool River (downstream Barbers Creek)	05	EDWK05_01	La Rosa
Mid Wakool River (downstream Barbers Creek)	05	EDWK05_02	Gee Gee Bridge
Mid Wakool River (downstream Barbers Creek)	05	EDWK05_03	Glenbar
Lower Wakool River	06	EDWK06_01	Stoney Creek Crossing
Colligen Creek	08	EDWK08_01	Calimo
Colligen Creek	08	EDWK08_02	Werrai Station
Upper Neimur River	09	EDWK09_01	Burswood Park
Upper Neimur River	09	EDWK09_02	Ventura
Lower Niemur River	10	EDWK10_01	Niemur Valley
Edward River (downstream Stephens Weir)	11	EDWK11_01	Elimdale
Mid Edward River	13	EDWK13_01	Balpool
Mid Edward River	13	EDWK13_02	Moulamien US Billabong Creek
Lower Edward River	14	EDWK14_01	Moulamien DS Billabong Creek
Lower Edward River	14	EDWK14_02	Kyalite State Forest
Little Merran Creek	15	EDWK15_01	Merran Downs
Merran Creek	16	EDWK16_01	Erinundra
Merran Creek	16	EDWK16_02	Merran Creek Bridge
Edward River, Stevens weir	20	EDWK20_01	Weir1
Edward River, Stevens weir	20	EDWK20_02	Weir2
Mulwala canal	21	EDWK21_01	Canal1
Mulwala canal	21	EDWK21_02	Canal2

Yallakool Creek 11/11/2014, 496 ML/day (e-flow)   2/3/2015, 335 ML/day (no e-flow)

Wakool River (zone 2) 11/11/2014, 92 ML/day (no e-flow)   2/3/2015, 69 ML/day (no e-flow)

Wakool River (zone 3) 10/11/2014, 441 ML/day (e-flow)   3/3/2015, 222 ML/day (no e-flow)

Wakool River (zone 4) 10/11/2014, 402 ML/day (e-flow)   2/3/2015, 217 ML/day (no e-flow)

Figure 3. Photos of study sites in the four hydrological zones in November 2014 during the environmental watering (zones 1, 3 and 4) and in March 2015 during operational flows. Yallakool Creek (zone 1), Wakool River (zone 2) Wakool River upstream of Thule Creek (zone 3) and Wakool River downstream of Thule Creek (zone 4).

5. Hydrological responses to Commonwealth environmental watering in 2014-15

The hydrology of zones 1 to 4 was examined from July 1 2014 to June 30 2015. The following questions were addressed:

Q1: *What is the effect of Commonwealth environmental water on the hydrology of the four zones in the Edward-Wakool system that were monitored for the Long Term Intervention Monitoring project?*

Q2: *What did Commonwealth environmental water contribute to hydrological connectivity*?

Daily discharge data for automated gauges in zones 1, 2 and 4 was obtained from New South Wales Office of Water website. Discharge data for the Wakool escape and daily usage of Commonwealth environmental water were obtained from WaterNSW. The daily discharge data for zone 3 was estimated by combining daily discharge data from Yallakool Creek regulator, Wakool offtake and the Wakool escape with adjustment to account for travel time and estimated losses.

There were three different hydrological regimes observed the focal area in 2014-15 (Figure 4):

i) In Yallakool Creek zone 1 there was extended in-channel fresh of approximately 500 ML/day from August until the end of December 2014, followed by a recession to operational flows in the range of 200 to 240 ML/day.
ii) In Wakool River zone 2 there was an extended period of base operational flows in the range of 50 to 100 ML/day between August and March followed by an operational fresh in March and April 2014 of approximately 300 to 330 ML/day that had both a steep rise and recession
iii) In zones 3 and 4 in the Wakool River there was an extended in-channel fresh of approximately 450 ML/day from August until the end of December followed by a recession to operational flows in the range of 200 to 240 ML/day. This was followed by an operational fresh in March and April 2014 of approximately 300 to 330 ML/day that had both a steep rise and recession

The Commonwealth environmental water increased the maximum, mean, median and variation of discharge in Yallakool Creek and the Wakool River zones 3 and 4. The watering action achieved the objective set by the CEWO of creating a maintenance flow in Yallakool Creek and the Wakool River zones 3 and 4 of about 500 ML/day. The environmental watering action in Yallakool Creek contributed to longitudinal connectivity in the upper and mid sections of the Wakool River, influencing the downstream hydrograph as far as Gee Gee Bridge. However the influence of Commonwealth environmental water was diminished at the Coonamit and Stoney Crossing gauges, as these reaches are more strongly influenced by flows from the River Murray.

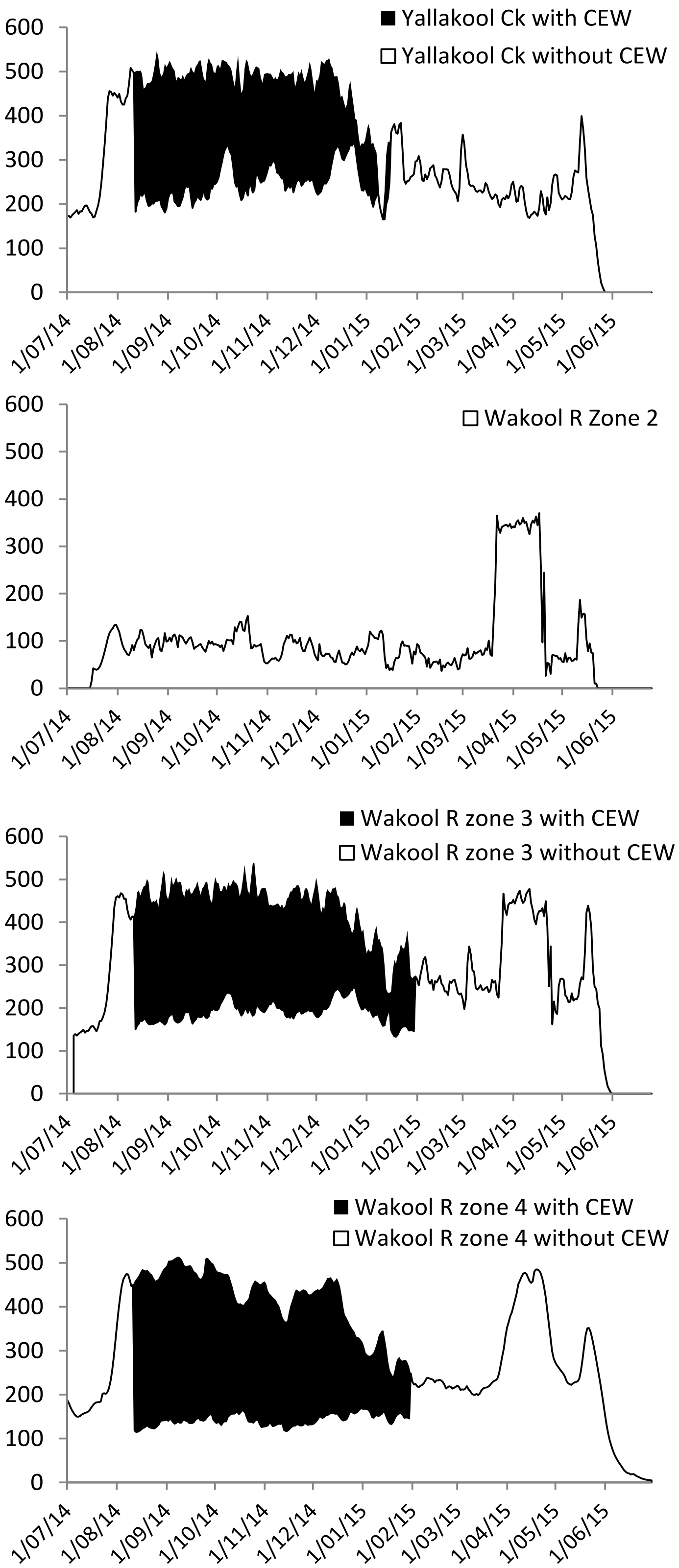


Figure 4. Hydrographs of zones 1 Yallakool Creek, and zones 2, 3 and 4 in the Wakool River for the period from 1 July 2014 to 30 June 2015. The portion of the hydrographs coloured black is attributed to the delivery of Commonwealth Environmental Water (CEW). There was an unregulated flow in zones 1, 3 and 4 in August. The MDBA operational flow from the Wakool Escape is evident in the hydrograph of zones 2, 3 and 4 in March.

6. CHANGES IN HYDRAULIC HABITAT IN RESPONSE TO COMMONWEALTH ENVIRONMENTAL WATERING

A two-dimensional hydraulic model was generated for nineteen reaches; five in Yallakool Creek, five in the Wakool River (zone 2), four in Wakool River upstream of Thule Creek (zone 3) and five in the Wakool River downstream of Thule Creek (zone 4). The model was used to estimate the extent of wetted benthic surface area and the area of three velocity zones for seven discharge scenarios, ranging from low flows to bankfull flows.

The following questions were addressed:

Q1: *What did Commonwealth environmental water contribute to the in-channel wetted benthic area?*

Q2: *What did Commonwealth environmental water contribute to the area of slackwater and slow flowing water?*

Q3: What did Commonwealth environmental water contribute to hydrological connectivity

There was variation in the extent of in-channel inundation to Commonwealth environmental water among sites, including variation among reaches within the same hydrological zone. There was an increase in wetted benthic area at all sites that received environmental water. The greatest increase was observed at 'Barham Rd Bridge' site in the Wakool river zone 3 (Figure 5).

During the environmental watering action between August 2014 and January 2015 Commonwealth environmental water increased the area of slackwater (< 0.02 ms^{-1}) and slow water (0.02 – 0.3 ms^{-1}) in some of the reaches whereas at other reaches there was a reduction in the area of slackwater and slow water and an increase in fast water under environmental watering (Figure 6). In Yallakool Creek (zone 1) there was a loss in area of slow water at 'Hopwood' and 'Cumnock' but an increase in the area of slow water under environmental watering at Mascott and Windra Vale (Figure 6). In contrast, at most sites in Wakool River zone 3 and 4 (with the exception of Noorong 2) there were substantial increases in the area of slow water under the environmental watering scenario. Slackwater and slow water patches are important for the survival and growth of some aquatic organisms.

There was not a strong relationship between discharge and wetted benthic area in these river reaches because river geomorphology has a strong influence on the response to environmental watering actions. The results suggest it may be more appropriate to examine the relationship between inundation area and ecosystem responses to in-channel flows rather than examining relationships with daily discharge.

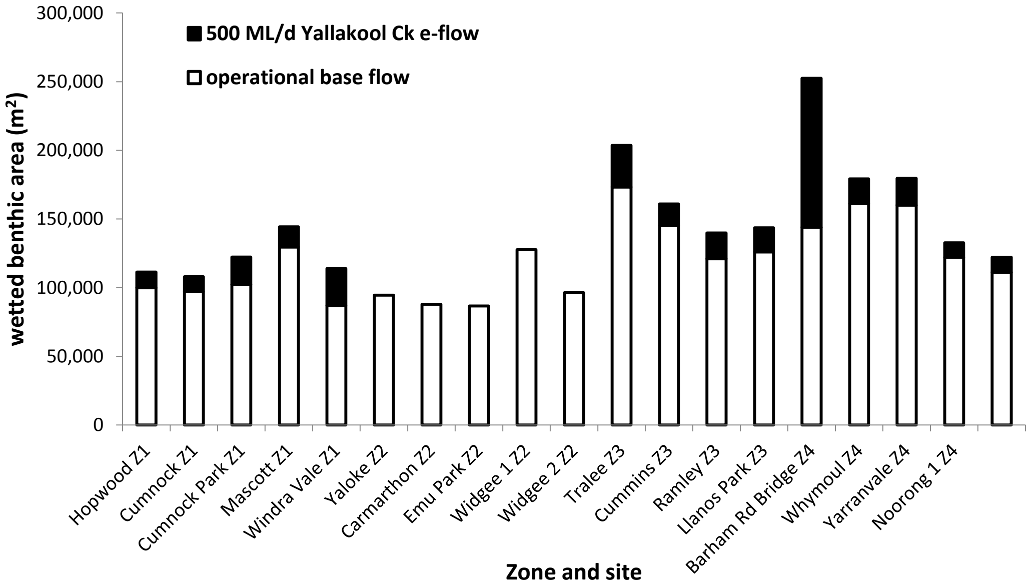


Figure 5. Wetted benthic area (m^2) modelled for 19 reaches in the Edward-Wakool Selected Area under a) operational base flow and b) Commonwealth environmental watering in Yallakool Creek where discharge was increased to approximately 500 ML/d between August 2014 and January 2015. Zone 1 = Yallakool Creek, Zone 2 = upper Wakool River, Zone 3 = Wakool River upstream of Thule Creek and Zone 4 = Wakool River downstream of Thule Creek. Dicharge levels for operational and environmental flows are provided in Table 5.3. (Source: Watts et al 2015)

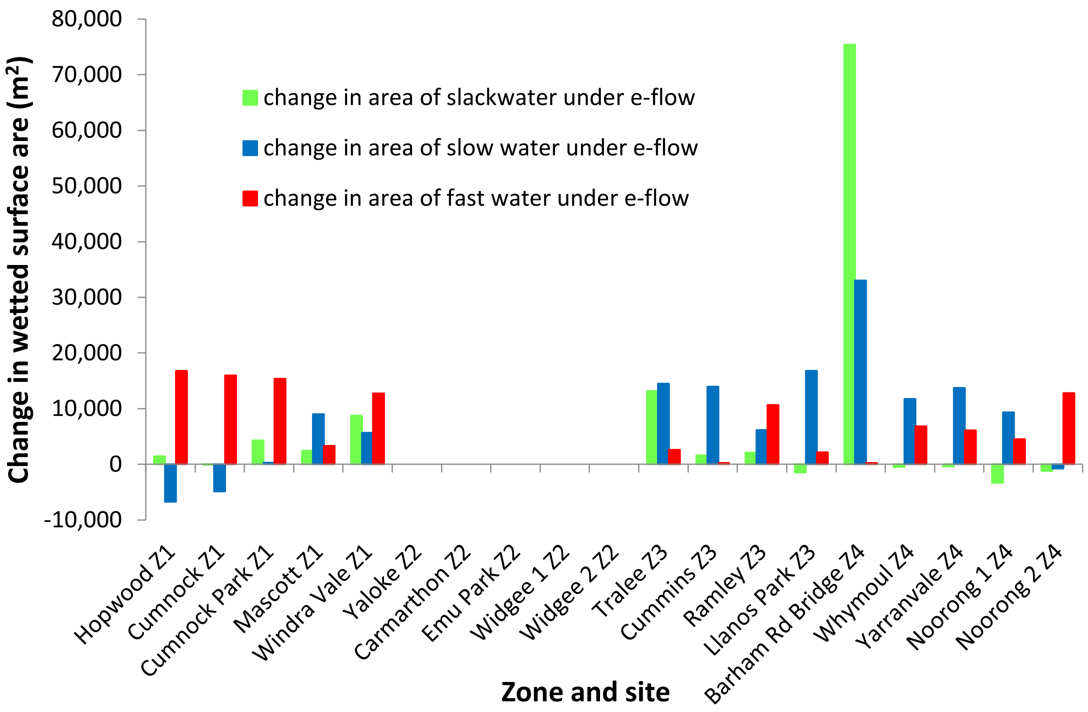


Figure 6. Positive or negative change in wetted surface area (m^2) of slackwater, slow water and fast water for nineteen reaches in the Edward-Wakool Selected Area under environmental watering in Yallakool Creek between August 2014 and January 2015 relative to operational base flow. slackwater (< 0.02 m.s^{-1}), slow water (0.02-0.3 m.s^{-1}), fast water (>0.3m.s^{-1}). Hydrological zones: Zone 1 = Yallakool Creek, Zone 2 = upper Wakool River, Zone 3 = Wakool River upstream of Thule Creek and Zone 4 = Wakool River downstream of Thule Creek. (Source: Watts et al 2015)

7. Response of water quality and carbon to Commonwealth environmental watering

Water quality was monitored in four hydrological zones of the Edward-Wakool system in 2014-15 to assess the contribution of Commonwealth environmental water contribute to water quality. Water quality parameters were assessed by a combination of continuous logging (temperature and dissolved oxygen) supplemented with spot measurements and collection of water samples (monthly) two sites within each zone, and from Stevens Weir on the Edward River and the Mulwala Canal for laboratory measurement of: dissolved organic carbon, nutrients and absorbance and fluorescence spectroscopy for organic matter characterisation.

The following questions were addressed:
Q1: *What did Commonwealth environmental water contribute to temperature regimes?*
Q2: *What did Commonwealth environmental water contribute to dissolved oxygen concentrations?*
Q3: *What did Commonwealth environmental water contribute to nutrient concentrations?*
Q4: *What did Commonwealth environmental water contribute to modification of the type and amount of dissolved organic matter through reconnection with previously dry or disconnected in-channel habitat?*
Q5: *What did Commonwealth environmental water contribute to reducing the impact of blackwater in the system?*

Commonwealth environmental water did not influence water temperature. Zones 1, 3 and 4 receiving Commonwealth environmental water had higher dissolved oxygen concentrations than the Wakool River in Zone 2 (Figure 7). This difference among zones with and without environmental water persisted beyond the end of the watering action, thus Commonwealth environmental water assisted in the maintenance of dissolved oxygen concentrations over the summer period in the zones receiving the additional flow. Total Nitrogen and Total Phosphorus were generally higher in the Wakool River in Zone 2 than in the sites receiving Commonwealth environmental water, however bioavailable nutrients were at similar very low concentrations at all sites.

A pulse of organic matter was observed passing through the system from upstream during August 2014. Very small differences between organic matter in the Wakool River in zone 2 and the other study sites were measured during the environmental watering action. These are unlikely to be ecologically significant. Organic matter remained well below concentrations associated with blackwater events.

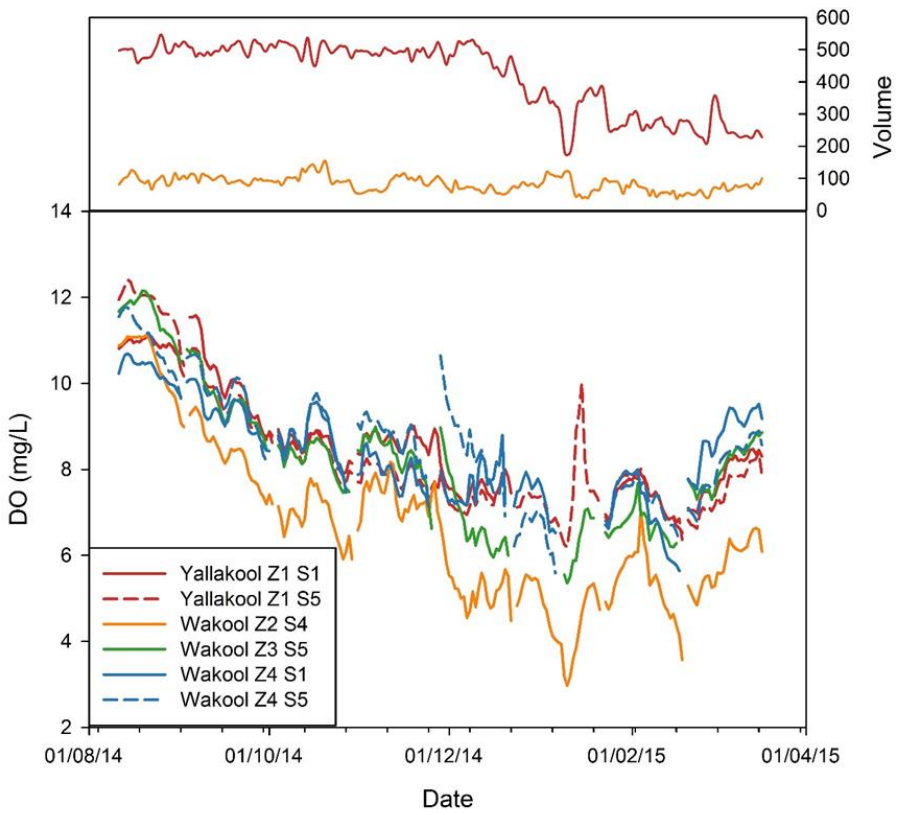


Figure 7. Daily average dissolved oxygen concentration in each of the study zones. Representative hydrographs for Yallakool Creek zone 1 (red line) and Wakool River zone 2 (orange line, no environmental water) are shown in the upper portion of the graph to indicate the difference in flow. Zone 3 and 4 have similar hydrographs to zone 1.

8. EFFECT OF COMMONWEALTH ENVIRONMENTAL WATER ON STREAM METABOLISM

Battery-powered loggers were deployed at the six designated sites and recorded dissolved oxygen concentration and water temperature every 10 minutes. The metabolic parameters, gross primary production and ecosystem respiration were calculated for each day using the prescribed BASE model.

The following questions were addressed:

Q1: *What did Commonwealth environmental water contribute to patterns and rates of decomposition?*

Q2: *What did Commonwealth environmental water contribute to patterns and rates of primary productivity?*

Q3: *How does the timing and magnitude of Commonwealth environmental water delivery affect rates of gross primary productivity and ecosystem respiration in the Edward- Wakool River system?*

Q4: *What did Commonwealth environmental water contribute to patterns and rates of primary productivity?*

Rates of primary production and ecosystem respiration during 2014-2015 were at the lower end of the normal range found in streams worldwide, with the exception of zone 2 Site 4, where rates were comparable with many other streams. Much higher ecosystem respiration rates leading to low in-stream dissolved oxygen in January 2015 were observed in Zone 2 (no Commonwealth environmental water) compared to the three zones that received Commonwealth environmental water (Figure 8). Primary production and ecosystem respiration are constrained by the very low concentrations of bioavailable nutrients and organic carbon, respectively. This is both beneficial in that the risks of severe algal blooms or anoxic events are very low, but problematic if this lack of organic carbon input into the base of the aquatic foodweb is limiting maintenance and recovery of fish populations.

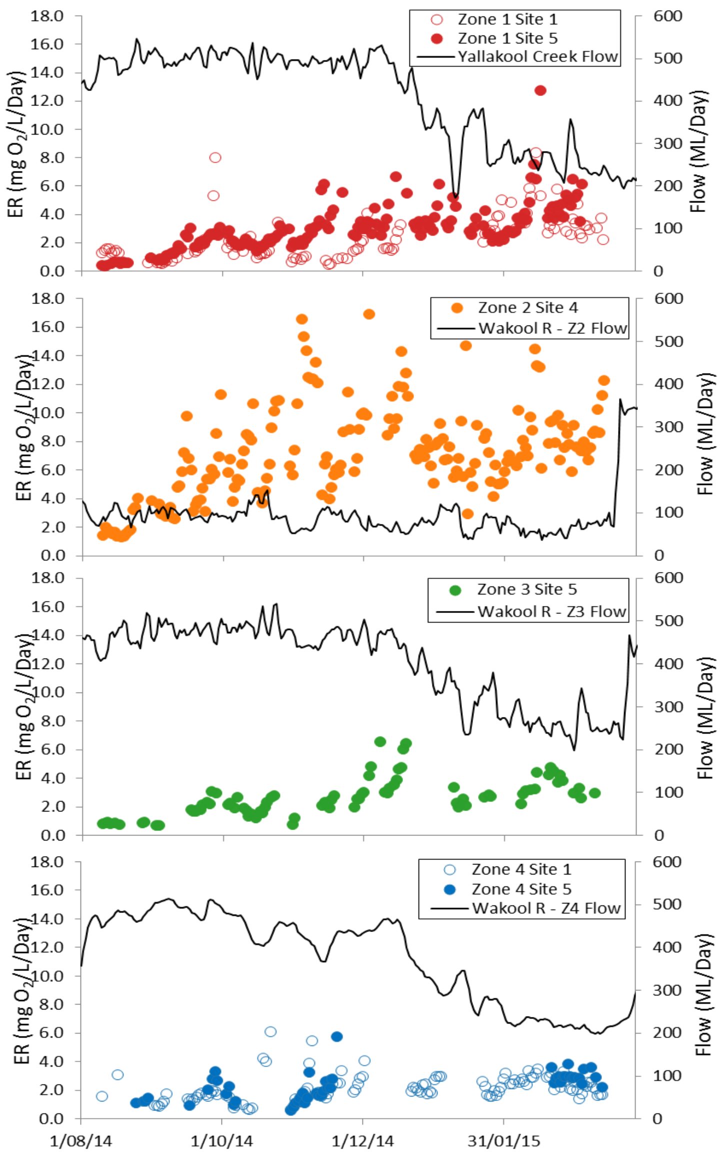


Figure 8. Relationships between Flow and Ecosystem Respiration (ER) for Yallakool Creek (zone 1) and Wakool River (zones 2, 3 and 4) from August 2014 to March 2015.

9. RESPONSE OF RIVERBANK AND AQUATIC VEGETATION TO COMMONWEALTH ENVIRONMENTAL WATERING

The diversity and percent cover of aquatic and riverbank vegetation was monitored monthly from October 2014 to June 2015 at four sites in each of four hydrological zones in the Edward-Wakool system. The following questions were addressed:

Q1: *What did Commonwealth environmental water contribute to the total percent cover of riverbank and aquatic vegetation?*

Q2: *What did Commonwealth environmental water contribute to the percent cover of abundant riverbank and aquatic vegetation taxa?*

Q3: *What did Commonwealth environmental water contribute to the diversity of riverbank and aquatic vegetation?*

The most abundant taxa observed include rush (*Juncus* spp.) floating pondweed (*Potamogeton tricarinatus*), old man weed (*Centipeda cunninghammii*), *Chara* spp. (Figure 9), water couch (*Paspalum distichum)*, milfoil (*Myriophyllum* spp.), sedge (*Cyperus* spp*.*) and common spike rush (*Eleocharis acuta*)(Figure 9). There were more riverbank and aquatic vegetation taxa recorded in the three zones that received Commonwealth environmental water (zones 1, 3 and 4).

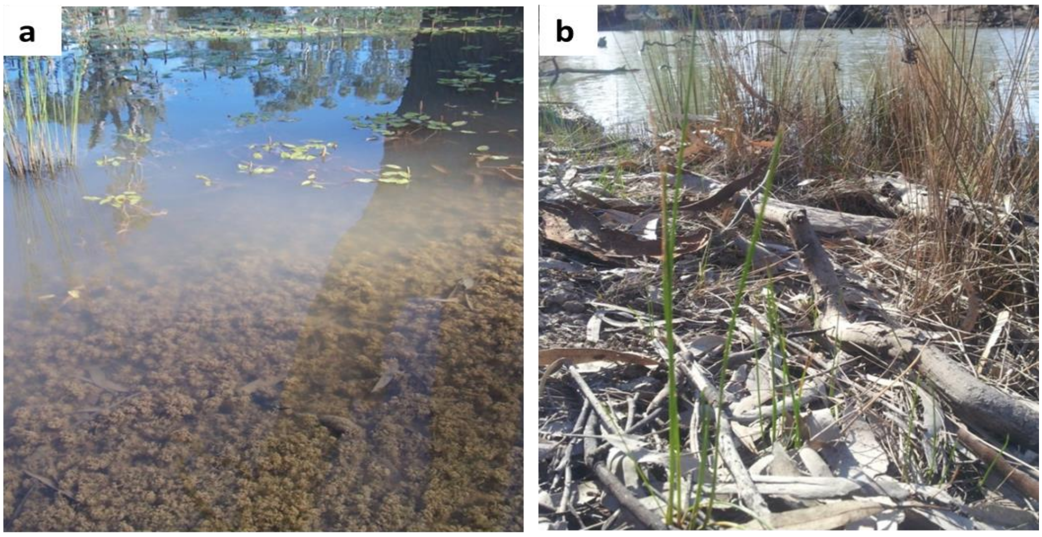


Figure 9. Photos of aquatic and riverbank vegetation in the Edward-Wakool system in 2014-15. a) The charophyte *Chara* spp. growing at the edge of the water at site 1 zone 3 in November 2014. b) Small *Eleocharis acuta* plants sprouting on the edge of zone 3 site 3 following the recession of environmental water. (Photos R. Watts)

There was a significant response of aquatic vegetation to environmental watering in 2014-15. There was a higher percent cover of riverbank and aquatic vegetation growing on the inundated edge of the river zones 3 and 4 that received environmental water compared to the Wakool River zone 2 that did not receive environmental water (Figure 10). The cover of vegetation in Yallakool Creek zone 1 was not significantly different to that in zone 2, so there was no benefit of the Commonwealth environmental water in Yallakool Creek. There was a significant positive correlation between percent cover of vegetation and average wetted benthic area of each river reach (Figure 11).

There was a significantly different assemblage of vegetation among zones. The species contributing to the dissimilarity between zone 2 (no environmental water) and zones 1, 3 and 4 (Commonwealth environmental water) include taxa such as *Centipeda cunninghammii* that responds to wetting of the riverbank. Several aquatic taxa such as *Potamogeton* spp., *Myriophyllum* spp. and *Azolla* spp. were absent from zone 2. Other aquatic taxa such as *Chara* spp., *E. acuta* and mudwort were in very low abundance in zone 2. The response of aquatic and riverbank vegetation to environmental watering has been an ongoing process. There has been a gradual improvement in vegetation observed at sites that have received Commonwealth environmental water over the past three years.

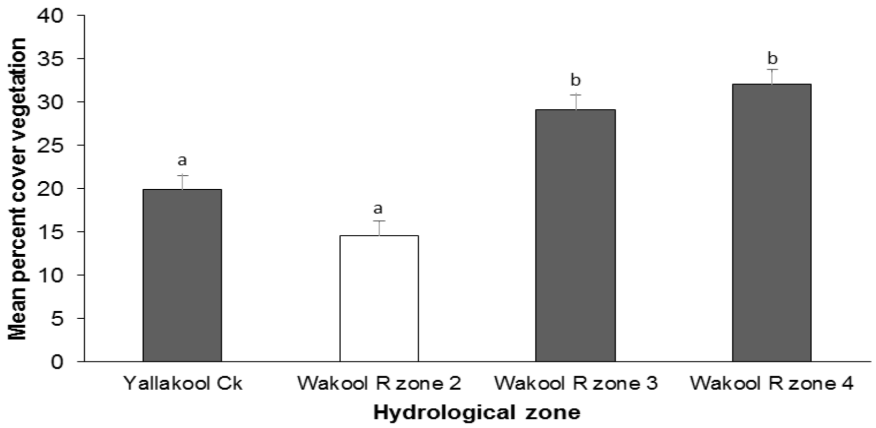


Figure 10. Mean percent cover (±SE) of riverbank and aquatic vegetation sampled in 2014-2-15 in the Edward-Wakool system. Yallakool Creek and the Wakool River zones 3 and 4 received Commonwealth environmental water in 2014-15 and Wakool River zone 2 did not receive environmental water. (Source: Watts et al 2015)

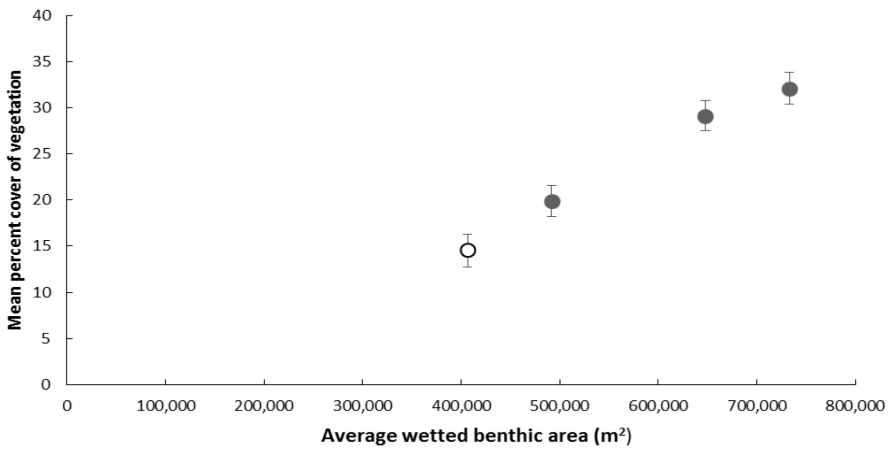


Figure 11. Relationship between mean wetted benthic area (m^2) for each hydrological zone and average percent cover (±SE) of riverbank and aquatic vegetation sampled in 2014-2-15 in the Edward-Wakool Selected Area. (Source: Watts et al 2015)

10. Response of the fish community to Commonwealth environmental watering

This is the first year of a multi-year monitoring project, and as such this report will provide a benchmark that will be used by the LTIM program to determine if there is a system-wide change in the fish community assemblage structure in the Edward-Wakool system with respect to Commonwealth environmental water delivery. The following long-term Selected Area evaluation questions will be assessed over the next 5 years:

Q1: *Does Commonwealth environmental water contribute to maintain or enhance existing levels of fish recruitment in the Edward-Wakool river system?*

Q2: *Does Commonwealth environmental water contribute to maintain or increase native fish diversity and abundance in the Edward-Wakool river system?*

Q3: *Does Commonwealth environmental water contribute to maintain or increase native fish biomass in the Edward-Wakool river system?*

Q4: *Does Commonwealth environmental water contribute to maintain or enhance fish condition in the Edward-Wakool river system?*

Q5: *Does Commonwealth environmental water contribute to the recovery of fish communities following negative conditions within the Edward-Wakool river system?*

Fish community sampling was undertaken in May and June 2015 at 19 in-channel sites throughout the Edward-Wakool system. Data from these sites was compared with a long-term annual dataset encompassing 2010–2014 from the same sites to provide context for the 2015 LTIM baseline data.

There is a general trend of improvement in the native fish community in the Edward-Wakool system following the Millennium drought, widespread flooding and hypoxic blackwater fish kills in recent times. Improvement was species and location-specific, and the overall fish community assemblage is still considered to be in poor condition. Nativeness (the proportion of native abundance, biomass and species) was the highest on record based on six years of sampling and is classified as good (Figure 12).

There was no significant difference in the abundance of the fish community assemblage between 2014 and 2015. There was, however, a significant difference in biomass, and this was driven by increases in golden perch and common carp biomass, and decreases in Murray cod, goldfish and bony herring biomass in 2015. Recent recruits of four native short-lived species (Australian smelt, carp gudgeon, Murray-Darling rainbowfish and un-specked hardyhead) and three native longer-lived species (bony herring, Murray cod and silver perch) were detected.

The current study provides a benchmark with which to compare changes in the fish community assemblage composition across the Edward-Wakool system over the next five years under the LTIM program. The data indicate that the fish communities of the system and region have been dynamic over the past ten years. Previous monitoring consisting of annual surveys dating back to 2010 provided context for the current study. Sustainable Rivers Audit indicators were calculated from each annual survey from 2010–2015. There is a general trend towards improvement of the native fish community in the Edward-Wakool system back toward 2010 levels.

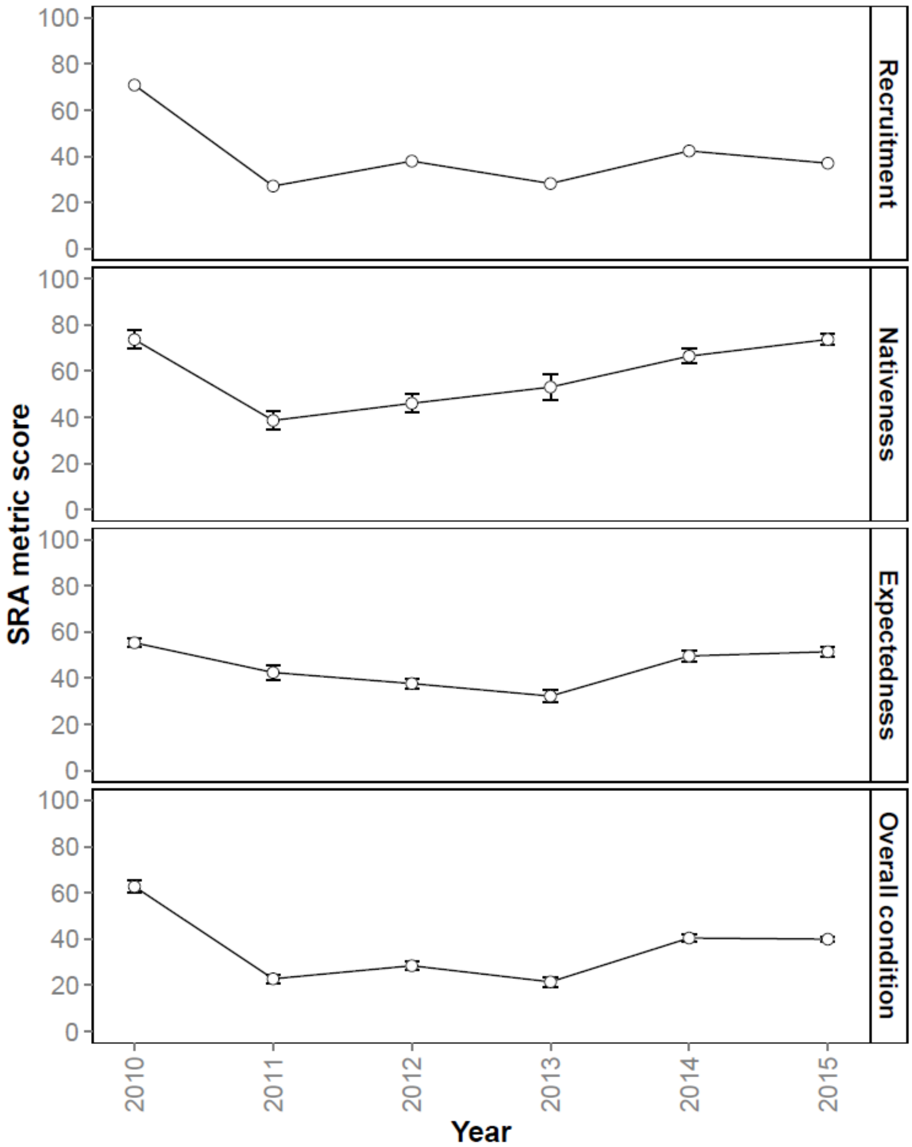


Figure 12. Sustainable Rivers Audit (SRA) indices, separated among sampling years, in the Edward-Wakool river system. Note that only data collected from the same 19 in-channel sites each were used in the calculation of these metrics. (Source: Watts et al 2015)

11. Fish spawning and reproduction responses to Commonwealth environmental watering

Fish spawning and reproduction responses to Commonwealth environmental watering were assessed by monitoring the presence and abundance of fish larvae throughout the spring and summer of 2014-15. Larval fish were sampled fortnightly from September 2014 to March 2015 using a combination of light traps and drift nets across four study zones: Yallakool Creek, Wakool River zone 2, Wakool River zone 3, and Wakool River zone 4.

The following questions were addressed:
Q1: *Did the delivery of the sustained flow in Yallakool Creek during the Murray cod spawning period result in significantly more fish larvae compared to rivers that did not receive environmental water?*
Q2: *What is the effect of Commonwealth environmental water on the spawning of small-bodied opportunistic species?*
Q3: *What is the effect of Commonwealth environmental water on the spawning of flow-dependent spawners?*

Seven of the 11 native fish species known to occur in the selected area were collected as larvae or early juvenile stages, indicating the successfully spawning of these species. In addition, a recently described species, *Galaxias oliros* (obscure galaxias, Raadik 2014), was collected as a juvenile in Yallakool Creek (Figure 13). This is the first collection of a Galaxiid species in the region since regular monitoring of the system commenced in 2011.

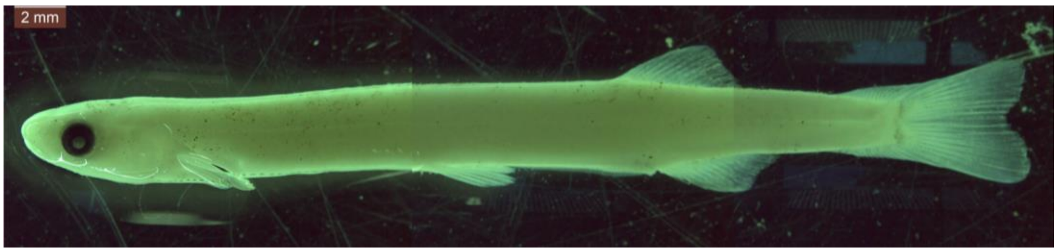


Figure 13: Juvenile obscure galaxias (*Galaxias oliros*) collected from the Wakool River (Photo: N. McCasker)

The spawning patterns of the Edward-Wakool fish community appeared independent of Commonwealth environmental watering actions in 2014-15. The Yallakool Creek environmental watering action during the Murray cod spawning season did not result in a significantly greater number of Murray cod larvae in Yallakool Creek or the Wakool River zones 3 and 4 when compared to Wakool River zone 2 (no environmental water). These findings concur with results observed during monitoring of similar watering actions in 2012-13 and 2013-14 and support the body of knowledge that shows that Murray cod spawn at peak times in November and December, regardless of flow conditions.

The Yallakool Creek watering action did not trigger a golden and silver perch spawning response in the monitored reaches, as evidenced by the absence of larvae or eggs, but this is not surprising as the watering action was not planned to target a spawning response in these species.

Larval abundance of opportunistic species were not significantly different in study zones receiving environmental water (zones 1, 3 and 4) to that not receiving environmental water (zone 2). Those species that spawned, such as carp gudgeon, Australian smelt and flathead gudgeon, are common and widespread throughout the Murray-Darling Basin. Other species such as unspecked hardyheads and Murray rainbowfish, spawned, but in low numbers. Slackwater and slow water environments, and the presence of aquatic vegetation are considered important for the spawning and recruitment of many small bodied species. Environmental watering actions that target the inundation of in-channel geomorphological features, increase the area of slackwater available, and help establish instream aquatic vegetation are likely to be advantageous to small bodied fish species for spawning and nursery grounds. With the positive response in aquatic vegetation to environmental water delivery in the Edward Wakool System in 2014-15, it is anticipated that this will have positive effects for such species in the upcoming spawning seasons.

The seasonal timing of the appearance of larvae in the Edward-Wakool River System in 2014-15 was similar to patterns to previous years (Watts et al. 2013, Watts et al. 2014). Australian smelt larvae were the first species detected as larvae in 2014-2015, occurring from September to early December 2014. Murray cod larvae were found in all four zones between 27 October 2014 and 8 Dec 2015, with abundance peaking in mid November, showing consistent trends to the 2012-13 and 2013-14 spawning periods. Carp gudgeon had the longest spawning period of all fish, with larvae detected in sampling gear for more than four months. Flathead gudgeon had a narrower spawning window than carp gudgeon, detected as larvae in all study zones for 3 months between October 2014 and January 2015. The smaller numbers of larvae caught for Murray River Rainbowfish, unspecked hardyhead, river blackfish and gambusia make it difficult to generalise spawning patterns. However, river blackfish were collected as larvae from only two sites in Wakool River (Zone 2), also consistent with previous observations.

12. Murray cod, golden perch and silver perch recruitment and growth responses to Commonwealth environmental watering

The 2014-15 watering year is the first time that selected area fish recruitment monitoring been undertaken to evaluate long-term annual changes in recruitment and growth of Murray cod, silver perch and golden perch in the Edward-Wakool system. The selected area fish recruitment monitoring enables a comparison of recruitment among different hydrological zones in this system. This approach is different to the basin-scale fish recruitment index (see Section 10) that calculates one overall recruitment index for the entire system. Four sites were sampled in each of four hydrological zones in the Edward-Wakool system: Yallakool Creek, Wakool River Zone 2, Wakool River Zone3 and Wakool River Zone 4. Each of 16 sites were sampled between February and March 2015. Autumn sampling was undertaken to allow fish larvae hatched during spring and summer to reach the juvenile, Young-of-Year (YOY) stage, while at the same time sampling age-class 1 (1+) recruits which survived a previous winter. Three sampling methods including backpack electrofishing, standardised angling and baited set-lines were undertaken.

The following questions were addressed:
Q1: *Did Commonwealth Environmental Water affect the growth rate of Murray cod, golden perch and silver perch during the first year of life?*
Q2: *Did Commonwealth Environmental Water contribute to the recruitment of Murray cod, golden perch and silver perch?*

Recruitment of Murray cod, including young-of-year (YOY) and age-class 1 (1+) fish, was consistent among all zones. Extremely low numbers of silver perch and golden perch recruits sampled was interpreted as low recruitment of these species in the Edward-Wakool system during 2014-15.

Differences in the growth of Murray cod recruits among zones were unrelated to Commonwealth environmental water delivery in 2014-15. Although there were no differences in age-length models among zones, the length-at-age of 1+ Murray cod recruits was highly variable (Figure 14). A high degree of zone-specific variation in length-at-age of 1+ Murray cod recruits suggests that growth of this species is likely to be a useful indicator to evaluate long-term annual changes in response to environmental watering. Analyses suggest that additional recruitment sampling effort, increasing from 4 to 12 sites per zone or visiting the 4 sites on 3 sampling occasions, would be required in order to confidently assess the effect of environmental water delivery among different zones of the Edward-Wakool system.

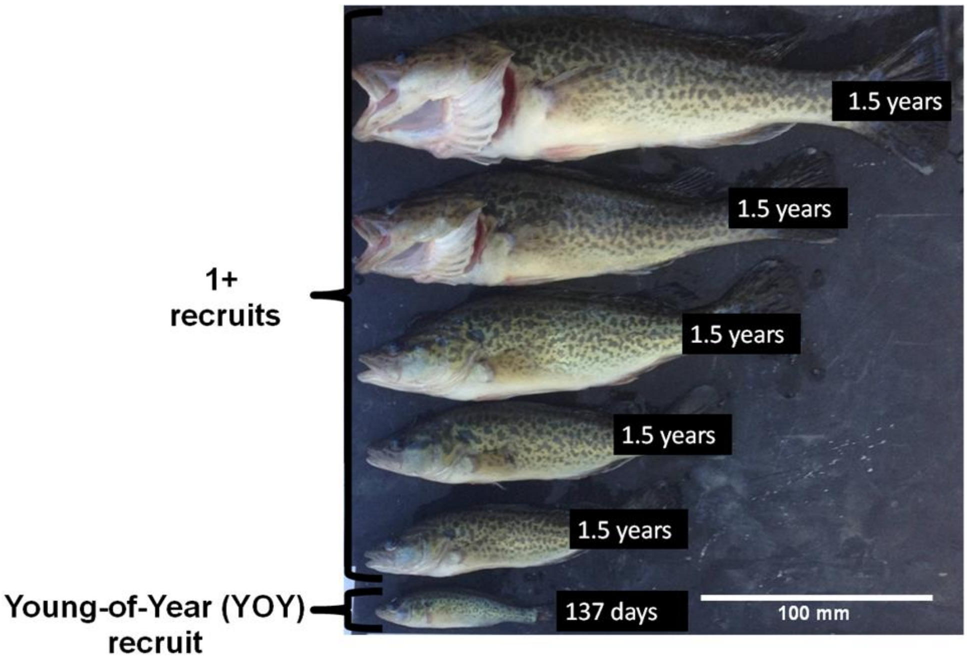


Figure 14. Variation in length-at-age of Murray cod recruits sampled in the Edward-Wakool system 2014-15. (Source: Watts et al 2015)

13. CONCLUSION

Commonwealth environmental water delivered to Yallakool Creek in 2014-15 had the following positive outcomes in reaches receiving environmental water:

- Increased variation in discharge
- Maintained dissolved oxygen levels and ecosystem respiration
- Increased in-channel longitudinal connectivity and lateral connectivity. There was an increase in wetted benthic area and area of slackwater and slow water in Wakool River zones 3 and 4
- Increased cover and diversity of instream aquatic vegetation, particularly in Wakool River zones 3 and 4, but not consistently in Yallakool Creek zone 1.
- Increased the diversity of native fish with one new species, *Galaxias oliros* (obscure galaxias) recorded in Yallakool Creek.

In addition to these positive outcomes there were a number of indicators where there was no detectable response (positive or negative) to environmental watering and there was one negative response observed in 2014-15, being a reduction in the area of slackwater in Yallakool Creek during watering actions compared to area of available slackwater during base flows. The responses to Commonwealth environmental watering observed in 2014-15 were consistent with those observed previously in this system. The good outcomes for water quality, connectivity and aquatic vegetation will help to set-up the system for longer term benefits to be realised.

14. ACKNOWLEDGEMENTS

We respectfully acknowledge the Traditional Owners, their Elders past and present, their Nations of the Murray–Darling Basin, and their cultural, social, environmental, spiritual and economic connection to their lands and waters. We extend our thanks to the Wakool River Association, the Edward-Wakool Anglers Association and landholders in the Edward-Wakool river system for allowing access to their properties and for their keen interest in this project. Community liaison was undertaken by the Murray Local Land Services, with particular thanks to Josh Campbell. We particularly thank James Abell and Chris Smith who undertook the majority of the field work. Assistance with fieldwork and/or laboratory work was undertaken by Tom Butterfield, Josh Campbell, Jonathon Doyle, Peter Graham, Duncan McLay, Timothy McGarry, Glenn Miller, Sean Lethlean, Kate Martin, Rod Martin, Rohan Rehwinkel, Lachlan Webster, John St Vincent Welch, Ian Wooden. Maps were prepared by Simon McDonald and Deanna Duffy (Charles Sturt University Spatial Analysis Unit), Rod Martin (NSW DPI) and Ian Wooden (NSW DPI). Tina Hines at the Monash University Water Studies Centre processed carbon and nutrient samples. Fish sampling was carried out under NSW Fisheries license (P11/0003-1.0) and approved by the CSU Animal Care and Ethics Committee (10/101). This project was funded by the Commonwealth Environmental Water Office with in-kind contributions from Charles Sturt University, Murray Local Land Services, NSW Department of Primary Industries, Monash University and NSW Office of Environment and Heritage.

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