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Monitoring and Evaluation Plan for the Edward-Wakool Selected Area



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1 Introduction

The Commonwealth Environmental Water Holder (CEWH) is responsible under the *Water Act 2007* (Cth) for managing Commonwealth environmental water holdings. The holdings must be managed to protect or restore the environmental assets of the Murray-Darling Basin, and other areas where the Commonwealth holds water, so as to give effect to relevant international agreements. The Basin Plan (2012) further requires that the holdings must be managed in a way that is consistent with the Basin Plan's Environmental Watering Plan. The *Water Act 2007* (Cth) and the Basin Plan also impose obligations to report on the contribution of Commonwealth environmental water to the environmental objectives of the Basin Plan.

Monitoring and evaluation are critical for supporting effective and efficient use of Commonwealth environmental water. Monitoring and evaluation will also provide important information to support the CEWH meet their reporting obligations.

The Long-Term Intervention Monitoring Project (LTIM Project) is the primary means by which the Commonwealth Environmental Water Office (CEWO) will undertake monitoring and evaluation of the ecological outcomes of Commonwealth environmental watering. The LTIM Project will be implemented at seven Selected Areas over a five year period from 2014-15 to 2018-19 to deliver five high-level outcomes (in order of priority):

1. Evaluate the contribution of Commonwealth environmental watering to the objectives of the Murray-Darling Basin Authority's (MDBA) Environmental Watering Plan
2. Evaluate the ecological outcomes of Commonwealth environmental watering at each of the seven Selected Areas
3. Infer ecological outcomes of Commonwealth environmental watering in areas of the Murray-Darling Basin not monitored
4. Support the adaptive management of Commonwealth environmental water
5. Monitor the ecological response to Commonwealth environmental watering at each of the seven Selected Areas.

This Monitoring and Evaluation Plan (M&E Plan) details the monitoring and evaluation activities that will be implemented under the LTIM Project in the Edward-Wakool Selected Area. The Plan includes:

- A description of the Edward-Wakool Selected Area (section 2);
- A description of the Commonwealth environmental watering expected to occur in the Edward-Wakool system over the next 5 years (section 3);
- A discussion of monitoring priorities (section 4);
- A summary of evaluation questions relevant to the Basin-scale evaluation and Edward-Wakool Selected Area evaluation (section 5);
- Standard operating procedures for each indicator (section 6);
- A monitoring schedule (section 7);
- A description of the evaluation methods (section 8);
- A communication and engagement plan (section 9);
- A description of project management and project governance, risk management plan, quality plan, and health, safety and environment plans (section 10); and
- A monitoring and evaluation budget (section 11).

1.1 LTIM Project context

The Commonwealth Environmental Water Office (CEWO) Long Term Intervention Monitoring (LTIM) Project seeks to quantify the outcomes of the management of Commonwealth environmental water and its contribution to Basin Plan environmental objectives.

The Basin Plan identifies a number of environmental objectives for water-dependent ecosystems in the Murray-Darling Basin (MDB). These objectives are described at a Basin-scale and there is a need to link local outcomes from environmental allocations to long-term, Basin-scale changes in environmental condition. This process is facilitated through the use of an Outcomes Framework, with the highest level objectives generically described as Biodiversity, Ecosystem function, Resilience and Water quality as shown in Table 1.

Table 1. Basin Plan environmental and water quality objectives for water-dependent ecosystems. (Source CEWO 2013)

Basin Plan reference	Basin Plan objective	Referred to throughout as:
Environmental Watering Plan	“To protect and restore water dependent ecosystems of the Murray-Darling Basin” (Basin Plan, Chapter 8, Part 2, 8.04(a))	Biodiversity
	“To protect and restore the ecosystem functions of water-dependent ecosystems” (Basin Plan, Chapter 8, Part 2, 8.04(b))	Ecosystem function
	“To ensure that water-dependent ecosystems are resilient to climate change and other risks and threats” (Basin Plan, Chapter 8, Part 2, 8.04(c))	Resilience
Water Quality and Salinity Management Plan	“To ensure water quality is sufficient to achieve the above objectives for water-dependent ecosystems, and for Ramsar wetlands, sufficient to maintain ecological character” (Basin Plan, Chapter 9, (Part 3, 9.04(1&2))	Water Quality

The outcomes framework (Table 2) provides the focus for monitoring and helps bring together results from across the Basin in a consistent way for managing information. Two types of diagrams are used to show the relationships between spatial and temporal scale of expected outcomes and the causes of these outcomes:

- spatio-temporal diagrams (for whole of Basin outcomes) – illustrate the links, across a range of temporal and spatial scales, between expected outcomes that contribute to the particular whole of Basin outcome
- cause and effect diagrams – explain the influence of flow and other factors on elements of the outcomes framework.

Table 2. Environmental Water Outcomes Framework (Source: CEWO 2013)

Basin Plan Objectives	Basin Outcomes		5 year Expected Outcomes	1 year Expected Outcomes	Related Cause and Effect Diagram (Reference only)
Biodiversity (Basin Plan S.8.05)	Ecosystem diversity				<i>Landscape Ecosystem Diversity</i>
			• Species diversity		<i>Within Ecosystem Diversity</i>
	Species diversity	Vegetation	• Vegetation diversity		<i>Landscape Vegetation Diversity</i>
				• Reproduction • Condition	<i>Vegetation Condition and Reproduction</i>
			• Growth and survival	• Germination • Dispersal	<i>Vegetation Recruitment and Extent</i>
		Macroinvertebrates	• Macroinvertebrate diversity		<i>Within Ecosystem Macroinvertebrate Diversity</i>
		Fish	• Fish diversity		<i>Landscape Fish Diversity</i>
				• Condition	<i>Fish Condition</i>
				• Larval abundance • Reproduction	<i>Fish Reproduction</i>
			• Larval and juvenile recruitment		<i>Fish Larval growth and survival</i>
		Waterbirds	• Waterbird diversity		<i>Landscape Waterbird Diversity</i>
	• Waterbird diversity and population condition (Abundance and Population structure)		• Survival and condition	<i>Waterbird Survival and Condition</i>	
			• Chicks	<i>Waterbird Reproduction</i>	
	• Fledglings		<i>Waterbird Recruitment and Fledging</i>		
Other vertebrate diversity		• Young	<i>Other Vertebrate Reproduction</i>		
	• Adult abundance		<i>Other Vertebrate Growth and Survival</i>		
Ecosystem Function (Basin Plan S. 8.06)	Connectivity		• Hydrological connectivity including end of system flows	<i>Hydrological Connectivity (including end of system flows)</i>	
			• Biotic dispersal and movement	<i>Biotic Dispersal</i>	
			• Sediment transport	<i>Sediment Transport</i>	
	Process		• Primary productivity (of aquatic ecosystems)	<i>Primary Production</i>	
			• Decomposition	<i>Decomposition</i>	
			• Nutrient and carbon cycling	<i>Nutrient and Carbon Cycling</i>	
Resilience (Basin Plan S.8.07)	Ecosystem resilience	• Population condition (individual refuges)	• Individual survival and condition (Individual refuges)	<i>Individual Refuges</i>	
		• Population condition (landscape refuges)		<i>Landscape Refuges</i>	
			• Individual condition (Ecosystem resistance)	<i>Ecosystem Resistance</i>	
		• Population condition (Ecosystem recovery)		<i>Ecosystem Recovery</i>	
Water quality (Basin Plan S.9.04)	Chemical		• Salinity	<i>Salinity</i>	
			• Dissolved Oxygen	<i>Dissolved Oxygen</i>	
			• pH	<i>pH</i>	
			• Dissolved Organic Carbon	<i>Dissolved Organic Carbon</i>	
	Biological		• Algal blooms	<i>Algal Blooms</i>	

1.2 About this M&E Plan

The overarching principle that underpins this monitoring and evaluation plan (M&E Plan) for the Edward-Wakool Selected Area is that we are taking an ecosystem approach to evaluate the responses to Commonwealth environmental watering. A suite of questions and indicators have been selected that all have clear linkages to other components of the M&E Plan (see Figure 1). The plan has a strong focus on fish, including fish movement, reproduction, recruitment and adult populations. The Edward-Wakool system is recognised as a priority area for fish diversity in the Murray-Darling Basin, including threatened and endangered fish, and it is 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*). Outcomes for fish have been the main focus of watering actions in the Edward-Wakool system and they are the key environmental asset valued by the Edward-Wakool community. However, many of the other indicators being considered (such as water quality, metabolism and aquatic vegetation) will indirectly influence fish population dynamics, and thus a key goal of this M&E Plan is to improve our understanding and interpretation these interdependencies.

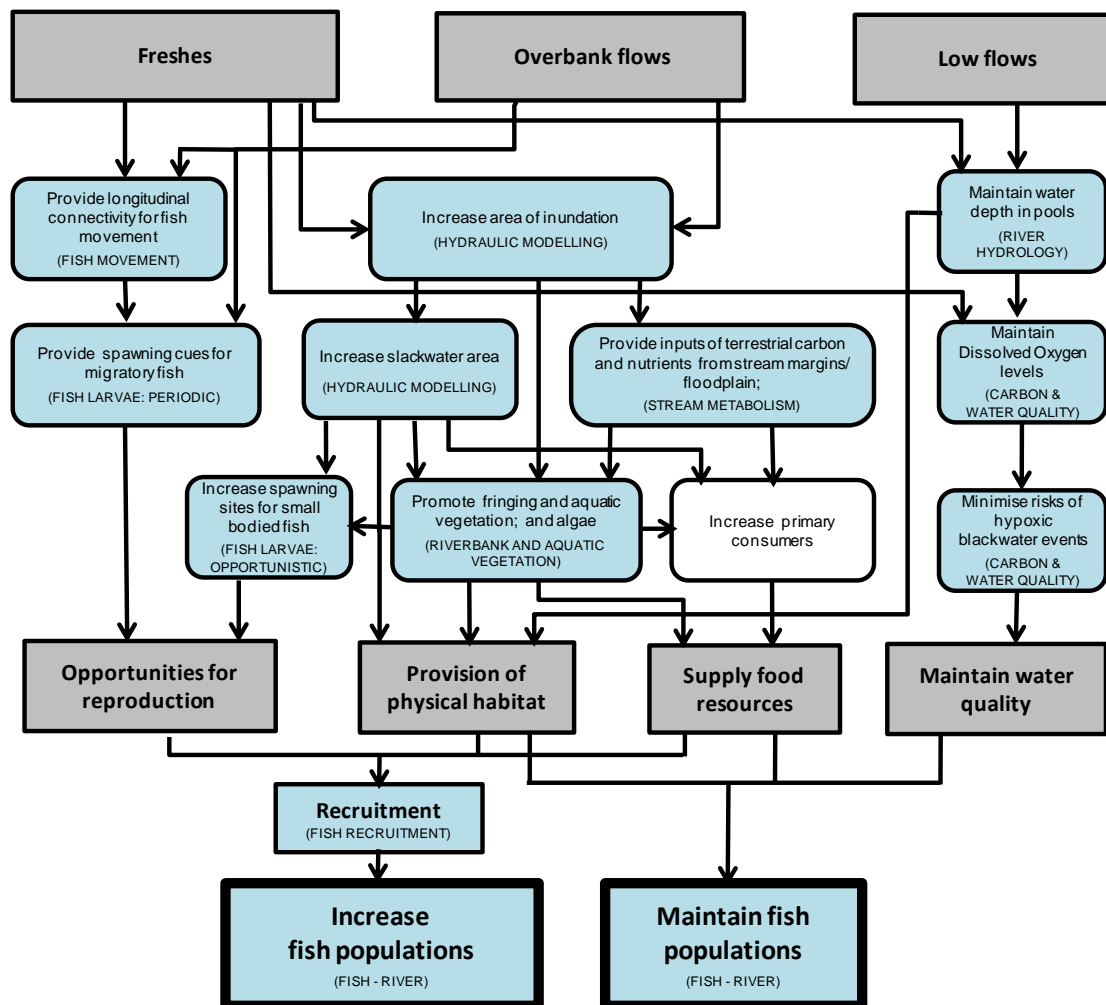


Figure 1: Conceptual diagram illustrating the three main flow types (low flows, freshes, overbank flows) and their influence on ecosystem components and processes that, in turn, influence fish population dynamics. Indicators that are included in the Edward-Wakool Selected Area Monitoring and Evaluation plan are shown in brackets in boxes shaded blue.

Ecosystem responses to Commonwealth environmental watering in the Edward-Wakool system will be assessed by:

1. Selecting monitoring zones to enable a control-treatment analysis to be undertaken, especially for event-based hypotheses. The creeks and rivers that comprise the Edward-Wakool system provide a unique opportunity to undertake this type of evaluation as in any given watering year it is likely that one of the rivers will not receive environmental water and can thus serve as a study 'control', with another river receiving environmental water serving as 'treatment' systems. Such opportunities are relatively rare in testing the effectiveness of environmental flows as control systems are often difficult to find (Konrad 2011). This makes the Edward-Wakool system an important test case for this sort of analysis. This type of analysis will facilitate an assessment of the marginal benefit of Commonwealth environmental water.

2. We also intend to employ data from across several zones within the Edward-Wakool system to undertake a gradient analysis, in which variation in the hydrologic conditions at individual sites are included in a regression model. For this analysis we will employ hierarchical mixed-effects models, which allow the integration of both continuous and categorical variables, as well as measurements that vary at different spatial scales (e.g. from rivers, zones or sites). The creeks and rivers that comprise the Edward-Wakool system provide the ideal situation in which to undertake this type of evaluation because a wide range of flow types are experienced in this system within a single year, which strengthens the modelling capability and reduces the risk of having to wait many years to sample a wide range of flows. The range of flow types and environmental watering options that will be included in the model range from low base flows, to small freshes that remain in channel, to larger freshes that connect low lying geomorphic features, such as in-channel benches, backwaters and flood runners. Using this modelling approach, the effects of Commonwealth environmental watering decisions can be tested directly, but also can be inferred in a post-hoc fashion by using the predictive models to answer 'what-if' type questions about the outcomes of alternative watering scenarios, or, for example what would have been expected in the absence of watering.

3. The responses measured across multiple indicators will also be used in a multiple lines of evidence approach to evaluate competing hypotheses about underlying mechanisms driving or limiting the outcomes from environmental water delivery. For example, if watering achieves increases in production and fish spawning, but not recruitment, it would be possible to identify potential bottlenecks and strategies for overcoming those as part of an adaptive management cycle. This accords with the qualitative approach outlined in the LTIM Project Draft Evaluation Plan.

2 Description of the Edward-Wakool Selected Area

The Edward-Wakool system is a large anabranch system of the Murray River main channel. The system begins upstream of the Barmah choke, and travels northwest through river red gum forests before discharging back into the Murray River downstream of Kyalite (Figure 2). It is a complex network of interconnected streams, ephemeral creeks, flood runners and wetlands including the Wakool River, Yallakool Creek, Colligen-Niemur Creek, Coobool Creek and Merran Creek.

For the purposes of the LTIM Project, the Edward-Wakool river system Selected Area can be broadly divided into three areas / aquatic ecosystem types:

- the main permanent flowing rivers including Yallakool and Colligen creeks and Wakool, Niemur and Edward rivers
- the floodplain forests and woodlands including the Niemur and Werai Forests
- several small intermittent and ephemeral creeks of ecological significance including Tuppal (intermittent), Jimaringle, Cockran and Gwynnes.

The Edward-Wakool system is considered to be 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*). This system has abundant areas of fish habitat, and historically had diverse fish communities which supported both commercial and recreational fisheries.

The area supports a productive agricultural community, has a rich and diverse Indigenous history, and supports both active and passive recreational uses such as fishing, bird-watching and bush-walking. Many Aboriginal nations maintain strong connections to the country (including the Yorta Yorta, Wiradjuri, Barapa Barapa, Wemba Wemba and Wari Wari), with the Werai Forest in the process of conversion to an Indigenous Protected Area.

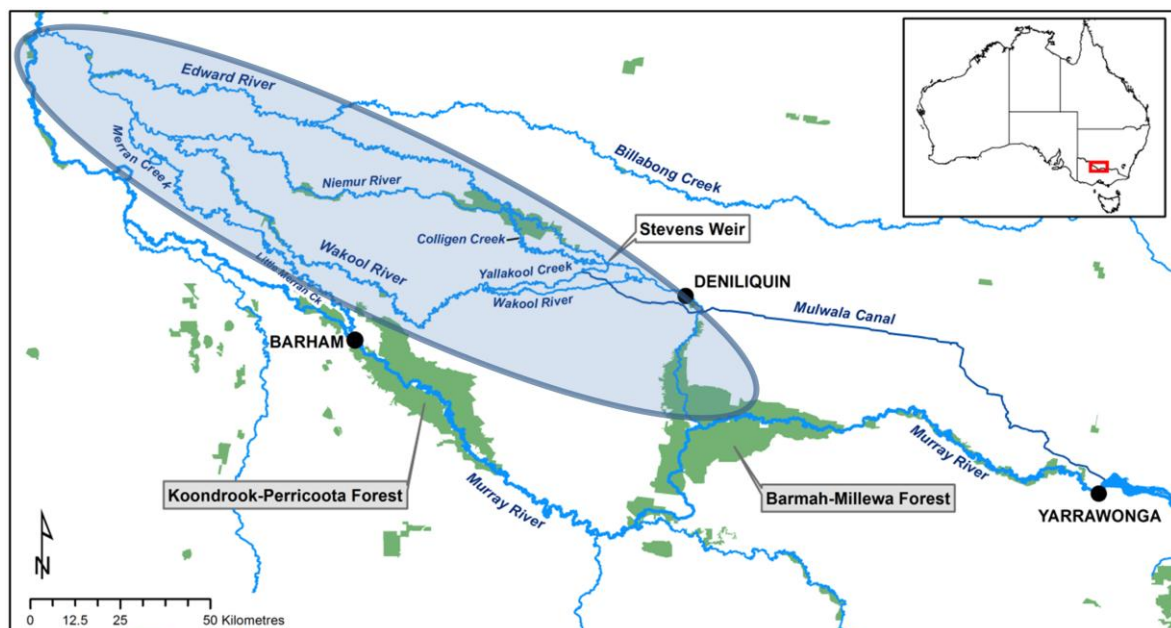


Figure 2. Map showing the location of the Edward-Wakool system.

Like many rivers of the Murray-Darling Basin, the Edward-Wakool anabranch system has suffered from the effects of river regulation, migration barriers and degradation of water quality. Water regimes within the Edward-Wakool River have been significantly altered by river regulation (Green 2001; Watkins et al. 2010), with changes to the timing and volume of flows (Green 2001). Natural flows in the river system would have been high in spring and very low in summer and autumn. The alteration of flow regime has resulted in changes in water velocities, the availability of in-channel habitat types, and ecosystem processes and functions.

Ecosystem responses to environmental watering will be influenced by the history of flows in this system. Between February 2006 and September 2010 there were periods of minimal or no flow in the Edward-Wakool system (Figure 3) due to severe drought conditions. These problems were manifested in a fish kill event in 2007/08 which resulted in a loss of many thousands of native fish, including large individuals of the iconic Murray cod. The event caused much angst within the local community and brought the issue of sustainable water into the spotlight. At the break of the drought a number of large natural flow events occurred in the Edward-Wakool system between September 2010 and March 2011 (Figure 3). Commonwealth environmental water has been delivered to the Edward-Wakool system since 2010.

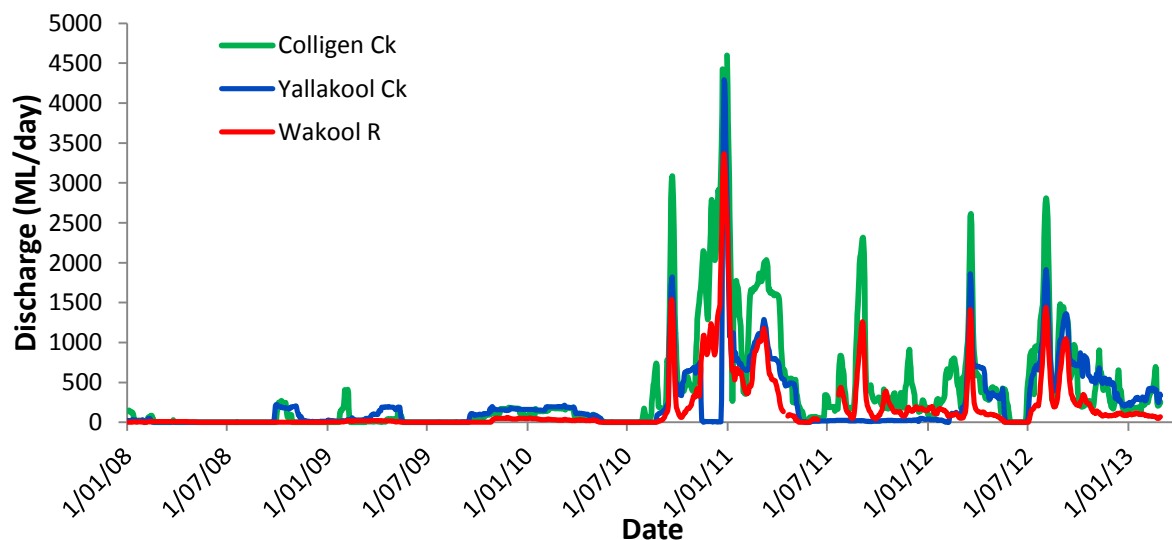


Figure 3. Daily discharge between 01/01/08 and 28/02/13 in three rivers in the Edward-Wakool system: Colligen Creek, Yallakool Creek, and the Wakool River. Daily discharge data was obtained from NSW Government water information website (NSW Office of Water, 2012) for three stations: Colligen Creek regulator (409024), Wakool River offtake regulator (409019), Yallakool Creek offtake regulator (409020).

Analysis of daily discharge data from 14 hydrological stations in the Edward-Wakool system along with information on geomorphology and location of major distributaries was used to classify the system into distinct hydrological zones. Fifteen distinct zones were identified (Figure 4). Transitions between these zones occur where there are major inflows or outflows to a river or at locations where there are significant changes in geomorphology. The zones range from ephemeral watercourses (zone 15), to smaller creeks and rivers (Wakool River, Yallakool Creek, Colligen-Niemur system, and the Merran and Little Merran systems) to the larger Edward River system.

In section 3 we describe the expected Commonwealth environmental watering in the Edward-Wakool system, the process for selecting the hydrological zones for inclusion in the M&E Plan, and a rationale and description of the zones that were selected for inclusion in the M&E Plan.

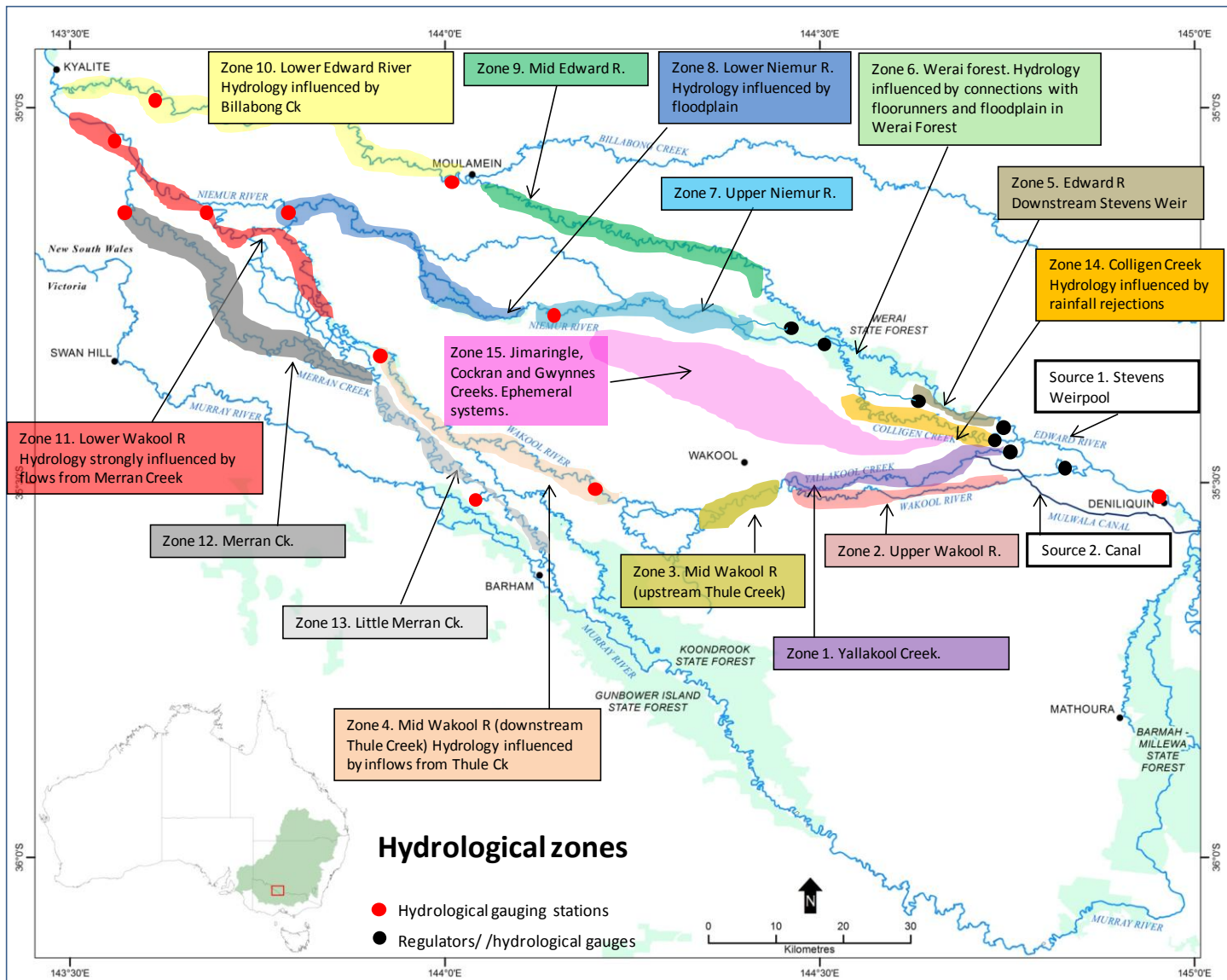


Figure 4. Map showing 15 hydrological zones within the Edward-Wakool system.

3 Commonwealth environmental watering

3.1 Water use options

Each year the CEWO develops water use options that seek to scope the range of environmental watering that may be required in the Edward-Wakool system in the following year. The broad aim of Commonwealth environmental watering in the Mid-Murray Region in recent years has been to support the on-going environmental recovery following the drought (CEWO 2013). Commonwealth environmental watering options for the Edward-Wakool system that are expected for this Selected Area over the next 5 years were summarised by Gawne et al. (2013b)(Table 3). In addition there is the potential for a future option of watering in Werai Forest for cultural purposes (Table 3).

Table 3. Summary of water use options for the mid-Murray system that are relevant for the LTIM Project in the Edward-Wakool system (Information from Gawne et al. 2013b with additions).

Option and sites	Watering option purpose
<p>Option 1 – Edward Wakool River system instream flows Target sites: Edward River, Yallakool Ck, Wakool River, Colligen Creek-Niemur River, Gulpa Creek, Merran System</p>	<p>The purpose of this option is to support the condition and reproduction of native fish, which may involve contributing to instream flows to maximise available breeding habitat, create flow conditions favourable for reproduction (e.g. freshes), or contribute to the survival of native fish. Contribute to river base flows and freshes, and the recession of bankfull and overbank flows. If very low flow periods are experienced, the focus of environmental watering will be on the delivery of base flows to provide refuge habitat for native fish. This option may also contribute to managing water quality issues within instream environments.</p>
<p>Option 2 – Ephemeral water courses Target sites: Jimaringle-Cockran-Gwynnes & Tuppall Creek</p>	<p>The purpose of this option is to provide environmental water to ephemeral streams in the Murray River catchment to contribute to the recovery of these systems. Expected outcomes include supporting: the condition of native vegetation, fish, and other vertebrates, hydrological connectivity, end of system flows, refuges, dissolved oxygen, salinity and pH.</p>
<p>Option 3 – Werai Forest Target sites: Werai Forest</p>	<p>This option would provide overbank flows (regulator assisted) to Werai Forest to:</p> <ul style="list-style-type: none"> • Support the condition and reproduction of wetland and floodplain vegetation of Werai Forest (e.g. river red gum and phragmites). • Provide refuge for, and support the condition and reproduction of native fish, waterbirds and other vertebrates (e.g. frogs and turtles). • Support processes such as primary production and contribute to decomposition and nutrient and carbon cycling. • Increase hydrological connectivity between the river channels, floodplain, and low lying wetlands, as water moves from the Edward River through to Colligen Creek and the Niemur River. Increasing hydrological connectivity will support associated functions, such as biotic dispersal and sediment transport.
<p>Potential future option of watering in Werai Forest for cultural purposes</p>	<p>In the future environmental water may be supplied to sites throughout the Basin to support Aboriginal cultural values and uses. Werai Forest offers opportunities in this area – outcomes to Aboriginal community wellbeing would complement environmental outcomes outlined above</p>

For the purposes of this M&E Plan the instream environmental watering option number 1 (see Table 3) has been further classified into three sub-options (1a, 1b and 1c)(Figure 5), that better describe the type of delivery and circumstances under which the watering options will occur.

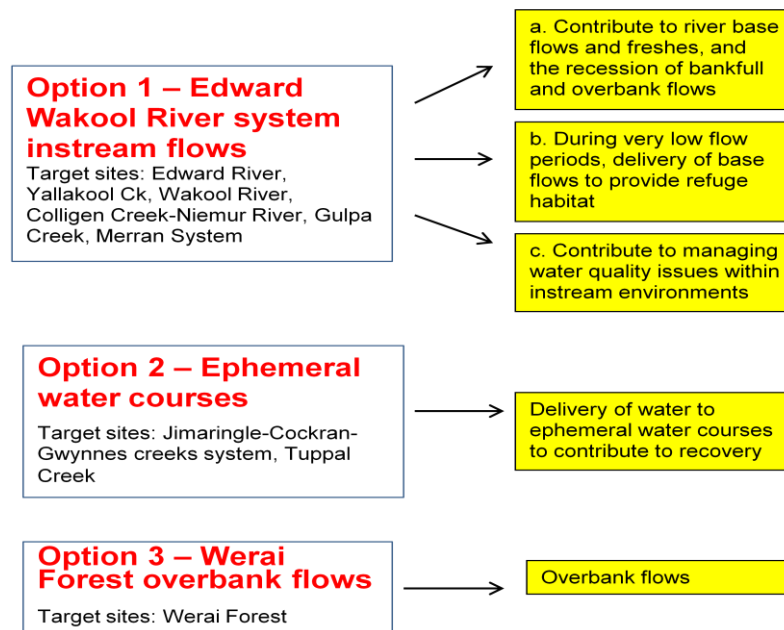


Figure 5. Environmental watering options for the Edward-Wakool system

3.2 Practicalities of watering

History of Commonwealth environmental watering actions

There has been a history of environmental watering actions in the Edward-Wakool system since 2010 with significant volumes of Commonwealth environmental water delivered to this system each year. As at 31 March 2014, 156,822 ML of environmental water has been delivered to the Edward-Wakool system, comprising 130,287 ML Commonwealth environmental water and 26,535 from delivery partners (CEWO, 2014). In addition, Commonwealth environmental water from upstream watering actions or Commonwealth environmental water that is targeted for downstream watering actions transits through the Edward-Wakool system.

Delivery of Commonwealth environmental water

The main source of Commonwealth environmental water for the Edward-Wakool system is from the River Murray through the Edward River and Gulpa Creek. Water diverted into the Mulwala Canal can also be delivered back into the Edward-Wakool system water courses through “escapes” or outfalls, of which the major escapes discharge to the Edward River, Wakool River and Yallakool Creek (Hale and SKM 2011).

The main flow regulating structure within the Edward-Wakool system is Stevens Weir, located on the Edward River downstream of Colligen Creek. This structure creates a weir pool that allows Commonwealth environmental water to be delivered to Colligen and Yallakool Creeks, the Wakool River, the Edward River and Werai Forest. Flow regulators have been placed on the inlets to the Werai Forest, which allow flow deliveries to be controlled when flow in the Edward River is regulated (Hale and SKM 2011). Information on delivery triggers for delivering environmental water have been summarised in Hale and SKM (2011).

Delivery constraints

The ability to deliver environmental water to the Edward-Wakool system will depend on circumstances in the river system at any given time. Delivery constraints in the Edward-Wakool system were described in Gawne et al. (2013). The following section summarises that information.

Commonwealth environmental water delivery in the Edward-Wakool river system involves various considerations, including:

- the capacity of the off takes / regulators and irrigation escapes
- channel constraints (e.g. to avoid third party impacts)
- the availability of third party infrastructure to assist in delivering water into the system
- existing flows and other demands on the system.

Delivery considerations for key sites within the Selected Area include the following:

- Instream flows (Edward River, Wakool River, Yallakool Creek, Colligen Creek, Niemur River, and Merran River system) will be managed within regular operating ranges as advised by river operators. Target flow rates will be within channel capacity to avoid third party impacts. Thus, the types of flow components that can be achieved with environmental releases are baseflows and freshes. Environmental flows may also contribute to the recession of higher flow components, once existing higher flows receded to within regular operating ranges. Instream flows may also be delivered during low flow period to provide refuge habitat, or delivered to manage water quality issues.
- Environmental watering of Werai Forest is likely to be contingent on overbank flows at Millewa Forest, due to the flow rates required to begin to inundate these forested areas. Flows in the Edward River (below Stevens Weir) of greater than 2,100 megalitres per day are required for water to begin entering the Werai Forest, via the Tumudgerly and Reed Bed Creek regulators. Due to delivery constraints, managed watering of Werai Forest may be limited to a small portion of the forest only.
- Delivery of environmental water to a number of ephemeral creeks in the Selected Area has occurred using Murray Irrigation Limited infrastructure and landholder infrastructure. The availability of this infrastructure is subject to arrangements with MIL and landholders. Existing demand on the irrigation system can limit available capacity to delivery environmental water. Delivery would also be limited by the capacities of the irrigation escapes and managed within channel to avoid third-party impacts. During the irrigation off-season (May to July) regulating / irrigation systems are shut down.
- Due to the limitations on how much water can be delivered into the Edward-Wakool river system under regulated conditions, at times of high irrigation demand environmental watering may be limited. Conversely, if the system is receiving higher unregulated flows, there may not be enough capacity (or need) to deliver environmental water.

3.3 River zones most likely to receive Commonwealth environmental water

An assessment of the likelihood that the fifteen hydrological zones (see section 2, Figure 4) will receive Commonwealth environmental water was undertaken drawing on available literature, discussions with CEWO and members of the Edward-Wakool Operations Group, and the past history of Commonwealth environmental watering in this system. A summary of the zones that are likely to receive Commonwealth environmental water is presented in Table 4.

Table 4. List of hydrological zones in Edward-Wakool system and the likelihood of these zones receiving Commonwealth environmental water.
 ✓✓✓ = highly likely, ✓ = likely, but effect of Commonwealth environmental water may be attenuated, x = unlikely, N/A = not applicable

Zone number	Zone name	Commonwealth environmental water use options				
		Option 1a. Contribute to river base flows and freshes, and the recession of bankfull and overbank flows	Option 1b. During very low flow periods, delivery of base flows to provide refuge habitat	Option 1c. Contribute to managing water quality issues within instream environments	Option 2. Ephemeral water courses	Option 3. Werai Forest overbank flows
1	Yallakool Creek	✓✓✓	✓✓✓	✓✓✓	N/A	N/A
2	Upper Wakool River	✓	✓✓✓	✓✓✓	N/A	N/A
3	Mid Wakool River (upstream Thule Creek)	✓✓✓	✓✓✓	✓✓✓	N/A	N/A
4	Mid Wakool River (downstream Thule Creek)	✓✓✓	✓✓✓	✓✓✓	N/A	N/A
5	Edward River between Stevens Weir and Werai	✓✓✓	x	✓✓✓	N/A	✓
6	Edward River in Werai Forest	✓✓✓	x	✓✓✓	N/A	✓✓✓
7	Upper Niemur River	✓	✓	✓	N/A	✓
8	Lower Niemur River	✓	✓	✓	N/A	x
9	Mid Edward R (Between Werai and Billabong Ck)	✓	x	✓	N/A	✓
10	Lower Edward River (downstream Billabong Ck)	✓	x	✓	N/A	x
11	Lower Wakool River	✓	✓	✓	N/A	N/A
12	Merran Creek	x	x	x	N/A	N/A
13	Little Merran Creek	x	x	x	N/A	N/A
14	Colligen Creek	✓✓✓	✓✓✓	✓✓✓	N/A	N/A
15	Jimaringle, Cockran and Gwynnes Creek	N/A	N/A	N/A	✓✓✓	N/A

3.4 Expected and desired outcomes of Commonwealth environmental watering

Ecological values

Key ecological values associated with each of the main ecosystems of the Edward-Wakool system are outlined in Gawne et al. (2013) and are summarised as follows:

Edward River, Colligen- Niemur, Yallakool Creek and Wakool River

These rivers and creeks support high regional biodiversity values and have significant value as drought refugia for native fish and other biota. The dominant vegetation is river red gum (*Eucalyptus camaldulensis*) with areas providing habitat for a number of threatened species.

Floodplain – Werai and Niemur Forest

Werai Forest is of special significance to the Aboriginal community. The higher floodplain areas are dominated by river red gum with lower lying areas typically dominated by giant rush. The low lying areas, floodrunners and backwaters in Werai Forest may be important habitat for larval and juvenile fish. The Werai Forest supports significant breeding colonies of several species of cormorants, whilst the Niemur Forest supports egrets and nankeen knight heron breeding colonies. Both forests support a number of listed species and migratory species. Werai Forest is part of the Ramsar listed NSW Central Murray State Forests and Niemur Forest is located in a National Park (CEWO 2012c).

Ephemeral and intermittent creeks - Tuppal, Jimaringle, Cockran and Gwynnes

Tuppal Creek is an intermittent flood runner connecting the Murray River to the Edward River and has a largely continuous riparian corridor which provides habitat connectivity for over 120 terrestrial native species and supports a number of state listed threatened and vulnerable species (Brownbill and Warne 2010; CEWO 2012c). Jimaringle, Cockran and Gwynnes Creeks are all ephemeral creeks and considered a biodiversity hotspot of significant regional value.

Community values

Consultation by the former Murray Catchment Management Authority on the Edward-Wakool River system using a whole-of-community approach (including scientific, industry, government, Aboriginal, landholder, special interest group, and general public stakeholders) identified a number of values and priorities for the system which have been used to inform this M&E Plan.

Ecological objectives

Ecological objectives for the Edward-Wakool system to maintain or improve the condition of key environmental attributes and address significant threats are outlined in Hale and SKM (2011) and presented in Table 5.

Table 5. Objectives for environmental water use in the Edward-Wakool system (From Hale & SKM 2011)

Broad objective	Location	Ecological Targets
<p>Within channel flows – to provide sufficient ecological baseflow and suitable water quality in the regulated streams during dry conditions so they can act as drought refuges for vulnerable fish, frog and crustacean species; avoid the build-up of organic matter and maintain vegetation health.</p> <p>To provide within channel pulse flows to stimulate productivity and reproduction.</p>	<p>Permanent, semi permanent regulated rivers and creeks (>1,000 km; includes wetlands connected at pool level).</p>	<p>Maintain water quality within channels and pools. Reduce the frequency and magnitude of blackwater events, by preventing the long-term accumulation of litter in channel and on bars and benches.</p> <p>Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna.</p> <p>Maintain connectivity between main channel and lower commence to fill billabongs and backwaters.</p> <p>Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.</p> <p>Maintain inundation of low lying wetlands associated with the river channels to prevent exposure of acid sulphate soils.</p> <p>Aid in floodplain access for wetland specialist fish, frogs and crustaceans.</p>
<p>Flood flows – To reinstate some small and medium floods that provide the flow variability required to improve and restore wetland diversity, resilience and connectivity to the main river channels.</p>	<p>Reed Bed Creek Wetlands (Werai – 400 ha)</p>	<p>Maintain extent and health of reed bed vegetation. Maintain connectivity through the forest (Tumudgery Creek and Reed Beds Creek from Edward River to Colligen-Neimur) between river channel and low lying wetlands for fish and other aquatic fauna. Promote successful breeding of waterbirds. Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.</p>
	<p>River red gum forests (15,000 ha)</p>	<p>Maintain health of river red gum forests and woodlands. Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. Maintain connectivity between main channel and floodplain. Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages. Promote successful breeding of waterbirds.</p>
	<p>Ephemeral wetlands and watercourses</p>	<p>Maintain health of ephemeral wetlands and watercourses (approximately 800 km; includes: Cockran Creek, Yarrien Creek; and Poon Boon Lakes).</p>
	<p>Black Box woodland and depressional wetlands at high elevations.</p>	<p>Maintain the health of Black Box woodlands. Maintain connectivity and promote productivity. Prevent fish stranding and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.</p>

Expected outcomes sought from the use of Commonwealth environmental water

Gawne et al. (2013) summarised the expected outcomes of watering options and mapped these outcomes to the objectives hierarchy set out in the LTIM Project Logic and Rationale document. This has been done by identifying the expected outcomes from the four flow components; base flow, freshes, bankfull and overbank as well as overbank assisted flows into wetlands which have the appropriate infrastructure. The summary tables from Gawne et al. (2013) for each of the three main ecosystems of the Edward- Wakool system are reproduced here as Tables 6, 7 and 8.

Table 6. Expected outcomes for permanent streams of the Edward-Wakool river system Selected Area mapped against Basin Plan objectives and flow type. Systems included are: Edward River, Colligen Creek-Niemur River, Yallakool Creek and Wakool River. (Source: Gawne et al. 2013)

Flow component	Level 1 objectives	Level 2 and 3 objectives	< 1 year expected outcome	1-5 year expected outcome
Base flow	Biodiversity	Vegetation	Contribute to in-stream and riparian native vegetation population viability particularly extent and condition.	Maintain population, and landscape vegetation diversity.
Base flow	Biodiversity	Fish	Contribute to protection of native fish diversity.	As for <1-year outcome.
Base flow	Function	Process Connectivity	Maintain productive biofilms.	As for <1-year outcome
Base flow	Function	Process	Contribute to transport of nutrients and carbon in the Edward, Yallakool, Colligen-Niemur, and Wakool.	As for <1-year outcome
Base flow	Water Quality	Chemical	Contribute to the maintenance or improvement of water quality to support recruitment, growth and survival of native species (fish, macroinvertebrates, and other vertebrates).	Increased availability of physical habitat for fish, other vertebrates and macroinvertebrates.
Fresh	Biodiversity	Vegetation	Contribute to in-stream and riparian native vegetation population viability particularly extent and condition.	As for <1-year outcome
Fresh	Biodiversity	Fish	Contribute native fish reproduction.	Improved native fish population, diversity and condition.
Fresh	Ecosystem function	Connectivity	Contribute to opportunities for fish dispersal.	Improved native fish population, diversity and condition.
Fresh	Ecosystem function	Connectivity	Maintain hydraulic habitat/conditions in the Edward, Yallakool, Colligen-Niemur, and Wakool which sustain in-stream habitat for aquatic flora and fauna.	Increased in-channel geomorphic diversity and hence availability of physical and hydraulic habitat for aquatic flora and fauna (e.g. benches, bars, pools & large woody debris).
Fresh	Ecosystem function	Process	Maintain productive biofilms.	As for <1-year outcome
Fresh	Resilience	Ecosystem resilience	Maintain hydraulic habitat/condition, notably in-stream pool depth in the Edward, Yallakool, Colligen-Niemur, and Wakool which provide refugia for aquatic flora and fauna.	Maintenance of refugia at landscape scale.
Fresh	Water quality	Chemical	Contribute to the maintenance or improvement of water quality to support recruitment, growth and survival of native species (fish, macroinvertebrates, and other vertebrates).	Increased availability of physical habitat for fish.

Table 7. Expected outcomes for floodplain of the Edward-Wakool river system Selected Area mapped against Basin Plan objectives and flow type. Systems included are: Werai Forest and Niemur Forest. (Source: Gawne et al. 2013).

Flow component	Level 1 objectives	Level 2 and 3 objectives	<1 year expected outcome	1-5 year expected outcome
Overbank / regulator assisted	Biodiversity	Vegetation	Contribute to native wetland and floodplain vegetation population viability particularly extent and condition.	Maintained condition and extent of floodplain and wetland vegetation.
Overbank / regulator assisted	Biodiversity	Fish	Contribute to native fish reproduction, diversity and abundance through maintaining suitable habitat.	Increase in native fish population, diversity and condition.
Overbank / regulator assisted	Biodiversity	Waterbirds	Support waterbird breeding in Werai Forest.	Support waterbird breeding in Werai Forest.
Overbank / regulator assisted	Biodiversity	Other vertebrates	Contribute to restoration/protection of frog and turtle diversity and populations through provision of habitat to support breeding and recruitment.	As for <1-year outcome .
Overbank / regulator assisted	Ecosystem function	Connectivity	Contribution to opportunities for fish dispersal.	Improved fish dispersal throughout Werai.
Overbank / regulator assisted	Resilience	Ecosystem and population resilience	Provide refuge habitat for frogs.	As for <1-year outcome.
Overbank / regulator assisted	Resilience	Population resilience	Maintain viability of seed bank/rhizomes and long-lived vegetation.	As for <1-year outcome .

Table 8. Expected outcomes for ephemeral and intermittent creeks of the Edward-Wakool river system Selected Area mapped against Basin Plan objectives and flow type. Systems included are: Tuppal, Jimaringle, Cockran, and Gwynnes. (Source: Gawne et al. 2013)

Flow component	Level 1 objectives	Level 2 and 3 objectives	<1 year expected outcome	1-5 year expected outcome
Fresh	Biodiversity	Vegetation	Contribute to in-stream and riparian native vegetation population viability particularly extent and condition.	Maintained condition and extent of floodplain and wetland vegetation.
Fresh	Biodiversity	Macroinvertebrates	Contribute to protection of the diversity and abundance of macroinvertebrates.	As for <1-year outcome.
Fresh	Biodiversity	Fish	Contribute to protection of the diversity and abundance of native fish.	Increase in native fish population, diversity and condition.
Fresh	Biodiversity	Other vertebrates	Contribute to protection of the diversity and abundance of other vertebrates, notably turtles and frogs.	As for <1-year outcome.
Fresh	Ecosystem function	Connectivity	Contribute to opportunities for fish dispersal.	Improved fish dispersal throughout Tuppal, Jimaringle, Cockran & Gwynnes creeks.
Fresh	Ecosystem function	Process	Contribute to transport and cycling of nutrients and carbon.	As for <1-year outcome.
Fresh	Resilience	Ecosystem and population resilience	Provide refuge habitat for frogs, turtles and other vertebrates.	As for <1-year outcome.
Fresh	Resilience	Population resilience	Maintain viability of seed bank/rhizomes and long-lived vegetation.	As for <1-year outcome.
Fresh	Water quality	Chemical	Contribute to the maintenance or improvement of water quality to support the recruitment, growth and survival of native fish, frogs and invertebrates.	Increased availability of physical habitat for fish, frogs.

4 Monitoring priorities

4.1 Prioritisation of hydrological zones

Due to funding constraints it will not be possible to undertake monitoring and evaluation in all fifteen of the hydrological zones identified in the Edward-Wakool system (Figure 4). The following factors were considered when narrowing down the number of zones to include in the M&E Plan:

- Likelihood of receiving Commonwealth environmental water or serving as a control zone (i.e. not receive Commonwealth environmental water) (Table 4)
- Overlap with other ongoing monitoring programs
- Location of hydrological gauging stations
- Availability of historical monitoring data in each zone and existing arrangements for access
- Ease of access for undertaking fieldwork under a range of weather conditions
- Need for a number of zones that experience a range of flows to facilitate predictive ecosystem response modelling and Selected Area gradient analysis (see section 8)
- Capacity to inform on specific objectives aligned with values and needs of local community, including Aboriginal people
- Areas that were identified by Gawne et al. (2013) to be excluded from the M&E Plan

Taking all of these factors into account, the majority of the proposed monitoring and evaluation in the Edward-Wakool system will focus on the upper and mid reaches of the Wakool-Yallakool system (zones 1, 2, 3 and 4) (Figure 6) and watering options 1 a, b and c (Figure 5). These four hydrological zones will be referred to as the Focal Area. Some additional monitoring of fish community and water quality monitoring during blackwater events will occur outside this Focal Area.

Focal Area

Yallakool Creek (zone 1), the upper reach of the Wakool River (zone 2) and mid reaches of the Wakool River (zone 3 and 4) were selected as the Focal Area, as it is likely that these zones will receive Commonwealth environmental water from Stevens Weir under watering options 1a, 1b and 1c (Table 4). These rivers represent the numerous smaller rivers and creeks in this system. Zones 1 and 2 were the focus of monitoring of ecosystem responses to environmental watering between 2011 and 2014 (Watts et al. 2013a; Watts et al. 2013b). Annual survey of fish populations has been undertaken in the focal zone since 2010.

Under watering option 1a, the Focal Area will receive Commonwealth environmental water from Stevens Weir with delivery more likely to either Yallakool Creek (zone 1) or the upper Wakool River (zone 2), with the Mid Wakool River (zones 3 and 4) receiving the environmental water as it flows downstream. Either Yallakool Creek or the upper Wakool River can serve as a control. Inclusion of zones 3 and 4 in the M&E Plan facilitates an assessment of the influence of river geomorphology on ecosystem responses to environmental watering. The channel is relatively constrained in zone 1 and 2, whereas in zones 3 and 4 downstream of the confluence of the Wakool River and Yallakool Creek (Figure 6), there is a greater opportunity for lateral connection with floodrunners and backwaters.

Under watering option 1b zones 1, 2, 3 and 4 may receive Commonwealth environmental water during very low flow periods, with the aim to provide or maintain refuge habitat. Under watering option 1c these zones may receive Commonwealth environmental water to manage water quality issues during blackwater or other poor water quality events.

Sites outside the Focal Area that are included in the M&E Plan

In addition to zones 1, 2, 3 and 4 in the Focal Area, some monitoring will be undertaken at a larger spatial scale throughout the Edward-Wakool system.

Fish population assessment will be undertaken at 15 sites in zones 6, 7, 8, 10, 11, 12 and 14 to enable evaluation of the changes over 5 and >10 year timeframes and assist in providing an assessment of responses at the whole of system scale (Figure 6).

Monitoring of carbon and water quality will be routinely undertaken in the Stevens Weirpool and the Mulwala Canal as these are potential sources of Commonwealth environmental water.

Monitoring of carbon and water quality at additional sites during blackwater or other adverse water quality events is included as an option in this M&E Plan. Should the optional targeted component be triggered, four additional downstream sites will be selected to monitor the progress and severity of the event in the broader system. The location of these sites will be determined on an event basis in collaboration with the CEWO but options may include:

- To track the progress of blackwater down the Wakool River sites could include La Rosa, Gee Gee Bridge, Glenbar and Stony Crossing;
- To evaluate a more widespread event sites could include Gee Gee Bridge, Werai Station, Ventura and Moulamein; or
- To evaluate and event originating from the Koondrook/Gunbower forests sites could include Merran Downs, Gee Gee Bridge, Merran Creek Bridge and Stony Crossing.

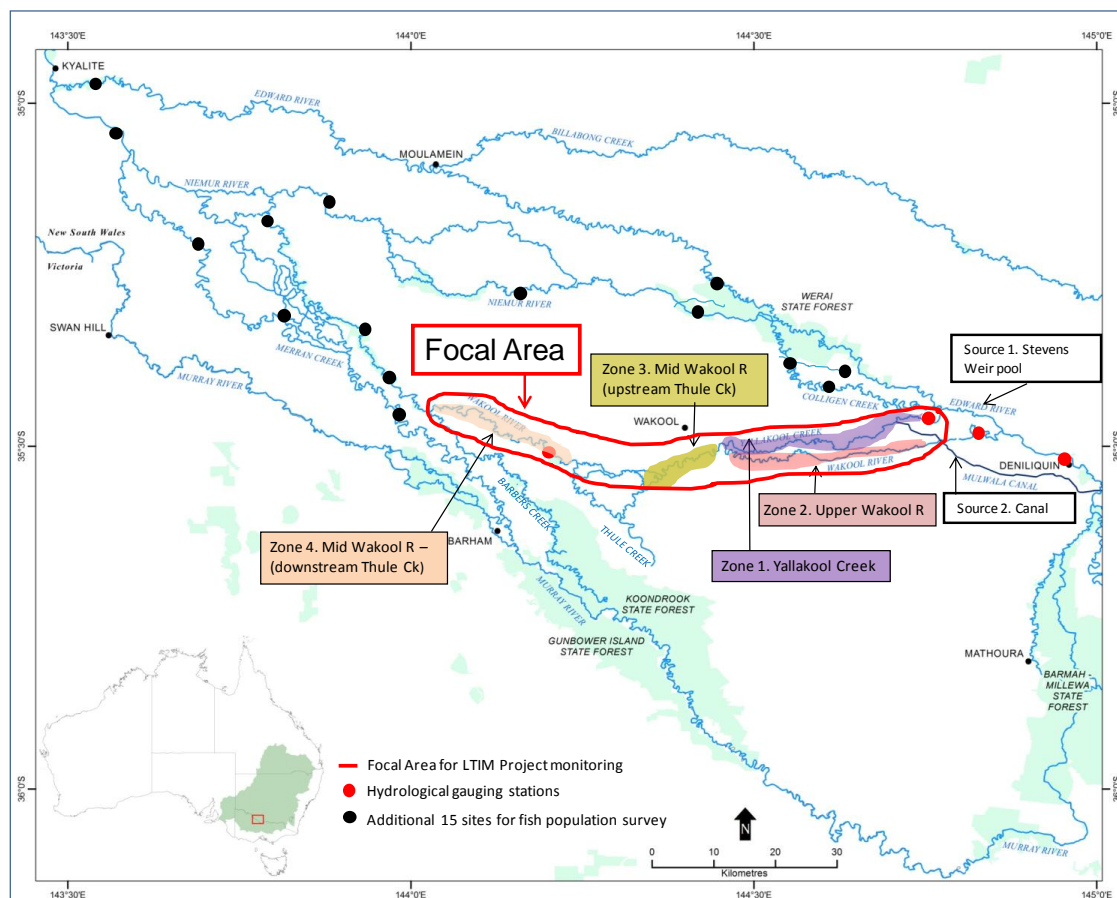


Figure 6. Location of hydrological zones selected for inclusion in the Edward-Wakool Monitoring and Evaluation Plan for the Long-Term Intervention Monitoring Project. Stevens Weir and the Mulwala canal will be sampled as potential sources of Commonwealth environmental water for the focus reaches.

Hydrological zones excluded from the M&E Plan

The LTIM Project monitoring and evaluation requirements for the Edward-Wakool system are outlined in Gawne et al. (2013) and this document states that monitoring for the LTIM Project is to exclude Niemur floodplain forest, Millewa Forest, and Koondrook-Perricoota forest. It is stated that these 'exclusions' don't preclude these areas from receiving environmental water, just that they currently are not the focus of the monitoring for this Selected Area.

The ephemeral creeks in zone 15, Jimaringle, Cockran and Gwynnes Creek, were excluded from the M&E Plan. Monitoring of ecosystem responses to watering option 2 in these ephemeral creeks and Tuppal Creek has been undertaken by the NSW Office of Environment and Heritage (OEH) over the past 3 years and OEH has indicated that they will continue to undertake monitoring in this system and report on the outcomes separately from the LTIM Project. To avoid duplication, the current M&E Plan does not include monitoring in these systems, but we will seek to integrate outcomes of environmental watering in these systems in the qualitative evaluation of the outcomes of Commonwealth environmental water in the Edward-Wakool system.

The Werai forest was excluded from the M&E Plan because the focus of Commonwealth environmental watering in this system is on instream flows under watering option 1. Watering of large wetlands and forests is the focus of other Selected Areas.

4.2 Preliminary identification of indicators by stakeholders

A stakeholder workshop led by LTIM Project Scientific Advisors (Murray-Darling Freshwater Research Centre) was held in Deniliquin on 5 February 2013 to seek input to the development of the M&E Requirements. The consultation was important to the development of the area description, identification of area values and the prioritisation of indicators. Stakeholder messages relevant to the development of the M&E Plan as summarised in Gawne et al. (2013) include:

- Local stakeholders felt that Niemur floodplain forest should be considered for inclusion
- Resilience did not appear to gain much support in the regional prioritisation of outcomes, however it is likely it will be captured through monitoring of other outcomes.
- Hydrological connectivity is considered by CEWO to be important in terms of adaptive management; however this was not reflected in the results of the workshop
- Outcomes associated with the Level 3 vegetation objective were identified as the only regional high priority outcome for the permanent rivers (Edward, Colligen-Niemur, Yallakool and Wakool). This was unexpected as the focus of Commonwealth environmental water deliveries to date has been for fish, not vegetation. The fact that vegetation outcomes were also considered achievable was also unexpected.
- An issue that was not adequately discussed was in regards to the practicality of monitoring different areas / ecosystems within the watering area. For example Werai Forest is known to be hard to access in wet conditions and this may influence design considerations
- Monitoring site selection recommendations were not addressed in the workshop or in correspondence with stakeholders; this will need to be addressed during the development of the M&E Plan for the Edward-Wakool river system. The successful service provider will need to liaise with stakeholders to receive local advice regarding access, constraints etc.

Gawne et al. (2013) identified priority indicators for the Edward-Wakool system based on the LTIM Project expected outcomes, stakeholder input, the needs of annual reporting of outcomes, five-year reporting against Basin Plan objectives and the needs of adaptive management (Table 9).

Table 9. Summary of indicators to be monitored at the Edward-Wakool river system Selected Area as presented in Gawne et al. (2013). Effect indicators are those that quantify an expected outcome (denoted as 'E') while others are causal factors that link flow to an expected outcome (denoted as 'C'). 'Y' denotes that the indicator is recommended for that area. '?' denotes a potential indicator. 'X' indicates the CED was identified as a priority in the regional stakeholder workshop. (From Gawne et al. 2013).

Cause effect diagram	Indicators	Type of indicator (Effect or cause)	Stakeholder	Basin Plan reporting	Adaptive Management	Selected (Gawne et al 2013)
a. Landscape ecosystem diversity	Ecosystem type and extent	E	X	Y		Y
b. Landscape vegetation diversity	Species number and abundance	E C	X	Y		
c. Vegetation recruitment and extent	Extent, distribution and contiguousness of vegetation	E C				Y
d. Vegetation condition and reproduction	Individual condition	E C		Y	Y	Y
e. Within ecosystem macroinvertebrate diversity	Species number and abundance	E C		Y		Y
f. Landscape fish diversity (channel)	Native species number and abundance	E	X	Y		Y
g. Landscape fish diversity	Micro-invertebrate abundance	C			Y	?
h. Fish reproduction	Egg and larval abundance, species & individual abundance	E	X			Y
i. Landscape waterbird diversity, reprod, recruitment, fledging	Nests, eggs, chicks, fledglings, species number and abundance	E	X	Y		
j. Other vertebrates growth and survival, reproduction	Abundance, population structure, size, survival and reprod of nominated species	E	X	Y		Y
k. Hydrological connectivity	Volume, duration, depth, timing, type of connection	E C	X	Y	Y	Y
l. Sediment transport	Suspended sediment, geomorphology	E C		Y	Y	Y
m. Biotic dispersal	Fish movement, distribution, abundance, population structure	E	X	Y	Y	Y
n. Primary productivity	River channel metabolism, NDVI	E C		Y	Y	Y
o. Decomposition	River channel metabolism	E C			Y	Y
p. Decomposition	Floodplain surface and sediment organic matter	E C				Y
q. Nutrient and carbon cycling	Total nitrogen, total phosphorus, NOx, filtered reactive phosphorus, DOC	E C		Y	Y	?
r. Resilience, Recovery, Refugia	Population and individual condition, population structure	E		Y		Y
s. Salinity, Dissolved oxygen, pH, Dissolved organic carbon	Salinity, DO, pH, temperature, turbidity, DOC	E C		Y	Y	Y
t. Hydrology*	Depth, duration, timing, hydraulics, dry rate, rise rate, area, hydroperiod, dry duration	C			Y	Y

The monitoring priorities presented in Gawne et al. (2013) guided the development of the first draft of the M&E Plan for the Edward-Wakool system. The Edward-Wakool Stakeholder Committee (EWSC) was established in January 2014 to provide guidance on the Edward-Wakool LTIM Project and other related projects in the Edward-Wakool system. At the first meeting of EWSC on the 11th February 2014, Robyn Watts (Leader of Edward-Wakool M&E Team) presented an outline of the approach the team was taking to develop the Edward-Wakool LTIM Project draft M&E Plan. The EWSC members were invited to provide comment on that approach and were later invited by email to rank (as high, medium or low) the different components that were being considered for inclusion in the draft M&E Plan.

Three members of the EWSC submitted rankings on the proposed indicators listed in Table 10. All three respondents indicated that it was a difficult task to rank the components because “they are all important, depending on what the rationale is for the various components”. The responses were mostly consistent, with all three respondents giving high rankings for inundation modelling, fish populations and fish movement, and two of the three respondents giving high ranking for hydrology, stream metabolism, fish spawning, fish recruitment, and lowest ranking for tree stand condition. The EWSC rankings, in addition to those identified by Gawne et al. (2013), guided the development of evaluation questions that will underpin the M&E Plan for the Edward-Wakool Selected Area.

A summary of the draft M&E Plan was presented at the EWSC meeting on 11th June. Feedback from EWSC included a request to include some monitoring of fish populations in mid and lower zones of the system. CEWO considered feedback from EWSC and comments from agencies and the M&E team and advised the M&E Team to revise the plan.

Table 10. Summary of priority ranks (H=High, M=Medium, L=Low) received from members of the Edward-Wakool Stakeholder Committee on the proposed indicators for the Edward-Wakool M&E Plan.

Indicator	Scores (high, medium, or low priority)	Comments
Indicators to be monitored in the Edward-Wakool system to contribute to an evaluation of the outcomes of Commonwealth environmental watering at the whole of basin-scale.		
River hydrology	H, M, H	I would like to emphasise the importance of flow loggers at all key sites, for all projects now and into the future
Stream metabolism	H, M, H	
Tree stand condition	L, L, M	If this is mandatory then I think it should be a scaled down version of TLM T&S condition monitoring program to include other reserves along the Wakool system such as Niemur, Wetuppa, Noorong
Fish river	H, H, combine	
Fish larvae	H, H, H	
Fish movement	H, H, very H	
Indicators that will be included in the draft plan to evaluate the outcomes of Commonwealth environmental watering in the Edward-Wakool system.		
River hydrology	H, M, H	I would like to emphasise the importance of flow loggers at all key sites, for all projects now and into the future
Inundation modelling and hydraulic habitat modelling	H, H, H	Likely to contribute to the Constraints Management Strategy and identify third party impacts and help identify mitigation measures (eg. capital works to upgrade crossings which will remove barriers to fish movement and allow e-flows to be increased).
Stream metabolism	H, M, H	
Riverbank vegetation and aquatic vegetation	H, M, M	
Fish movement	H, H, very H	
Fish spawning (Larvae)	H, H, M	
Fish recruitment	H, H, M	
Fish populations	H, H, H	
Frog recruitment	M/L, M, M	How useful will this be to develop a strategic e-water management plan and to guide river operations to provide optimal ecological outcomes? This is why I have ranked fish indicators HIGH. I am unsure about frogs. I wasn't too worried about frogs because they seem to grow whenever there is inundation, and were dormant after 10 year drought and went ballistic.
Shrimp recruitment	M, M, M	Is there a relationship between shrimp larval abundance and macrophyte/woody debris abundance/density?
Microinvertebrates	H, M, M	Will be interesting to measure density/biomass of microinvertebrates before and after overbank flooding events (I assume high densities of microinvertebrates are produced on floodplains and enter river systems during flood recession?).
Targeted monitoring of blackwater events	H, M, M	Hopefully overbank flooding occurs during the monitoring period! This information may help highlight the importance of using MIL escapes to assist with blackwater mitigation.

4.3 Prioritisation of Monitoring Indicators

There are three categories of monitoring indicators in the LTIM Project:

- **Category I** –Mandatory indicators and standard operating protocols that are required to inform Basin-scale evaluation and may be used to answer Selected Area questions
- **Category II** –Optional indicators with mandatory standard protocols that may be used to inform Basin-scale evaluation and may be used to answer Selected Area questions
- **Category III** – Selected Area specific monitoring protocols to answer Selected Area questions

The following factors were considered when narrowing down the indicators for the M&E Plan:

a. Contribution to both Basin-scale and Selected Area Evaluation

Indicators that have the potential to contribute to both the Basin-scale and Selected Area evaluation were ranked more highly than those which would contribute to only one of the evaluations.

b. Alignment of indicators with expected environmental outcomes of Commonwealth environmental watering in the Edward-Wakool system

Expected outcomes of Commonwealth environmental watering in the permanent stream of the Edward-Wakool system were mapped against Basin Plan objectives and flow type by Gawne et al (2013) and a summary was presented in section 3.4. Indicators that aligned with these objectives and outcomes were ranked more highly in the prioritisation process.

c. Contribution of indicators to predictive response models and multiple lines of evidence approach

The overarching principle that underpins the M&E Plan for the Edward-Wakool Selected Area is that we will use an ecosystem approach to evaluate the responses to Commonwealth environmental water (see Figure 1). The responses measured across multiple indicators will also be used in a multiple lines of evidence approach to evaluate competing hypotheses about underlying mechanisms driving or limiting the outcomes from environmental water delivery. For example, if watering achieves increases in fish movement and fish spawning but not recruitment, it will be possible to identify potential bottlenecks and develop strategies for overcoming those as part of an adaptive management cycle. This accords with the qualitative approach outlined in the LTIM Project Evaluation Plan (Gawne et al. 2014). Indicators that could contribute to the Selected Area response models or multiple lines of evidence approach were given a higher priority.

d. Contribution of indicators to short-term and longer term adaptive management cycles

Over the past four years the M&E Team have contributed to operational discussions regarding the delivery of environmental water. Some indicators (e.g. fish larvae, water quality and aquatic vegetation) have been used to provide rapid feedback to decision making and adaptive management during watering events. Other indicators, such as fish community composition, provide input to adaptive management over longer time frames. One of the aims of the prioritisation process was to include a mix of indicators that can contribute to both short-term and longer-term adaptive management.

e. Value for money of each indicator

The relative cost of indicators was also considered in the prioritisation process. As part of that we process we considered the cost of each indicator per zone over 5 years and also the in-kind contribution made by project partners to each indicator. Indicators were scored as low cost when < \$100,000 per zone, medium when cost was between \$100,000 and \$200,000 per zone, and high when cost was greater than \$400,000 per zone (Table 11).

f. Stakeholder values

Stakeholder values (as outlined in Table 10) were included in the prioritisation process. The Edward-Wakool community ranked highly all fish indicators (movement, larvae, recruitment and adult), as well as hydrology, hydraulic modelling and stream metabolism indicators.

g. Confidence in predicting a basin-scale response or Selected Area response

In Table 11 we have scored our confidence in predicting a Selected Area response, taking into account our knowledge of this system from previous projects undertaken in the system since 2010.

Recommended priority indicators

Indicators included in the M&E Plan were scored against each of the factors discussed above (Table 11). All of these factors were taken into account to provide an overall priority score for each indicator (high, medium and lower priority).

Table 11. Summary of priority ranks (H=High, M=Medium, L=Low) for the proposed indicators for the Edward-Wakool Monitoring and Evaluation Plan.

Indicator	Indicator Category	Basin- scale evaluation	Selected Area evaluation	Contribute to Selected Area response modelling	Contributes to Selected Area multiple lines of evidence approach	Short-term adaptive management	Longer term adaptive management	Cost per zone over 5 years (H,M,L)	In-kind contribution over 5 years	High value for money	Community values	Confidence detecting Selected Area response	Overall score
Cat I and II Indicators													
Ecosystem type	I	✓	✓					L		✓			H
Tree stand condition	I	✓					✓	M					L
Fish (river)	I	✓	partly	partly	✓		✓	H			✓		M
Fish (larvae)	I	✓	partly	partly	✓	✓	✓	H			✓	✓	M
River hydrology	I	✓	✓	✓	✓	✓	✓	L	✓	✓	✓	✓	H
Stream metabolism	I	✓	✓	✓	✓		✓	M	✓	✓	✓	✓	H
Fish movement	II	✓	✓		✓		✓	M	✓		✓	✓	H
Cat III indicators													
Fish (larvae)	III		✓	✓	✓	✓	✓	M		✓	✓	✓	H
Fish recruitment	III		✓	✓	✓		✓	M		✓	✓	✓	H
Fish (river)	III		✓	✓	✓		✓	L		✓	✓	✓	H
Microinvertebrates	III		✓	✓	✓		✓	L		✓		✓	M
Shrimp	III		✓	✓	✓		✓	L	✓	✓		✓	L
Frogs	III		✓		✓	✓	✓	L	✓	✓		✓	M
Hydraulic modelling	III		✓	✓	✓	✓	✓	L	✓	✓	✓	✓	H
Riverbank and aquatic vegetation	III		✓	✓	✓	✓	✓	L	✓	✓		✓	H
Carbon and WQ during adverse WQ events	III		✓	✓	✓	✓	✓	L	✓	✓		✓	H

4.4 Summary of hydrological zones and indicators selected for the M&E Plan

Table 12 provides a summary of the hydrological zones and indicators selected for the Edward-Wakool M&E Plan for the LTIM Project. The indicators included in the M&E Plan are:

- Ecosystem type
- River hydrology
- Hydraulic modelling
- Stream metabolism
- Carbon and water quality
- Riverbank and aquatic vegetation
- Fish movement – focus on silver perch and golden perch
- fish larvae – to evaluate the success of spawning
- fish recruitment – focus on young-of-year and 1+ Murray cod, golden perch and silver perch
- Fish (river) – annual survey of fish community

There is overlap between monitoring to support Basin evaluation activities and the Selected Area activities (Table 12). There are a number of zones and indicators to be monitored that will contribute only to the Selected Area evaluation. These additional zones and indicators are essential to capture the diversity of Commonwealth watering actions that can occur in the Edward-Wakool system to facilitate the gradient analysis approach outlined in section 8 (Evaluation).

Table 12. Summary of hydrological zones and indicators included in the final M&E Plan for the Edward-Wakool Selected Area. ✓ = to be monitored,

Indicator	Cat	Focal Area				Additional sites outside Focal Area			Used for Basin (B) Evaluation or Selected Area (SA) evaluation
		Zone 1	Zone 2	Zone 3	Zone 4	Source of Commonwealth environmental water (weir and canal)	Fish community assessment (15 sites)	Optional Carbon and water quality monitoring during adverse events (4 sites)	
Cat I and II Indicators									
Ecosystem type	I	✓	✓	✓	✓				B
Fish (river)	I			✓					B, partly SA
Fish (larvae)	I			✓					B, partly SA
River hydrology	I	✓	✓	✓	✓				B, SA
Stream metabolism	I	✓	✓	✓	✓				B, SA
Fish Movement	II	✓	✓	✓	✓				B, SA
Cat III indicators									
Fish Larvae	III	✓	✓	✓	✓				SA
Fish recruitment	III	✓	✓	✓	✓				SA
Fish (river)	III	✓		✓			✓		SA
Hydraulic modelling	III	✓	✓	✓	✓				SA
Riverbank and aquatic vegetation	III	✓	✓	✓	✓				SA
Carbon and water quality	III	✓	✓	✓	✓	✓		✓	SA

5 Evaluation questions

Three categories of indicators that will be used to answer the evaluation questions:

- **Category I** –Mandatory indicators and standard operating protocols that are required to inform Basin-scale evaluation and may be used to answer Selected Area questions
- **Category II** –Optional indicators with mandatory standard protocols that may be used to inform Basin-scale evaluation and may be used to answer Selected Area questions
- **Category III** – Selected Area specific monitoring protocols to answer Selected Area questions

5.1 Basin-scale evaluation questions

The Basin-scale questions that are relevant to the Edward-Wakool Selected Area are listed in Table 13. The approach to answering Basin-scale questions is described in the LTIM Project Evaluation Plan (Gawne et al. 2014).

5.2 Selected Area evaluation questions

The monitoring and evaluation priorities were summarised in section 4. The Edward-Wakool Monitoring and Evaluation Team used these priorities and our knowledge of the system from previous M&E projects to develop an approach to evaluation and a list of evaluation questions for the Edward-Wakool Selected Area Evaluation (Table 14).

The overarching principle that underpins the M&E Plan for the Edward-Wakool Selected Area is that we are taking an ecosystem approach to evaluate the responses to Commonwealth environmental watering (see Figure 1). The ecosystem approach has a strong focus on fish, including fish movement, reproduction, recruitment and adult populations. Outcomes for fish was one of the main priorities identified by Gawne et al. (2013) and ranked very highly in the Edward-Wakool System Stakeholder Committee responses (Section 4). Fish have been the main focus of previous watering actions in the Edward-Wakool system and they are the key environmental asset valued by the Edward-Wakool community. However, many of the indicators included in the M&E Plan (such as Water quality, metabolism and riverbank and aquatic vegetation) also strongly influence fish population dynamics. A key goal of including these in the M&E Plan is to allow these interdependencies to be better understood and interpreted.

Table 13. Basin-scale questions that are relevant to the Edward-Wakool Selected Area. ‘Cat’ refers to the category of indicator as described in Hale et al. (2014) and section 4. Commonwealth environmental water

Basin Plan Objectives	Basin Outcomes	Indicators	Cat	Basin-scale evaluation questions
Biodiversity	Ecosystem diversity	Ecosystem type and extent	I	<ul style="list-style-type: none"> • What did Commonwealth environmental water contribute to sustainable ecosystem diversity? • Were ecosystems to which Commonwealth environmental water was allocated sustained? • Was Commonwealth environmental water delivered to a representative suite of ecosystem types?
	Species diversity	Fish (River)	I	<ul style="list-style-type: none"> • What did Commonwealth environmental water contribute to native fish populations? • What did Commonwealth environmental water contribute to native fish species diversity? • What did Commonwealth environmental water contribute to native fish community resilience? • What did Commonwealth environmental water contribute to native fish survival?
		Fish (Larvae)	I	<ul style="list-style-type: none"> • What did Commonwealth environmental water contribute to native fish populations? • What did Commonwealth environmental water contribute to native fish species diversity? • What did Commonwealth environmental water contribute to native fish reproduction? • What did Commonwealth environmental water contribute to native larval fish growth and survival?
Ecosystem function	Connectivity	River hydrology	I	<ul style="list-style-type: none"> • What did Commonwealth environmental water contribute to hydrological connectivity?
		Fish Movement	II	<ul style="list-style-type: none"> • What did Commonwealth environmental water contribute to native fish populations? • What did Commonwealth environmental water contribute to native fish dispersal?
	Process	Stream metabolism	I	<ul style="list-style-type: none"> • What did Commonwealth environmental water contribute to patterns and rates of decomposition? • What did Commonwealth environmental water contribute to patterns and rates of primary productivity?
Resilience	Ecosystem resilience	Ecosystem type and extent	I	<ul style="list-style-type: none"> • See questions from above
		River hydrology	I	<ul style="list-style-type: none"> • See questions from above

Table 14. Questions relevant to the Edward-Wakool Selected Area evaluation. ‘Cat’ refers to the category of indicator as described in Hale et al. (2014) and Table 11.

Basin Plan Objectives	Basin Outcomes	Indicators	Cat	Basin-scale evaluation questions
Biodiversity	Species diversity	Fish (Larvae)	III	<p><i>Short-term (one year) and long term (five year) evaluation questions</i></p> <ul style="list-style-type: none"> • What did Commonwealth environmental water contribute to the spawning of 'Opportunistic' (e.g. Small bodied fish) species? • What did Commonwealth environmental water contribute to spawning in 'flow-dependent' spawning species (e.g. golden and silver perch)?
		Fish recruitment (Young of year)	III	<p><i>Short-term (one year) and long term (five year) evaluation questions</i></p> <ul style="list-style-type: none"> • What did Commonwealth environmental water contribute to native fish recruitment to the first year of life? • What did Commonwealth environmental water contribute to native fish growth rate during the first year of life?
		Fish (River)	III	<p><i>1-5 year evaluation questions</i></p> <ul style="list-style-type: none"> • Does Commonwealth environmental water contribute to maintain or enhance fish condition in the Edward-Wakool river system? • Does Commonwealth environmental water contribute to the recovery of fish communities following negative conditions within the Edward-Wakool river system? <p><i>Long-term (five year) evaluation questions</i></p> <ul style="list-style-type: none"> • Does Commonwealth environmental water contribute to maintain or enhance existing levels of fish recruitment in the Edward-Wakool river system? • Does Commonwealth environmental water contribute to maintain or increase native fish diversity and abundance in the Edward-Wakool river system? • Does Commonwealth environmental water contribute to maintain or increase native fish biomass in the Edward-Wakool river system?
Ecosystem function	Connectivity	River hydrology	I	<p><i>Short-term (one year) and long term (five year) evaluation questions</i></p> <ul style="list-style-type: none"> • What did Commonwealth environmental water contribute to hydrological connectivity? • What did Commonwealth environmental water contribute to hydrological variability?
		Hydraulic modelling	III	<p><i>Short-term (one year) and long term (five year) evaluation questions</i></p> <ul style="list-style-type: none"> • What did Commonwealth environmental water contribute to the in-channel wetted benthic area? • What did Commonwealth environmental water contribute to the area of slackwater and slow flowing water?

Ecosystem function (cont)	Connectivity (cont)	Fish (Movement)	II	<p><i>Short-term and long-term (one to five year) evaluation questions</i></p> <ul style="list-style-type: none"> • Were periodic species (golden and silver perch) present in the target reaches during Commonwealth environmental water delivery? • Did periodic species remain within the target reaches during Commonwealth environmental water delivery? • Did Commonwealth environmental water stimulate periodic fish species to exhibit movement consistent with reproductive behaviour • Does Commonwealth environmental water enable periodic species to disperse from and return to refuge habitat? • Does Commonwealth environmental water protect periodic species from adverse water quality
	Process	Stream metabolism	I	<p><i>Short-term (one year) and long term (five year) evaluation questions</i></p> <ul style="list-style-type: none"> • 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? • What did Commonwealth environmental water contribute to patterns and rates of primary productivity?
Resilience	Ecosystem resilience	Riverbank and aquatic vegetation	III	<p><i>Short-term (one year) and long term (five year) evaluation questions</i></p> <ul style="list-style-type: none"> • What did Commonwealth environmental water contribute to the percent cover and height of riverbank and aquatic vegetation? • What did Commonwealth environmental water contribute to the diversity of riverbank and aquatic vegetation?
		River hydrology	I	<ul style="list-style-type: none"> • See questions from above
Water quality	Chemical	Carbon and Water quality during adverse water quality events	III	<p><i>Short-term and long-term (one to five year) evaluation questions</i></p> <ul style="list-style-type: none"> • 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? • What did Commonwealth environmental water contribute to reducing the impact of blackwater in the system? • What did Commonwealth environmental water contribute to temperature regimes? • What did Commonwealth environmental water contribute to dissolved oxygen concentrations? • What did Commonwealth environmental water contribute to nutrient concentrations

6 Standard operating procedures (SOPs)

The Standard Operating Procedures for Category I and Category II indicators align with the Standard Methods outlined in Hale et al. (2014), with inclusions of information in the subsections on Location for monitoring, Responsibilities and Health and Safety Plan. The Standard Operating Procedures for Category III indicators have been developed by the Edward-Wakool Project Team.

6.1 Ecosystem type and extent

6.1.1 Evaluation questions

This monitoring protocol addresses the Basin-scale evaluation questions listed in Table 15.

Table 15. Questions for Ecosystem Type relevant to the Edward-Wakool Selected Area. Zone refers to the hydrological zones outlined in section 3. Boxes shaded red will be monitored using Cat I methods.

Questions	Focal Area				Additional sites outside Focal Area		
	Zone 1	Zone 2	Zone 3	Zone 4	Source of Commonwealth environmental water (weir and canal)	Fish community assessment (15 sites)	Optional Carbon and water quality monitoring during adverse events (4 sites)
Basin-scale evaluation questions							
<i>Short and Long-term (one to five-year) questions</i>							
What did Commonwealth environmental water contribute to sustainable ecosystem diversity?	✓	✓	✓	✓			
Were ecosystems to which Commonwealth environmental water was allocated sustained?	✓	✓	✓	✓			
Was Commonwealth environmental water delivered to a representative suite of ecosystem types?	✓	✓	✓	✓			

6.1.2 Standard Methods (Cat I)

This Ecosystem Type SOP (Cat I) is according to Hale et al. (2014), with inclusions of Location for monitoring, Responsibilities and Health and Safety Plan subsections. Ecosystem type (Cat I) will only be used for the Basin-scale evaluation.

Overview

This method for Ecosystem Type is the field validation of the ANAE classification that is required for the Basin-scale evaluation of ecosystem diversity for the LTIM Project. Brooks et al. (2013) applied the interim ANAE framework to aquatic ecosystems across the Murray Darling Basin using the best available mapping and attribute data. Wetland polygons, riverine polygons, and river centre lines were attributed with the majority coverage of each attribute without dividing them further. The scale and coverage of available mapping and attribute data varied considerably across the MDB has not yet been validated by the contributing jurisdictions. There is a need to validate the mapping outputs from Brooks et al. (2013) as they relate to specific sampling sites, and the Selected Areas.

Basin-scale evaluation questions

This is a protocol to validate the interim Australian National Aquatic Ecosystems (ANAE) classification at monitoring sites. The interim ANAE ecosystem typology and classification are relevant to the Basin-scale evaluation questions outlined in section 6.1.1.

The process for evaluating these questions is illustrated in Figure 7, with components covered by this protocol highlighted in blue.

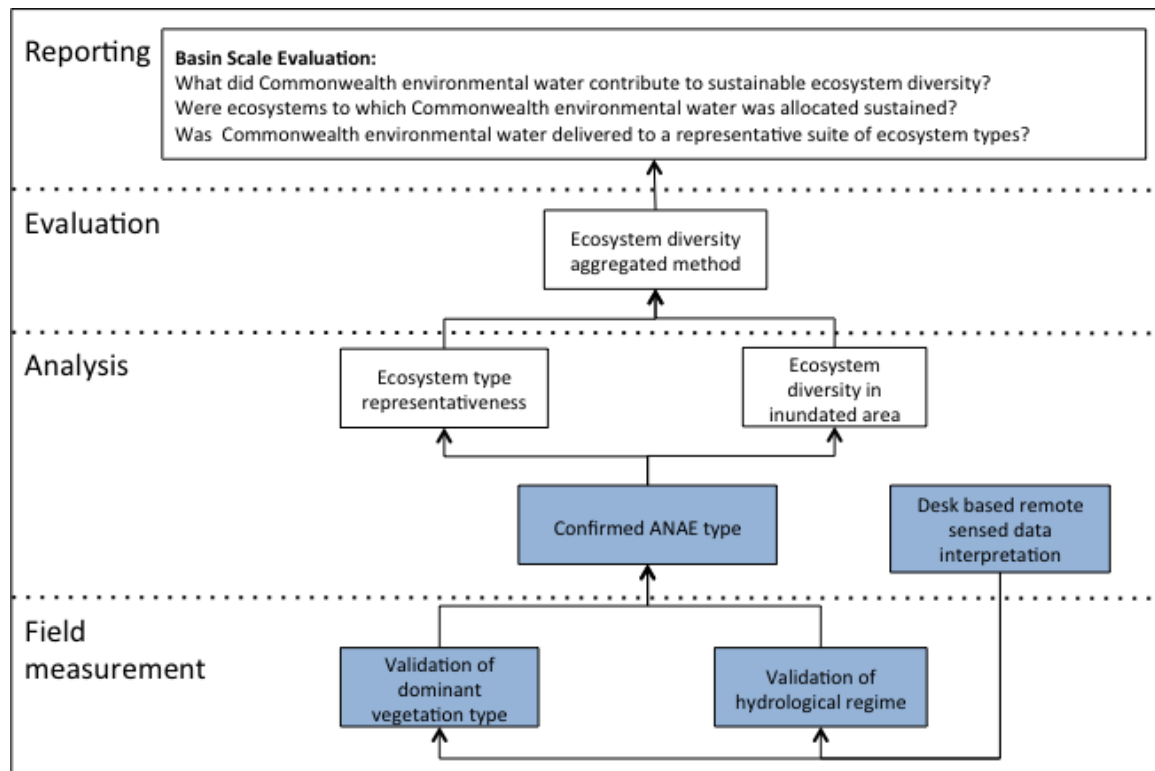


Figure 7: Schematic of key elements of the LTIM Project Standard Protocol: Ecosystem type. (Source Hale et al. 2014)

Complementary monitoring and data

Mapping output from Brooks et al. (2013) or any regional sources with updated feature mapping for the Selected Area, any fine scale resolution vegetation mapping and/or remote sensed data, current aerial photography, satellite imagery (e.g. SPOT6 – panchromatic resolution 1.5 m, multispectral resolution 8 m) and NVIS41_MDB vegetation mapping (NVIS v4.1 updated with CMA mapping by Brooks et al. 2013). These should be used in the first instance to aid in identifying aquatic ecosystem types prior to the field validation.

Location for monitoring

Ecosystem type will be assessed in zones included in the M&E Plan.

Responsibilities

Ecosystem type will be assessed by CSU staff with potential contribution from Murray LLS GIS staff.

Interim ANAE classification

Terminology

For the purposes of the LTIM Project aquatic ecosystems have been described in the Logic and Rational document as rivers, floodplains and wetlands. This is a simplification of four ecosystem classes into three common terms. For the validation protocol the terminology defined by the interim ANAE classification (Aquatic Ecosystem Task Group 2012) is to be applied. The ecosystem classes relevant to the LTIM Project are as follows:

- **Floodplain systems** are those aquatic systems that are either seasonally or intermittently flooded flat areas that are outside the riverine channels or palustrine/lacustrine systems but that display characteristics of hydric soils or vegetation that are characteristically adapted to the seasonal or intermittent presence of water. ***Excluded from this protocol.***
- **Lacustrine systems** (lakes) are open-water dominated systems, characterised by deep, standing or slow-moving water with little or no emergent vegetation (<30% cover)(Included as wetlands in Logic and Rational document).
- **Palustrine systems** are primarily shallow, vegetated, non-channel environments, including billabongs, bogs, swamps, springs, soaks etc. (Included as wetlands in Logic and Rational document).
- **Riverine systems** are those that are contained within a channel and its associated streamside vegetation. This definition refers to both single channel and multi-channel systems e.g. braided channel networks. The beds of channels are not typically dominated by emergent vegetation, may be naturally or artificially created, periodically or continuously contain moving water, and may form a connecting link between two bodies of standing water (Aquatic Ecosystem Task Group 2012) (Includes riparian systems).

The typology used to assign ecosystem types is presented as a dichotomous key in Hale et al. (2014) and as an extract from Brooks et al. (2013) in Hale et al. (2014).

An example of the mapping output from Brooks et al. (2103) for some saline Victorian systems is shown in Figure 8. This highlights some of the potential validation issues that may be encountered. In some cases the data provided for the MDB mapping project included situations where multiple polygons were sub-units of larger polygons. In most cases this is likely to represent a different habitat/vegetation type within a single wetland. In this case, as illustrated below, it is advised to use the larger ecosystem and unique identifier as the assessment ecosystem. Attribute mapping that overlays these polygons (e.g. vegetation, hydrological regime, salinity) may also contain inaccuracies. Confidence measures included in the Brooks et al. (2103) mapping product should be used to guide interpretation. Note that it is expected that updated mapping will be made available in coming years as attribute data improves, however the ecosystem typology is considered robust and is less likely to change significantly.

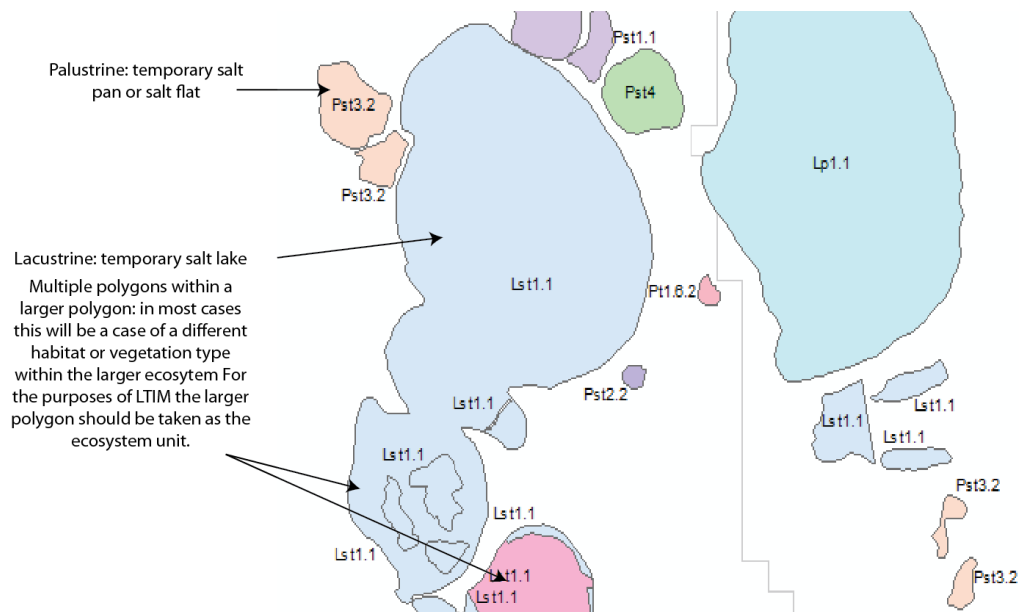


Figure 8: Example of mapping output from Brooks et al. (2013) with areas requiring validation.

A unique number (SYSID) for each polygon (wetland, lake, floodplain) or line (river, creek, stream) identifies each mapped unit (Brooks et al. 2013). On ground validation of the interim ANAE classification is required to confirm the aquatic ecosystem types for use in the LTIM Project.

Validation sites will include all sites for other monitoring protocols. Where a site has not been mapped the typology developed by Brooks et al. (2013) should be used to assign an ecosystem type *de novo* (Protocol step 3 below).

Equipment

- Maps of Selected Area including assessment site information
- Aerial imagery should be as current as possible and of sufficient resolution to identify vegetation
- Satellite imagery – e.g. SPOT6
- GPS
- Datasheets and/or field computer
- Appropriate safety gear
- Copy of this protocol
- Appropriate plant identification field guides.

Protocol

1. Prior to field visit, all information relevant to the potential area of influence of Commonwealth environmental water will be sourced and reviewed.
 - This will include, but not necessarily be limited to, mapping output from Brooks et al. (2013) for the Selected Area, current aerial imagery, satellite imagery, and any fine scale mapping (aquatic ecosystem type and or vegetation mapping).
2. Identify the ecosystems to be assessed and record/locate their unique identifier code.
 - If mapped by Brooks et al. (2013) use the SYSID as the unique identifier for each mapped ecosystem will be used.
 - If the ecosystem is not mapped then we will record coordinates (GDA94) of the centre of the ecosystem and either locate compatible GIS mapping or delineate the boundary of the ecosystem using remote sensed data. The Selected Area M&E Advisor will provide a unique identifier for the ecosystem.

3. Using the dichotomous key presented in Appendix A, we will assign an ecosystem type and code to each assessment ecosystem, noting any knowledge gaps that are relevant to an unambiguous classification
 - If the aquatic ecosystem is mapped then we will check if the interim ANAE type allocated to the polygon/line feature representing the ecosystem (see Appendix A) is correct. (Note that it is possible to have lacustrine and palustrine systems located on floodplains and some, or potentially many, of these may not have been captured in the interim ANAE mapping).
 - The correct interim ANAE type as per the typology in Appendix A will be recorded.
4. Locations for ground-truthing, mark on map and note GPS co-ordinates will be determined. The ground truthing will be designed to:
 - Confirm / identify dominant vegetation type (note the typology is based on dominant vegetation type only, so not all habitat/ vegetation types require ground-truthing).
 - Fill any knowledge gaps identified in step 2.
 - Be easily and safely accessible.
5. The information collected in the field will be used to update (if necessary) the ecosystem type as identified in step 4.

Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the M&E Plan for the Selected Area.

Data Description

All data provided for this indicator will conform to the data structure defined in the LTIM Project Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Project Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this validation is an ANAE feature identified by the ANAE SYSID.

Each row of data provided for this validation will identify the ANAE SYSID, the original classification, and the revised classification. The exact data structure for this indicator is maintained and communicated in the LTIM Project Data Standard and will be enforced by the MDMS when data is submitted.

Health and safety

The Edward-Wakool Selected Area Health and Safety Plan (HSP) includes an assessment of all identified potential risks and a plan on how these risks will be managed.

References

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6.2 River hydrology

6.2.1 Evaluation questions

The protocol for River Hydrology does not directly address specific evaluation questions but is important for informing the analysis and evaluation of monitoring outcomes for hydrological connectivity and native fish. It indirectly addresses the Basin-scale evaluation questions listed in Table 16.

Table 16. River Hydrology will be used to inform the following to the Basin-scale evaluation questions. Zone refers to the hydrological zones outlined in section 3. Boxes shaded red will be monitored using Cat I methods.

Questions	Focal Area				Additional sites outside Focal Area		
	Zone 1	Zone 2	Zone 3	Zone 4	Source of Commonwealth environmental water (weir and canal)	Fish community assessment (15 sites)	Optional Carbon and water quality monitoring during adverse events (4 sites)
Basin-scale evaluation questions							
<i>Long-term (five year) questions:</i>							
What did Commonwealth environmental water contribute to hydrological connectivity?	✓	✓	✓	✓			
What did Commonwealth environmental water contribute to native fish species diversity?	✓	✓	✓	✓			
What did Commonwealth environmental water contribute to native fish community resilience?	✓	✓	✓	✓			
<i>Short-term (one year) questions:</i>							
What did Commonwealth environmental water contribute to native fish reproduction?	✓	✓	✓	✓			
What did Commonwealth environmental water contribute to native larval fish growth and survival?	✓	✓	✓	✓			
<i>Short and Long-term (one to five-year) questions:</i>							
What did Commonwealth environmental water contribute to patterns and rates of decomposition?	✓	✓	✓	✓			
What did Commonwealth environmental water contribute to patterns and rates of primary productivity?	✓	✓	✓	✓			

6.2.2 Cat I Standard Methods

This SOP for Hydrology (River) is according to Hale et al. (2014), with inclusions of Location for monitoring, Responsibilities and Health and Safety Plan subsections. The Hydrology (River) – Cat I SOP will be used to inform both Basin-scale and Selected Area evaluations of Commonwealth Environmental Water.

Overview and context

Hydrology (river) is an event based monitoring protocol designed to capture aspects of a rivers water regime that influence behaviour and condition of native fish, stream metabolism, and water quality. In particular, this protocol aims to quantify the effect of Commonwealth Environmental Water on aspects of river hydrology that are most important for native fish, stream metabolism, and water quality. This protocol is based on a combination of field measures and hydrological modelling and comprises:

- Cross sectional survey
- Velocity measurements and development of a rating curve
- Daily Mean 'Stage' Height

The process for evaluating the Basin-scale evaluations questions is illustrated in Figure 9, with components covered by this protocol highlighted in blue.

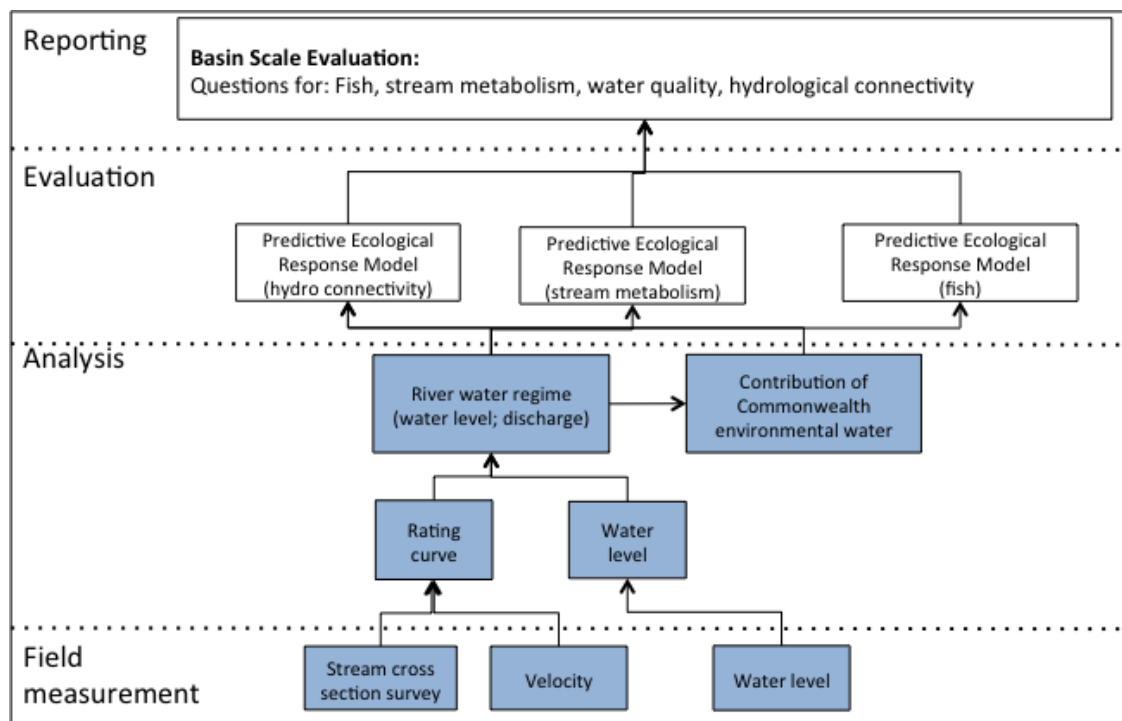


Figure 9. Schematic of key elements of the LTIM Project Standard Protocol: Hydrology (river). (Source Hale et al. 2014)

Selected Area evaluation questions

This protocol does not directly address specific Selected Area evaluation questions but is fundamental for informing the analysis and evaluation of monitoring outcomes for hydrological connectivity, water quality, stream metabolism, fish larvae, YOY fish recruitment and adult fish populations. It indirectly addresses all of the Selected Area evaluation questions included in the SOPS.

The process for evaluating these Selected Area questions is illustrated in Figure 10, with components covered by this protocol highlighted in grey.

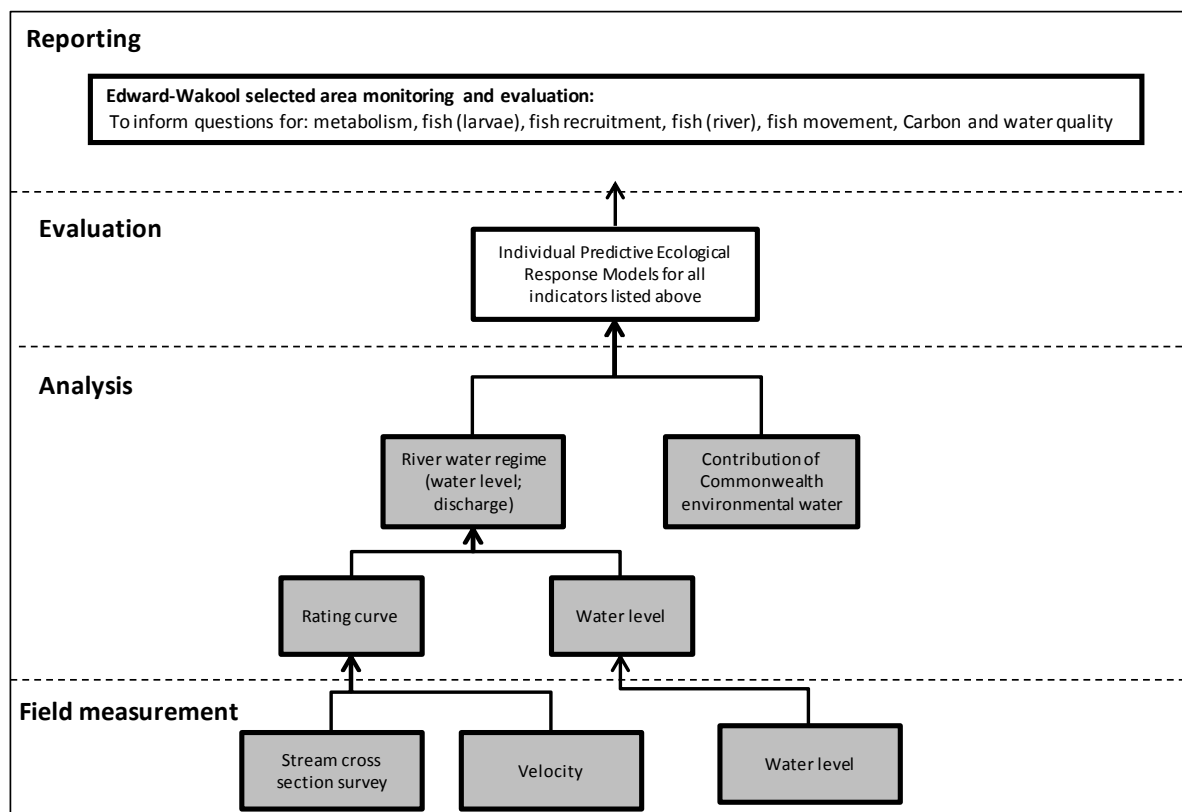


Figure 10: Schematic of key elements of the LTIM Project Standard Protocol: Hydrology (river) used for the Selected Area monitoring and evaluation. Components covered by this protocol are highlighted in grey.

Complementary monitoring and data

Data from water level loggers is available from previous Edward-Wakool short term intervention monitoring projects for some sites. Discharge data for all established gauging stations in the Edward-Wakool system is available from NSW Office of Water website. All gauges that will contribute to the M&E Plan are located within the defined hydrological zones.

Establishing sites

Zones and sites

The LTIM Project for Basin-scale evaluation has adopted a hierarchical approach to sample design (see (Gawne et al. 2013)). Briefly, the spatial hierarchy for stream metabolism is as follows:

- Selected Area
 - Zone
 - Site

A 'zone' is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands.

A site is the unit of assessment nested within a zone and in this instance will be a section of river. The sample design for the fish protocol involves a minimum of a single zone with 10 sites located within a 100 km stretch of river within the zone. Depending on the placement of fish sites, it may be possible to adequately capture river hydrology with a single gauging station.

Placement of stations

In the event that a suitable existing gauge is not available, manual gauging stations will be established at two positions within each site. These positions will be as far apart as possible while being within a straight, uniform reach where the slope is constant. The following will be taken into account when selecting positions for the gauging stations:

- The course of the stream is straight for approximately 100 meters upstream and downstream of the gauge.
- The flow is confined to only one channel at all stages and no flow bypasses the site.
- There are no tributaries between the two gauging stations.
- The flow is relatively uniform.
- The streambed is not affected by scouring, infilling, or excessive aquatic growth.
- Banks are permanent.
- The gauge is far enough upstream of a confluence or downstream control as to avoid variable backwater.

Location for monitoring

Hydrological data is currently available in zones 1 (Yallakool Creek), 2 (Upper Wakool River), and 4 (Wakool River, downstream Thule Creek) from established automated hydrological gauges in this system. A hydrological gauging station will be established in zone 3 (Mid Wakool River, upstream of Thule Creek). Establishing an automated gauge in this zone is essential for the evaluation of the outcomes of environmental watering because the nearest automated gauges are more than 50 km upstream from this zone. Also the geomorphology of this zone is such that environmental watering will result in greater lateral connection than in upstream zones.

A small number of gauge boards are located throughout the system and these complement the existing network of automated gauges. Discussions are underway with Murray LLS, OEH and MDBA to increase the number and spatial distribution of gauge boards in the Selected Area monitoring zones. Depth loggers will be established in each zone.

Timing and Frequency

This protocol is event based and aims to capture the influence of environmental watering. Therefore, monitoring will commence prior to the arrival of Commonwealth environmental water and continue for the period over which environmental water influences the hydrology of the river. Initial setup will be conducted before monitoring begins, when river flows are stable.

Hydrological data will be downloaded from the NSW Office of Water website once per month. Once established, depth loggers will be downloaded monthly. River heights on gauge boards will be read fortnightly from September to February in conjunction with the fish larval sampling trips, and opportunistically by Murray LLS staff and/or landholders at other times. The Acoustic Doppler Current Profiler surveys will take place in the first and second year, ideally during the rise or recession of discharge to ensure a range of discharges can be surveyed during a week-long field trip.

Responsibilities

A CSU Technical Officer will be responsible for maintaining and downloading data from depth loggers and recording water heights on gauge boards when in the field. A/Prof Robyn Watts (CSU) will download data from NSW Office of Water website. When possible, Murray LLS staff will record water height on gauge boards at other times. The project team will be seeking interest from landholders to record water heights on gauge boards to maintain a more consistent database of river heights in between field sampling trips.

Gauge station setup and measurement recording

River hydrology will be measured through the existing network of automated hydrological gauges or by the establishment of manual gauging stations. There are a number of accepted / standard methods for establishing and maintaining a river gauge site. At a minimum the method selected will involve:

- Cross section surveys at two or more locations at the beginning of the program, and at regular intervals (depending on reach stability) to account for geomorphological changes
- Measurement of cross section velocity at a number of river heights to establish a rating curve
- Development of a rating curve for the reach
- Continuous water level logging
- Calculation of daily mean discharge

The method described below (adapted from the United States Geological Survey Measurement and Computation of Streamflow standard http://pubs.usgs.gov/wsp/wsp2175/pdf/WSP2175_vol1a.pdf) may be used in the Edward-Wakool system in zone 3 where there are no existing automated hydrological gauges present.

Equipment

- Differential GPS and total station survey equipment
- Acoustic Doppler Current Profiler (ADCP)
- Depth sounder, or sounding weight
- Flow meter
- Tape measure or range-finder
- Camera
- Boat (for wide or deep streams)
- Life Jackets
- Data sheets
- A copy of this protocol

Gauge station setup

1. Find the assessment site using the point location established in the Monitoring and Evaluation Plan.
2. An ADCP will be deployed within each end of the appropriate reach (as defined above). The height in meters above sea level (to 2 decimal places) of both gauges will be recorded. The height of the lowest gauge is considered the zero point for the datum of River 'stage' Height for subsequent measures at both gauges. Therefore, the height above this zero point will also be measured for the higher of the two gauges.
3. Establish the location of a 'control' down-stream of the most-down-stream gauging station. A 'control' is a feature that impacts on the discharge of the upstream section, such as the narrowing of the channel, the presence of a riffle, or a weir. Measure its height above sea level, distance to nearest gauge, and the height from the zero point.
4. A series of photos of the whole channel including the banks and extending between the two gauge stations will be taken. These photos are to characterise the roughness of the channel surface.
5. A cross-section of river depth is to be surveyed at each gauge position (Figure 11). These surveys will be conducted once at initial set-up and then again at a number of river 'stage' heights in order to establish a discharge rating curve.

- The cross-section of the stream will be divided into sub-sections of varying width depending on the velocities present. Each sub-section should have no more than 10% of the total discharge and should aim to be around 5%; therefore, areas with greater depth and discharge should have sub-sections with vertical boundaries that are closer together. Establishing the correct layout may require surveying the reach a number of times before an appropriate cross-section is established.
- Place the tape-measure, or some means to measure distance from each bank, across the cross-section from bank to bank.
- Starting at one bank and working towards the other, at intervals mark the rope and measure the distance from the bank. The mark on the rope indicates the vertical border of a sub-section. The initial sub-section will be bordered by the bank and the first mark on the rope and subsequent sub-sections will be bordered by two marks. Take depth measurements at both the boundaries and the middle of the sub-section. The depth measurements as well as the horizontal measurement of the sub section will give an approximate area for the sub-section.
- Measure the velocity at two positions along the mid vertical of each sub-section at 0.2 and 0.8 of the depth. In sub-sections shallower than 1 m, a single measurement at 0.6 of the depth should be taken. Each velocity measurement should be taken as an average over 40 seconds.
- All measurements will be recorded on the appropriate record sheet.

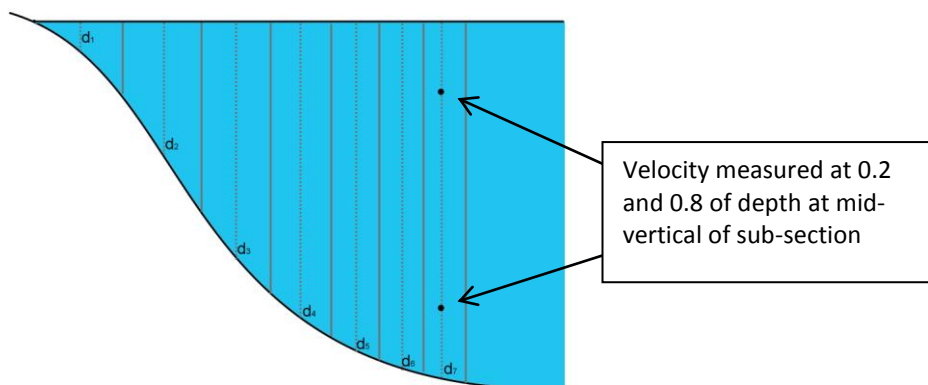


Figure11: Cross-section of river indicating division of sub-sections (solid grey lines) and mid verticals of those sub-sections (dotted grey lines). Sub-sections in the mid reach have widths less than those closer to the bank in order to account for greater discharge per unit area in the mid-sections of the river.

6. Banks in the un-wetted area are to be surveyed for future estimates of flow volume.
 - The maximum height of each bank will be determined and recorded as metres above sea level.
 - Starting from the bank take measurements at 1 m increments along a horizontal plane b) towards the water's edge. Additional measurement points may be established, where necessary to fully describe the cross-section of the channel. For instance, it may be necessary to establish further points beyond the river bank edge if the river bank is not well defined.
 - At each interval, measure the distance of the vertical (a) from the horizontal plane to the channel bed. The remaining axis (h) can be either measured or estimated as:

$$h = \sqrt{a^2 + b^2}$$

- Calculate the area of the first sub-section as:

$$\frac{1}{2} a * b$$

- For subsequent sub-sections measure from the base of the vertical of the previous sub-section out 1 m (if possible). Measure the vertical distance to the channel bed. The area is calculated as:

$$\left(\frac{1}{2} a * b\right) + h * \Sigma(a)$$

Where $\Sigma(a_{1-i})$ is the sum of the verticals from the preceding sub-sections.

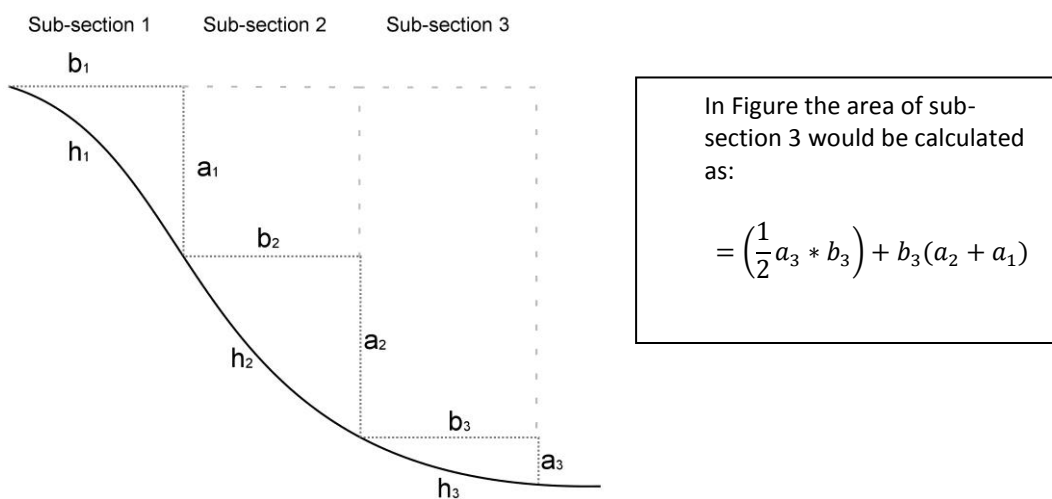


Figure12: Cross-section of dried portion of river channel indicating the various measurements to be taken

7. The survey of the cross-section will be used to calculate future discharge rates through measurements of stage height.

Daily Mean 'Stage' Water Height

The daily mean 'stage' water height is measured daily from the ADCP and recorded as meters above zero (to 2 decimal places), where zero is the point at which the lower of the two gauges sits in relation to sea level.

- Record Daily Mean 'Stage' Water Height from the ADCP.

Daily Mean Discharge

The Daily Mean Discharge will be calculated from a rating curve and the 'stage' water height. To establish a rating curve, surveys of the discharge under various 'stage' water heights will be conducted as per the method above. The number of surveys undertaken is at the discretion of the service provider but will provide a reasonable estimate of discharge within 10% error. Surveys may

be taken at any time throughout the monitoring effort and Daily Mean Discharge values ascribed after a reliable rating curve is established. At each survey event the height of the 'control' must be measured in order to gain measurements of Point Zero Flow (PZF).

An applicable software package will be used to develop a ratings curve and to calculate the Daily Mean Discharge. A free downloadable tool is available at: <http://www.dartmouth.edu/~renshaw/hydrotoolbox/>.

Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas.

In terms of this method, the Quality Plan addresses:

- Precision and accuracy of stream cross sectional surveys
- Calibration and maintenance of sensors and loggers

Data analysis and reporting

The following river water regime parameters will be reported:

- Daily mean river 'stage' water height (cm)
- Daily mean river discharge (ML/day)

Data management

All data provided for this indicator will conform to the data structure defined in the LTIM Project Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Project Monitoring Data Management System (MDMS).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Project Data Standard and will be enforced by the MDMS when data is submitted.

Health and safety

The Edward-Wakool Selected Area Health and Safety Plan (HSP) includes an assessment of all identified potential risks and a plan on how these risks will be managed.

References

Hale, J., Stoffels, R., Butcher, R., Shackleton, M., Brooks, S. and Gawne, B. (2014) Commonwealth Environmental Water Office Long Term Intervention Monitoring Project – Standard Methods. Final Report prepared for the Commonwealth Environmental Water Office by The Murray-Darling Freshwater Research Centre, MDFRC Publication 29.2/2014, January, 182 pp.

6.3 Hydraulic modelling

6.3.1 Evaluation questions

This monitoring protocol addresses the Selected Area evaluation questions listed in Table 17.

Table 17. Questions for hydraulic modelling relevant to the Edward-Wakool Selected Area. Zone refers to the hydrological zones outlined in section 3. Boxes shaded grey will be monitored using Cat III methods.

Questions	Focal Area				Additional sites outside Focal Area		
	Zone 1	Zone 2	Zone 3	Zone 4	Source of Commonwealth environmental water (weir and canal)	Fish community assessment (15 sites)	Optional Carbon and water quality monitoring during adverse events (4 sites)
Selected Area evaluation questions							
<i>Short-term (one year) questions:</i>							
What did Commonwealth environmental water contribute to the in-channel wetted benthic area?	✓	✓	✓	✓			
What did Commonwealth environmental water contribute to the area of slackwater and slow flowing water?	✓	✓	✓	✓			

In addition to the questions posed above, this protocol is important for informing the Selected Area evaluation for the following Selected Area indicators: Metabolism, Fish (Larvae), Fish recruitment, and Carbon and Water Quality

6.3.2 Standard methods (Cat III)

Overview and context

Understanding the extent of riverbank inundation under different discharge scenarios is essential to describe changes in wetted benthic surface area and shallow water habitat during environmental watering actions. Hydraulic modelling can also assist the interpretation of other indicators, such as nutrients, river metabolism, and emergence of zooplankton from riverbank sediments. Remote sensing is a useful method for estimating the extent of inundation under different flow scenarios because it provides results more cheaply and efficiently than ground based survey methods. Previous studies modelling river flow and floodplain inundation have been undertaken for wetlands on the Darling River (Shaikh et al. 2001), and floodplains on the Murrumbidgee River (Frazier et al. 2003) and the River Murray (Overton 2005; Overton et al. 2006). These studies have generally focussed on estimating floodplain inundation during overbank flows. Methods employed include optical satellite image analysis, radar remote sensing and landsat TM (Townsend and Walsh 1998; Shaikh et al. 2001; Frazier et al. 2003; Overton et al. 2006).

The use of digital elevation models to create a floodplain surface that can be inundated under different discharge scenarios may not give the best representation of floodplain inundation, because even small impediments on a predominantly flat floodplain can affect the models. However, in a system such as the Edward-Wakool system, where much of the environmental watering is contained within the channel, the use of digital elevation models to create flow path assessments below bankfull is an appropriate approach to compare the extent of riverbank inundation and the area of slow flowing slackwater under different discharge scenarios. The inundation models can also serve

as a tool to help predict the likely outcome of different flow management options on patterns of riverbank inundation.

The key objective of the hydraulic modelling is to estimate the extent of inundation and the area of slow flowing water that is created during flow events of different magnitude from base flows up to bankful flows. Inundation of riverbanks is important for river productivity and the creation of low flow zones is important for riverbank plants and the survival of organisms such as larval fish. The modelling will contribute to decision making regarding the magnitude of environmental watering and will assist the communication of likely outcomes of planned watering events with landholders.

The process for evaluating the evaluation questions is illustrated in Figure 13, with components covered by the protocol highlighted in grey.

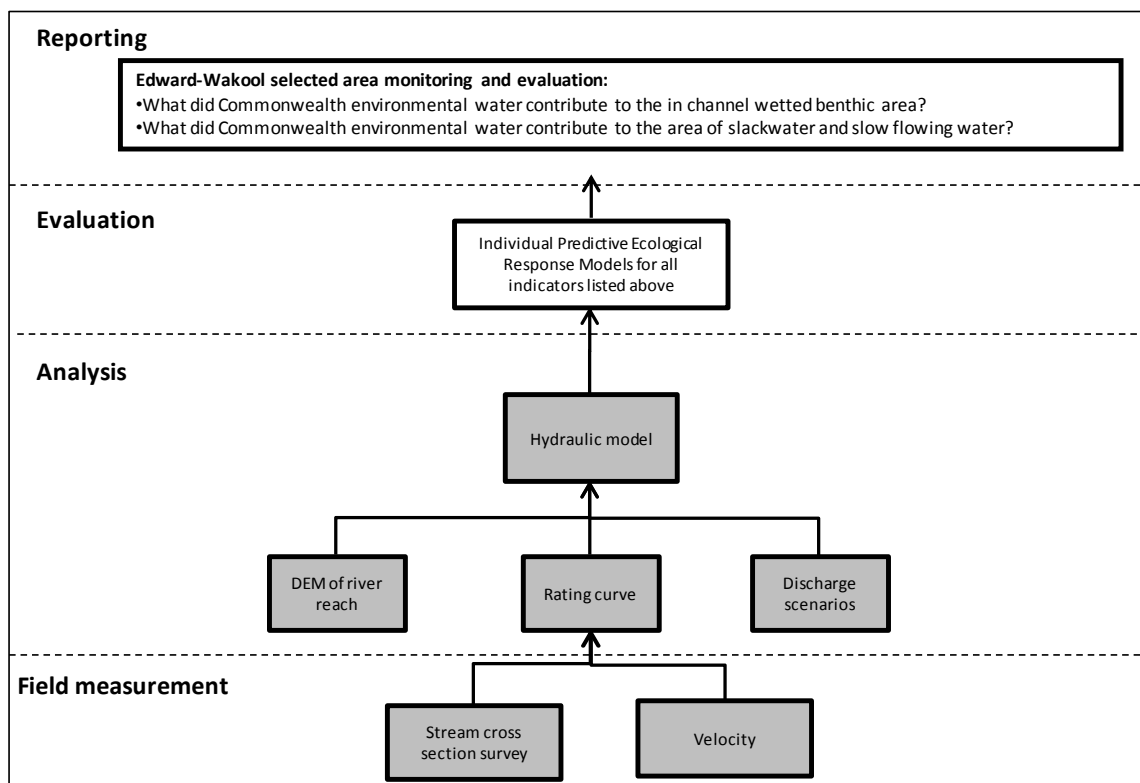


Figure 13. Schematic of key elements in the LTIM Project standard methods (Cat. III): Inundation modelling. Components covered by this protocol are highlighted in grey.

Indicators

- In-channel wetted benthic area under different discharge scenarios
- Area of slackwater and slow flowing water under different discharge scenarios

Complementary monitoring and data

Preliminary hydraulic modelling has been undertaken in zones 1 and 2. The results (such as those presented in Figures 14 and 15) have shown that in-channel wetted benthic area and area of slackwater and slow flowing water are not linearly related to discharge. When considered in relation to other monitoring data, preliminary data suggests there is a stronger relationship between ecological outcomes and these variables than to daily discharge. This type of modelling is essential for interpreting the outcomes of Commonwealth environmental water on river productivity, and fish spawning and recruitment.

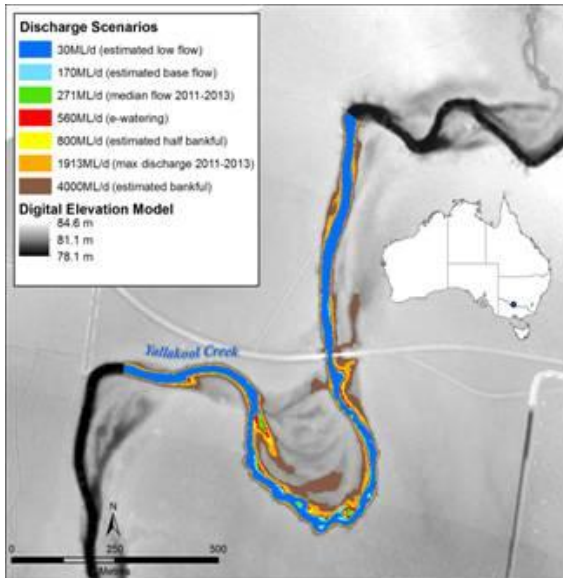


Figure 14. Example of outputs of hydraulic modelling showing change in wetted benthic area under different discharge scenarios.

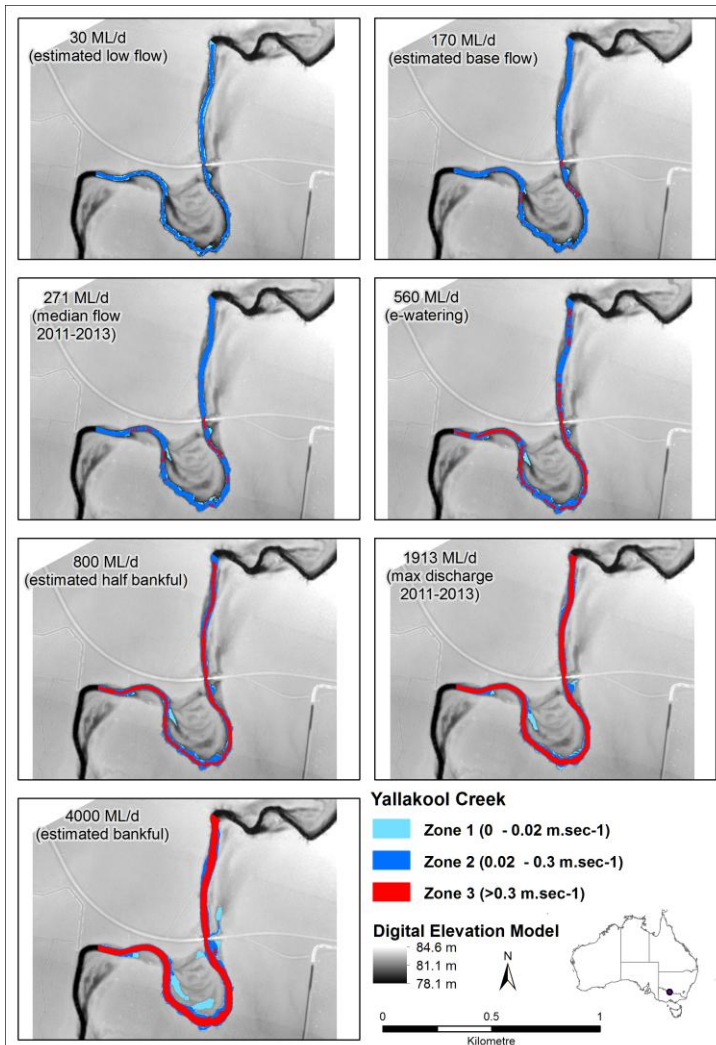


Figure 15. Example of outputs of hydraulic modelling showing change in area of slackwater and slow flowing water under different discharge scenarios. Zone refers to velocity of water; zone 1 slackwater ($< 0.02 \text{ ms}^{-1}$), zone 2 slow flowing water ($>0.02 \text{ ms}^{-1}$ to 0.3 ms^{-1}), and faster flowing water ($> 0.3 \text{ ms}^{-1}$).

Location for monitoring

Inundation modelling will be undertaken in four zones in the Edward-Wakool system: zone 1 (Yallakool Creek), zone 2 (Upper Wakool River), zone 3 (Mid Wakool River, upstream Thule Creek), zone 4 (Mid Wakool River, downstream Thule Creek).

Timing and frequency

The majority of the modelling will be undertaken in the first year of the project. In year 1 models will be set up and run for six flow scenarios in each zone. In the M&E Plan we have also budgeted for one additional flow scenario to be undertaken in each subsequent year, to facilitate assessment of particular discharges that reflect delivery conditions of Commonwealth environmental water. This could be a discharge of interest to be modelled during the watering planning phase, or could be modelled after the environmental watering has occurred.

Responsibilities

Inundation modelling will be undertaken by a consultant in collaboration with the Project Manager, A/Prof Robyn Watts (CSU). The Consultant will provide GIS layers and files to the Project team. The mapping of inundated benthic area and velocity zones will be undertaken by the Charles Sturt University Spatial Analysis Unit (SPAN). A/Prof Watts will be responsible for reporting.

Methods

Discharge scenarios will be modelled for the four zones. In each zone, 2 to 5 km reaches at each of the five fish sample sites will be modelled.

Each reach will be represented within the hydraulic model using a digital elevation model (DEM) supplied by the Murray LLS. It is fortunate that LIDAR was flown in the Edward-Wakool system during the drought when the majority of the river channels in this system were dry, so the DEMs are appropriate for modelling inundation within the river channel. Six discharge scenarios will be modelled for each zone or reach ranging from low flow to estimated bank-full flows including discharges at which Commonwealth environmental water is to be delivered.

Each scenario will be modelled assuming an initial dry starting condition with no residual water in the system. All scenarios will be run until stable state flow is achieved whereby the instantaneous flow rate at the downstream boundary condition stabilised and matched the upstream inflow value. Discharge scenarios will be modelled using the 2D grid implementation of Eonfusion Flood (Myriax Software) with model outputs post-processed using the GIS functionality of Eonfusion (Myriax Software).

Upon reaching stable state flow, an extent output from the model will be captured representing the spatial coverage of the water surface. Within each cell of the extent the water depth and surface elevation will be captured allowing a 3D surface of the stream bed underlying the water surface to be constructed. The wetted benthic surface area covered by the water surface will then be calculated using the derived 3D surface. Post-processing, including surface area calculations, will be undertaken achieved using Eonfusion (Myriax Software), Quantum GIS and made distributable using Google Earth.

Post processing of model outputs will be undertaken to quantify the spatial configuration of four velocity categories: Zone 1: 0 – 0.02 m.sec⁻¹ (still water/slackwater), Zone 2: 0.02 – 0.3 m.sec⁻¹ (slow water); Zone 3: >0.3 m.sec⁻¹ (fast water); Zone 4: >0 m.sec⁻¹ (entire flow field). Post-processing,

including surface area and depth calculations, was achieved using Eonfusion Quantum GIS, Excel and made distributable using Google Earth. The results will be ground truthed by comparison with depth logger data at each site and through engagement with local landholders, especially for modelling of large flow events.

Several data sets will be constructed to quantify and represent the spatial distribution of each velocity zone including:

- Water velocity frames exported as a multiband raster in GeoTiff format suitable for viewing in ArcGIS or a similar GIS platform (GDA_MGA_1994_Zone_55),
- Water surface extent for each velocity zone for each scenario exported as bounding contours and polygons suitable for viewing in ArcGIS or a similar GIS platform (GDA_MGA_1994_Zone_55),
- Water surface extent for each velocity zone exported in a KMZ vector format which can be loaded directly into Google Earth for viewing against satellite imagery (WGS84).
- 3D surface area calculations for each velocity zone provided in spread sheet format (.xlsx)

Data analysis and reporting

Data will be mapped for visual representation, and outputs of will be analysed for comparison among discharge scenarios.

Health and Safety

The Edward-Wakool Selected Area Health and Safety Plan (HSP) includes an assessment of all identified potential risks and a plan on how these risks will be managed.

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Shaikh M, Green D and Cross H (2001) A Remote Sensing Approach to Determine the Environmental Flows for Wetlands of the Lower Darling River, New South Wales, Australia. *International Journal of Remote Sensing*, 22, 1737-1751.

6.4 Stream metabolism

6.4.1 Evaluation questions

This monitoring protocol addresses the Basin-scale and Selected Area evaluation questions listed in Table 18.

Table 18. Questions for stream metabolism relevant to the Edward-Wakool Selected Area. Zone refers to the hydrological zones outlined in section 4. Boxes shaded red will be monitored using Cat I methods.

Questions	Focal Area				Additional sites outside Focal Area		
	Zone 1	Zone 2	Zone 3	Zone 4	Source of Commonwealth environmental water (weir and canal)	Fish community assessment (15 sites)	Optional Carbon and water quality monitoring during adverse events (4 sites)
Basin-scale evaluation questions							
<i>Short and Long-term (one to five-year) questions:</i>							
What did Commonwealth environmental water contribute to patterns and rates of decomposition?	✓	✓	✓	✓			
What did Commonwealth environmental water contribute to patterns and rates of primary productivity?	✓	✓	✓	✓			
Selected Area evaluation questions							
<i>Short and Long-term (one to five-year) questions:</i>							
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?	✓	✓	✓	✓			
What did Commonwealth environmental water contribute to patterns and rates of primary productivity?	✓	✓	✓	✓			

Selected Area Evaluation hypotheses

The following hypotheses relate to the effect of Commonwealth environmental water delivery on the rates of Gross Primary Productivity (GPP) and Ecosystem Respiration (ER) in the Edward-Wakool Selected Area:

- H₁ Under extended 'cease to flow' conditions of several weeks or more (unlikely), the responses of GPP and ER will greatly depend on the available nutrient supplies and the time of year. High nutrients and warm conditions may lead to very high rates associated with excessive phytoplankton growth.
- H₂ Under normal 'base' flow, rates of GPP and ER will be constrained to the low-moderate range, typically 1-3 mg O₂/L/Day.

- H₃ With in-stream freshes, rates of GPP and ER will increase slightly to 3-5 mg O₂/L/Day. Larger increases will occur if significant backwater areas are reconnected to the main channel due to enhanced nutrient delivery.
- H₄ Inundation and reconnection of backwater areas to the main channel during high flows will result in elevated rates of GPP and ER. Comparison of responses in different zones will address this important question.
- H₅ Primary production in the Edward-Wakool system will be limited by low phosphorus concentrations.

6.4.2 Standard Methods (Cat I)

This SOP is according to Hale et al. (2014), with inclusions of Hypotheses, Location for monitoring, Responsibilities, and Health and Safety Plan. This indicator will be used for both Basin-scale and Selected Area evaluations.

Overview

The key objective of the stream metabolism monitoring program is to enable determination of the effects of environmental watering actions on the rates of Gross Primary Production (GPP) and Ecosystem Respiration (ER) within the Edward-Wakool system. These processes support and sustain aquatic foodwebs hence are directly related to ecosystem health and viable fish populations. Important drivers for these processes, notably nutrient and organic carbon concentrations and light are collected concurrently to allow flow effects to be distinguished from nutrient variations and daily weather fluctuations.

The process for evaluating the questions outlined in Section 6.4.1 is illustrated in Figure 16, with components covered by the protocol highlighted in blue.

Indicators

Stream Metabolism is a Category I monitoring indicator. This requires continuous measurement of dissolved oxygen, temperature, surface light (PAR) and barometric pressure at a frequency of a reading every 10 minutes. Additionally, water samples for filterable reactive phosphorus (FRP), nitrate + nitrite (NO_x), ammonia, total phosphorus (TP), total nitrogen (TN), chlorophyll-a and dissolved organic carbon (DOC) will be collected during data logger downloads and maintenance. Further adventitious samples will be collected when staff are on-site for other purposes and will especially target flow events (see section 6.5 Carbon and water quality).

Analysis of stream metabolism behaviour will also require daily discharge measurements at these sites.

Daily rates of GPP and ER will be extracted from the supplied daytime regression model 'BASE', implemented using a Bayesian framework in R and OpenBUGS. The model also provides estimates of uncertainty in these parameters.

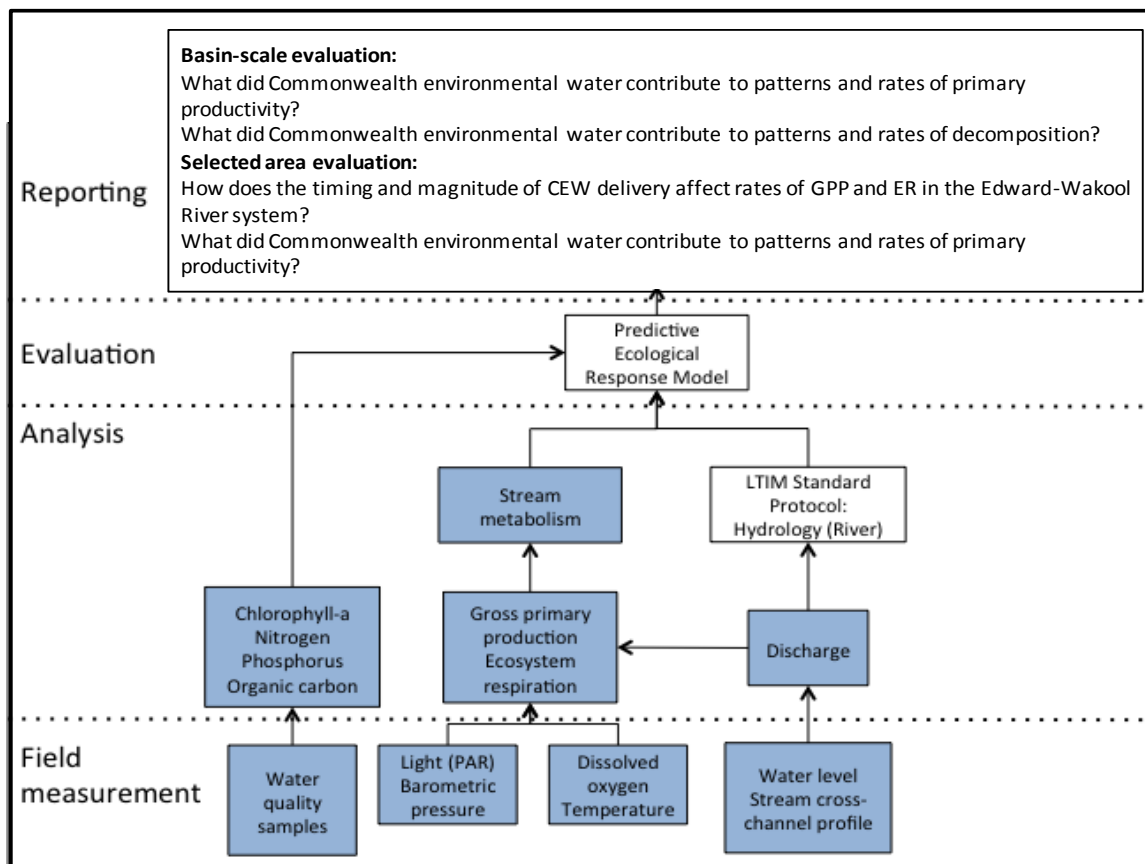


Figure 16. Schematic of key elements of the LTIM Project Standard Protocol: Stream metabolism. Components covered by this protocol are highlighted in blue. (Source Hale et al. 2014)

Complementary monitoring and data

Stream metabolism data are available for zone 1 (Yallakool Creek) and zone 2 (Upper Wakool River) as well as Colligen Creek and Little Merran Creek from 2012 to 2014 as part of the short-term intervention monitoring undertaken in the Edward-Wakool system.

Location for monitoring

Stream Metabolism measurements will be undertaken in four zones in the Edward-Wakool system: Zone 1 (Yallakool Creek), Zone 2 (Upper Wakool River), Zone 3 (Mid Wakool River, upstream of Thule Creek) and Zone 4 (Mid Wakool River, downstream of Thule Creek). Each logger integrates between 2 and 10 km of stream reach depending on water velocity and re-aeration rate. One logger will be deployed at the bottom end of each zone. In addition, one logger will be deployed at the top end of Zone 4 and one at the top end of zone 1.

Timing and frequency

Stream metabolism will be calculated for each site over the five year period, thus providing daily estimates of the metabolic parameters. Monitoring from mid-August to mid-March has been chosen to best capture the diversity of timing in unregulated flows and Commonwealth environmental water as well as the period when metabolic parameters are likely to demonstrate their greatest seasonal responses.

Measurement of dissolved oxygen, temperature, surface light (PAR) and barometric pressure will be recorded every 10 minutes. The need for a strict maintenance, calibration check and possible recalibration means that one day's data is lost per month as the probe is removed from the stream for these activities. Water samples for nutrient analysis (FRP, NO_x, ammonia, chlorophyll-a, TP, TN and DOC) will be collected once per month over the period mid-August to mid-March, during data logger downloads and maintenance.

Responsibilities

Maintenance, downloads, calibration checks and recalibration as well as the collection of water samples, on-site filtering for appropriate parameters and the organization of transportation of samples to the Water Studies Centre and EML will be performed by CSU staff. Data analysis and reporting will be the responsibility of Mike Grace (Water Studies Centre).

Field methods

d) Water Quality Measurements

Water quality variables are important for interpreting the stream metabolism results and are an input to the ecological response model for Basin scale evaluation. Water samples will be collected for: chlorophyll-a, total nitrogen (TN), total phosphorus (TP), nitrate-nitrite (NO_x), ammonium (NH₄), filterable reactive phosphorus (FRP) and dissolved organic carbon (DOC). In-situ spot measurements will also be taken for pH, turbidity and electrical conductivity (EC). As a minimum, these water quality samples and measures will be collected every month, when sensors are deployed and at each time the station is serviced and calibrated. Further in situ spot measurements will be taken during site visits for other purposes.

Equipment

- Sample containers and appropriate preservatives (sourced from laboratory)
- 0.2 µm filters and suitable filtering device (e.g. syringe filter) for dissolved nutrients and carbon
- 47 mm glass fibre (GFC) filters and suitable filtering device for chlorophyll-a
- Pre-calibrated Water quality meter (e.g. Horiba U10) with pH, turbidity and electrical conductivity probes
- Deionised water for sample blanks
- Eskies and ice for sample preservation and storage
- Datasheets and/or field computer
- Chain of custody sheets
- Copy of this protocol

Protocol

1. Samples and measurements will be collected mid stream and mid depth, provided it is safe to do so. Samples will be collected in the main flow path, avoiding backwaters and stratified pools.
2. Ensure that sampler stands downstream of sample collection point.
3. Avoid surface films, but if present, a description will be entered onto the field sheet.
4. Filtering for dissolved nutrients (NO_x, NH₄⁺, FRP, DOC) and chlorophyll-a will take place on site as samples are collected.
5. Samples will be stored on ice for transport to laboratories.

e) Stream Metabolism

Stream metabolism measures for temperature, dissolved oxygen, light (PAR) and barometric pressure will be logged at ten-minute intervals. Loggers will be deployed continuously throughout the period mid-August to mid-March.

Equipment

- Dissolved oxygen and temperature sensors with an integrated logger (e.g. ZebraTech DOpto) using optical (fluorescence) DO measurement.
- PAR sensor and logger (e.g. DataFlow Odyssey). The sensor will be calibrated against a laboratory-based sensor reading in $\mu\text{Es}/\text{m}^2/\text{s}$ across the full range of PAR expected throughout a bright summer's day.
- Barometric pressure sensor and logger (weather station).
- Tool kit and spare parts for the multi-parameter probe; including spare batteries
- Metal star pickets and star picket driver or mallet
- Anodized chain with padlock, plus cable ties to attach probe to a star picket or permanent structure
- GPS
- Probe calibration log
- Field sheets
- Laptop and data cables for connecting to probes / logger
- Air bubbler with battery (e.g. one suitable for a large fish tank) and a large bucket (e.g. 20 L), for probe calibration.

Protocol

Preparation

6. Prior to deployment in the field, the probe(s) will be calibrated, using a two point (100% & 0% DO saturation) according to manufacturer's instructions and results of calibration entered into a calibration log.
7. Before leaving the office / laboratory the following will be checked for all electronic equipment (probes, loggers, GPS):
 - Batteries are charged and properly inserted
 - Previous data downloaded and memory cleared
 - Check cable and cable connections
 - Check for any obvious/minor faults on sensors including growth or dirt on the probes or tubing
 - Check contents and condition of probe toolkit
 - All equipment listed above is present and in functional order

f) PAR, barometric pressure

8. A suitable location, above the area likely to be inundated and in a clear open (unshaded) area will be identified. This could be a nearby paddock. Note that on private property locations a fence post near gate access may be suitable.
9. Secure PAR logger to existing structure or if necessary, a newly placed star picket.
10. Set loggers to read at 10 minute intervals.

g) Water column measures

11. The following information will be recorded on field sheets:
 - River name and ANAE Streamid
 - Date and time
 - GPS coordinates (latitude and longitude; GDA94)
 - Name(s) of survey team
12. Record site characteristics:
 - Substrate type
 - Width of channel
 - Presence of any geomorphic features
 - Percent canopy cover
 - Land use immediate adjacent to site
13. Collect water quality samples and spot measures as described above.
14. Calibrate dissolved oxygen sensor on site:
 - Calibrate according to manufacturer's instructions for both oxygen free water (e.g. 1% sodium sulfite Na_2SO_3 solution) and 100% saturation (air saturated water). The easiest way to obtain a reliable on-site calibration of 100% saturation is to place the probe in a bucket of stream water which itself is sitting in the stream to ensure thermal control. Air is bubbled through the water in the bucket for at least 45-60 minutes. This should result in a stable reading from the probe. It is important that the probe is not in the direct line of air bubbles.
15. Set the dissolved oxygen, temperature, PAR and barometric pressure loggers to record at ten minute intervals. Synchronise loggers so as to obtain corresponding readings.
16. Select appropriate place for deployment of sensors and loggers noting:
 - Dissolved oxygen and temperature sensors must be placed in open water, mid stream and at a depth that will not expose sensors for entire deployment period. Sensors should not be placed in eddies, stratified zones, backwaters or where flow is influenced by structures.
 - Sensors can be deployed on suitable existing structures or on star pickets securing embedded mid-stream.
17. Deploy loggers.
18. Leave loggers deployed for between four and six weeks. *Experience over the 2013-14 short term intervention monitoring program in these streams indicated that more frequent cleaning was required, hence loggers will be maintained every 2-3 weeks.*
19. Perform servicing, cleaning and calibration of loggers at each repeat visit.
20. Repeat water quality samples and spot measures at each repeat visit.
21. Repeat 100% saturation value check (water saturated air) and note the value of any drift.
22. Record any relevant information, such as changes in site characteristics since deployment.
23. Upload data onto laptop following manufacturer's instructions.
24. Calibrate all sensors and loggers and perform routine maintenance / cleaning as necessary.

Laboratory methods

All chemical analyses apart from chlorophyll-a will be performed by the Water Studies Centre's Analytical Laboratory at Monash University. This lab is NATA-accredited for each of the required analyses. The Officer in Charge of the laboratory (and NATA signatory) is Mrs Tina Hines. As the WSC laboratory does not have accreditation for chlorophyll-a analysis, samples for this parameter (filter papers wrapped in aluminium foil) will be sent to the Eastern Melbourne Laboratory's chemical analysis unit. Grace Boonthakanon is the officer in charge. The WSC and EML have over ten years of highly successful co-operation in chemical analyses for a range of clients. Each laboratory will incorporate their mandated QA/QC procedures for each analysis including spike recoveries, duplicate measurements, blanks, and standard reference materials.

Data analysis and reporting

This method adopts the approach of determining GPP, ER and reaeration rate (K_{O_2}) from the diel dissolved oxygen curves using the daytime regression model reviewed by Kosinski (1984). A program to evaluate these parameters for the diel dissolved oxygen curve, 'BASE', has been developed by Mike Grace, Darren Giling and Ralph MacNally at Monash University using Bayesian analysis implemented in OPenBUGS with an interface in 'R'. This freeware package and is available for the LTIM Project via the Govdex website.

The model requires data for dissolved oxygen in mg O_2 /L, temperature, PAR and barometric pressure (in atmospheres) at 10 minute intervals. The salinity also needs to be entered. This will be approximated as 0 unless the electrical conductivity increases above 500 μ S/cm, in which case salinity = $6 \times 10^{-4} \times EC$ (Based on conversion factor of 1 μ S/cm = 0.6 mg/L TDS). The 'BASE' program provides estimates of GPP and ER in mg O_2 /L/Day with uncertainties for each and goodness of fit parameters.

Subsequent data analysis will involve correlating the daily estimates for the two metabolic parameters with the collected explanatory variables (nutrients, DOC, chlorophyll-a, light) as well as daily discharge and season.

Health and safety

The Edward-Wakool Selected Area Health and Safety Plan (HSP) includes an assessment of all identified potential risks and a plan on how these risks will be managed.

References

Grace, M. and Imberger, S. (2006) Stream Metabolism: Performing and Interpreting Measurements, Monash University.

Hale, J., Stoffels, R., Butcher, R., Shackleton, M., Brooks, S. and Gawne, B. (2014) Commonwealth Environmental Water Office Long Term Intervention Monitoring Project – Standard Methods. Final Report prepared for the Commonwealth Environmental Water Office by The Murray-Darling Freshwater Research Centre, MDFRC Publication 29.2/2014, January, 182 pp

6.5 Carbon and Water Quality

6.5.1 Evaluation Questions

This component of the monitoring is composed of two parts: annual core sampling and targeted studies of adverse water quality events (funded on an optional basis and including additional sites – see Table 19).

This monitoring protocol addresses the Selected Area evaluation questions listed in Table 19.

Table 19. Questions for Carbon and Water Quality relevant to the Edward-Wakool Selected Area. Zone refers to the hydrological zones outlined in section 3. Boxes shaded grey will be monitored using Cat III methods.

Questions	Focal Area				Additional sites outside Focal Area		
	Zone 1	Zone 2	Zone 3	Zone 4	Source of Commonwealth environmental water (weir and canal)	Fish community assessment (15 sites)	Optional Carbon and water quality monitoring during adverse events (4 sites)
Selected Area evaluation questions for core sampling							
<i>Short and Long-term (one to five-year) questions:</i>							
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?	✓	✓	✓	✓	✓		
What did Commonwealth environmental water contribute to temperature regimes?	✓	✓	✓	✓	✓		
What did Commonwealth environmental water contribute to dissolved oxygen concentrations?	✓	✓	✓	✓	✓		
What did Commonwealth environmental water contribute to nutrient concentrations?	✓	✓	✓	✓	✓		
Selected Area evaluation questions for targeted sampling							
<i>Short and Long-term (one to five-year) questions:</i>							
What did Commonwealth environmental water contribute to reducing the impact of blackwater in the system?	✓	✓	✓	✓	✓		✓

6.5.2 Standard Methods (Cat III)

Overview and context

Dissolved organic carbon characterisation by ultra-violet/visible spectroscopy and fluorescence excitation-emission spectroscopy is proposed as a category 3 indicator for the Edward Wakool River System, to be interpreted in conjunction with other water quality parameters. These methods have been applied to studies in this system since 2010 and have proved to be valuable tools for tracking the progress of blackwater events and as rapid-response indicators for evaluating the releases of Commonwealth environmental water from the Mulwala Canal to mitigate the effects of black water in the river system (Watts 2013). During the 2012-13 sampling season the fluorescence technique

also proved invaluable as a marker of connectivity and assisted with interpretation of a number of other key response variables as a result. This indicator is complementary to DOC, nutrient and DO indicators used as part of the metabolism analysis.

The Edward-Wakool River system has a history of hypoxic blackwater events (Baldwin et al. 2001; Howitt et al. 2007; Hladysz et al. 2011; Whitworth et al. 2012). In recent years the area has been impacted by blackwater generated upstream, (especially from the Barmah Forest) (Howitt et al. 2007; Watts et al. 2013), but has also seen blackwater generated within the system during re-wetting of non-flowing rivers (Hladysz et al. 2011). Understanding the processes controlling blackwater events and alternatively, flow conditions that result in the input of valuable organic matter resources to the river channel without creating blackwater conditions is essential for the long-term management of this system. In addition, it is important to fully understand the role of Commonwealth environmental water in the provision of temporary refuges within the river channel during severe hypoxic blackwater events.

As noted in the Cause and Effect diagrams (CED) from the LTIM Project standard methods manual for decomposition, dissolved oxygen and dissolved organic carbon (Figs. 21, 35, and 37, Hale et al. 2014) all of these parameters/processes are inter-related and have a flow dependence. A modified CED highlighting the linkages between key parameters involved in the development of blackwater is given below (Figure 17).

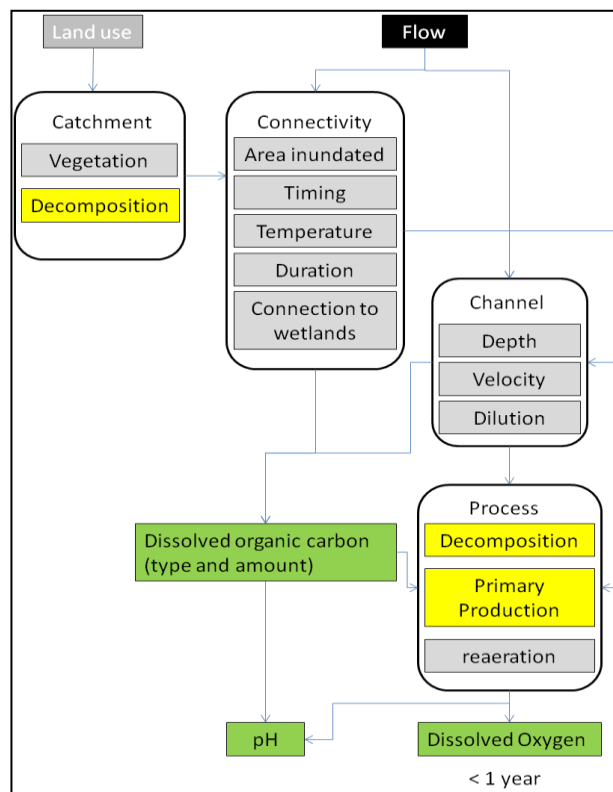


Figure 17. Modified Cause and Effect Diagram illustrating the effect of flow on key parameters associated with blackwater events.

Basin plan objectives and outcomes

- Ecosystem function (Process)
- Water quality (Chemical)
- Water quality (Biological)

The process for evaluating the evaluation questions is illustrated in Figure 18, with components covered by the protocol highlighted in grey. Components highlighted in blue are also required for the predictive ecological response model.

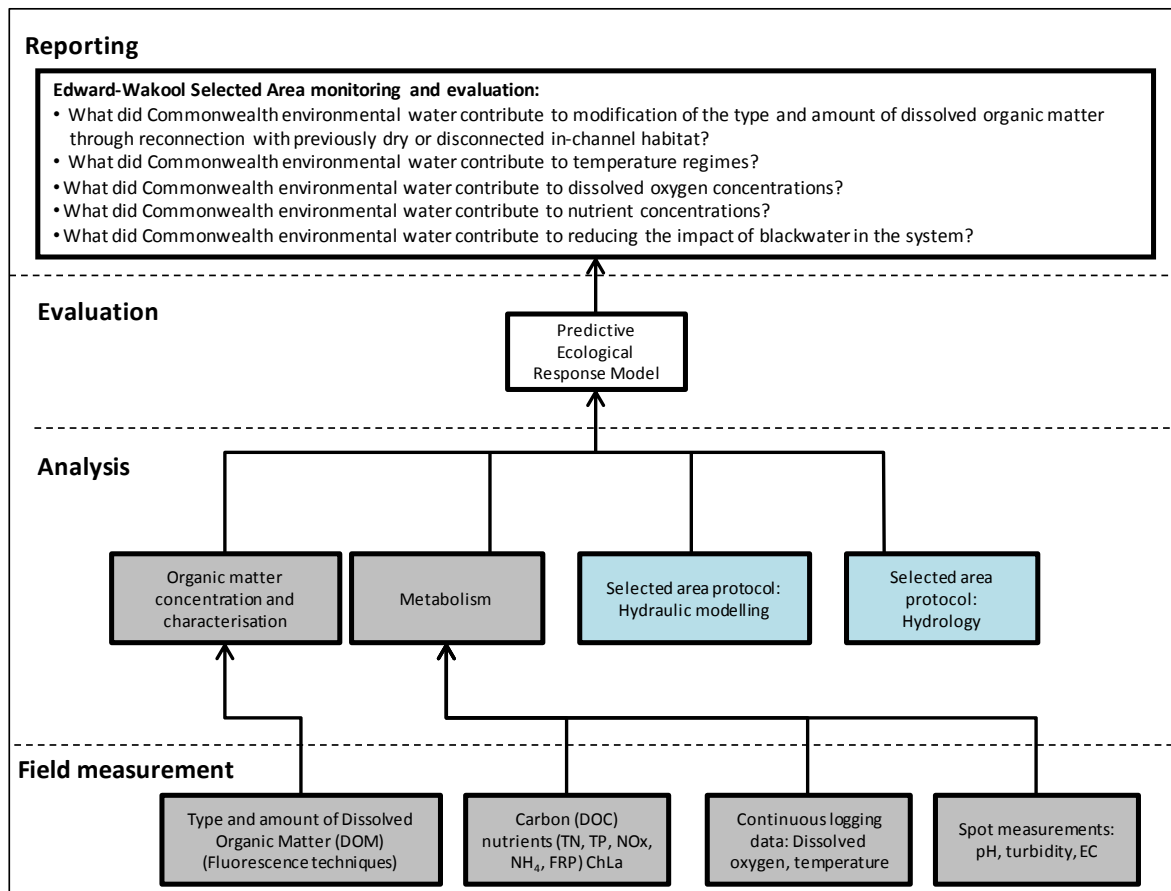


Figure 18. Schematic of key elements in Selected Area Monitoring and Evaluation – Water Quality. Components covered by this protocol are highlighted in grey. Components highlighted in blue are also required for the predictive ecological response model.

Complementary monitoring and data

Absorbance scans in the ultra-violet and visible region and fluorescence Excitation-Emission Matrices (EEM or 3D fluorescence spectra) have been collected for source water and in zones 1 and 2 since 2010.

Indicators

UV-vis and fluorescence organic matter profiles

Carbon fluorescence techniques can be used as rapid-response indicators of the progress of a blackwater event through the tracking of complex organic matter and serve as a sensitive marker of connectivity with previously dry habitat (Watts et al. 2013) During the natural flooding event in 2012 these techniques provided the only strong indicators that the blackwater event in the Edward Wakool system had originated upstream of the study sites and had not developed within the study rivers themselves. They also provided a rapid indication that the environmental water releases from

the Mulwala canal would be less effective than during the previous event (but still useful) due to floodwater impacts on the DOC concentrations in the canal(Watts et al. 2013).

The combination of fluorescence spectroscopy as an indicator of floodplain connectivity and the use of inundation models is valuable for the interpretation of other ecological indicators measured to assess the impacts of environmental water uses.

Critical covariates

DOC, nutrients (TN, TP, FRP/NOx), dissolved oxygen, pH, area of inundation, temperature

Locations for monitoring

This work has two components- an annual core monitoring component at standard sites and an expanded component with more frequent sampling and a broader range of sites which will come into effect if blackwater or other poor water quality occurs in the system and the Commonwealth Environmental Water Office chooses to trigger this option.

The core carbon fluorescence data will be collected in zone 1 (Yallakool Creek), zone 2, (upper Wakool River), zone 3 (mid Wakool River, upstream Thule Creek), zone 4 (mid Wakool River, downstream Thule Creek) and source water from Stevens Weirpool (Edward River) and the Mulwala Canal.

Should the optional targeted component be triggered due to blackwater or other adverse water quality in the system, four additional downstream sites will be selected from the fish monitoring sites to monitor the progress and severity of the blackwater in the broader system. The sites will be determined on an event basis in collaboration with the CEWO but options might include:

- a) La Rosa, Gee Gee Bridge, Glenbar and Stony Crossing to track the progress of blackwater down the Wakool River or;
- b) Gee Gee Bridge, Werai Station, Ventura and Moulamein to capture a more widespread event with a focus on the Werai forest
- c) Merran Downs, Gee Gee Bridge, Merran Creek Bridge and Stony Crossing for an event originating from the Koondrook/Gunbower forests.

Timing and frequency of sampling

The sampling design outlined is designed to assess a combination of questions, covering outcomes likely under watering options 1a, 1b, and 1c.

Core sampling - Establishing a baseline

The focus of the annual monitoring is the assessment of organic matter inputs during in-stream flows and interpretation of the interaction with other water quality parameters. During 2014-2015 the focus will be on establishing a baseline for all river sites and assessment of flows, especially in comparison with existing data sets for overlapping sites

Sampling will consist of water samples collected from two sites within each zone (1 to 4) and each source area for 8 months of the year. Where possible, sites will be aligned with dissolved oxygen loggers established for the assessment of metabolism. Zones 1, 2 and sources can be compared to historical data sets. Connection with previously dry habitats can be assessed through changes to the fluorescence signature as the water progresses downstream.

Targeted Sampling:

Large flow events and releases of environmental water for blackwater mitigation require more intensive sampling than the routine monthly monitoring. The sampling design includes weekly sampling over an eight week period for spectroscopic analysis, DOC, NO_x, ammonia, soluble phosphorus and spot measurements of DO and pH. All sites (Source 1 and 2 if required, 1, 2, 3, 4, plus 4 additional sites) will be monitored during this period and samples will be taken from 2 sites per zone (aligned with the metabolism and selected fish monitoring sites) to allow for assessment of changes as blackwater or mitigation water progresses down the system.

Responsibilities

- Water samples will be collected in the field by staff undertaking the metabolism and fish sampling (CSU and NSW fisheries)
- Laboratory analysis will be undertaken by casual assistants under the supervision and training of Dr Julia Howitt (CSU)
- Data analysis and reporting will be undertaken by Dr Julia Howitt (CSU)

Field Methods

Water samples (approx 30 mL) will be filtered in the field using 0.2 µm syringe filters. Samples will be stored on ice, in the dark (not frozen) and sent by courier to the CSU laboratories in Wagga Wagga by the end of each field trip.

Laboratory methods

Water samples will be analysed by UV-Vis and fluorescence spectroscopy within 1 day of receipt by the laboratory (48 hours may be necessary during a blackwater event due to the larger number of samples). Absorbance scans will be collected using a Varian Cary 4000 instrument across a wavelength range of 550 nm to 200 nm (green through to ultraviolet) with a 1 nm step size. Fluorescence scans will be collected using a Varian Eclipse spectrofluorometer scanning both emission and excitation wavelengths to give an excitation-emission matrix.

Data analysis and reporting

Spectroscopic analyses will be plotted using Sigma Plot for comparison between sampling sites and sampling dates. UV-Vis scans will be plotted as line graphs and fluorescence results will be corrected for sample absorption and plotted as contour plots (Howitt et al. 2008).

Spectroscopic analyses will be reported annually for the core monitoring component Spectroscopic analyses during targeted water quality monitoring can serve as rapid-response indicators with the UV-Vis results available on the day of analysis (same day as receipt if urgent) and the fluorescence results available within 2-3 days (due to the greater data processing requirements). Combined with spot water quality measurements, this data will provide a critical guide to the progress of a blackwater event and the impact of any releases from channel escapes.

Health and safety

The Edward-Wakool Selected Area Health and Safety Plan (HSP) includes an assessment of all identified potential risks and a plan on how these risks will be managed.

References

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6.6 Riverbank and aquatic vegetation

6.6.1 Evaluation questions

This monitoring protocol addresses the Selected Area evaluation questions listed in Table 20.

Table 20. Questions for riverbank and aquatic vegetation type relevant to the Edward-Wakool Selected Area. Zone refers to the hydrological zones outlined in section 3. Boxes shaded grey will be monitored using Cat III methods.

Questions	Focal Area				Additional sites outside Focal Area		
	Zone 1	Zone 2	Zone 3	Zone 4	Source of Commonwealth environmental water (weir and canal)	Fish community assessment (15 sites)	Optional Carbon and water quality monitoring during adverse events (4 sites)
Selected Area evaluation questions							
<i>Short and Long-term (one to five-year) questions:</i>							
What did Commonwealth environmental water contribute to the percent cover and height of riverbank and aquatic vegetation?	✓	✓	✓	✓			
What did Commonwealth environmental water contribute to the diversity of riverbank and aquatic vegetation?	✓	✓	✓	✓			

6.6.2 Standard methods (Cat III)

Overview

Riverbank vegetation and aquatic vegetation play an important role in river ecosystems and provide habitat for fish, invertebrates, frogs and birds (Roberts and Marston 2011). The cover and composition of aquatic vegetation can determine the availability of oviposition sites for macro invertebrates and calling and spawning locations for frogs (Wassens et al. 2010) and support wetland food webs and zooplankton communities (Warfe and Barmuta 2006). Furthermore, the response of aquatic and riverbank vegetation following a flow event can assist understanding the response of other biological indicators.

Riverbank plant survival and growth is affected by the frequency and duration of inundation (Toner and Keddy 1997; Johansson and Nilsson 2002; Lowe et al. 2010). Frequent inundation can delay reproduction (Blom and Voesenek 1996), whilst long duration of inundation can reduce growth or survival (Blom et al. 1994; Johansson and Nilsson 2002; Lowe et al. 2010). Favourable soil moisture and nutrient conditions created by a receding flood can encourage rapid recovery and root and shoot development and many plants, including emergent macrophytes and riparian understorey herbs, often germinate on flood recession (Nicol 2004; Roberts and Marston 2011). Differences in seasonal patterns of inundation within a single year can result in different survival, growth and reproduction responses of riverbank and aquatic plant species (Lowe 2002).

Basin plan objective and outcomes

- Biodiversity (Vegetation)
- Resilience

The process for evaluating the evaluation questions is illustrated in Figure 19, with components covered by the protocol highlighted in grey. Components highlighted in blue are also required for the predictive ecological response model.

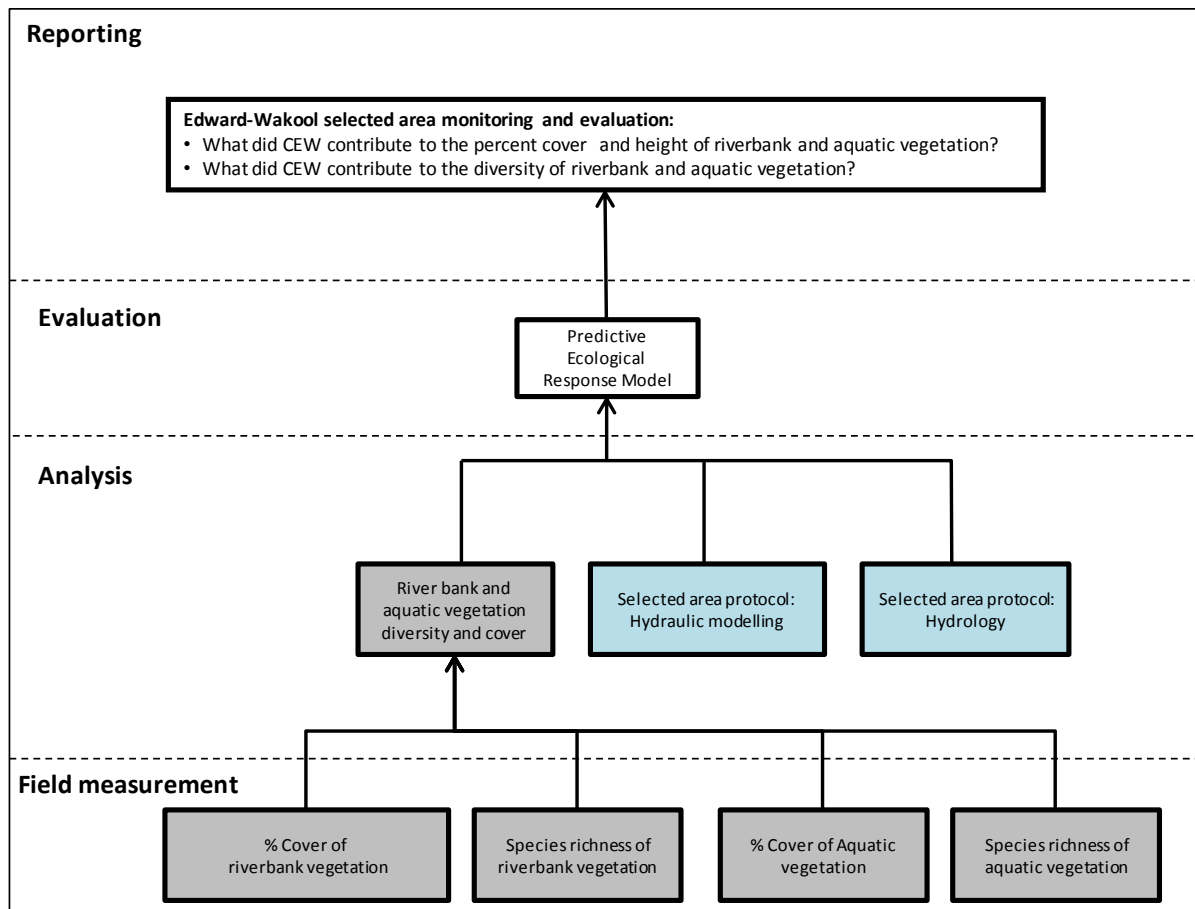


Figure 19. Schematic of key elements in Selected Area Monitoring and Evaluation – Riverbank and aquatic vegetation. Components covered by this protocol are highlighted in grey. Components highlighted in blue are also required for the predictive ecological response model.

Indicators

- Percent cover of aquatic vegetation
- Percent cover and maximum height of riverbank vegetation
- Diversity of aquatic vegetation
- Diversity of riverbank vegetation

Critical covariates

Season, area and duration of slackwater habitat, water depth, velocity, Δ discharge

Locations for monitoring

Monitoring will occur in zone 1 (Yallakool Creek), zone 2 (upper Wakool River), zone 3 (mid Wakool River, upstream Thule Creek), zone 4 (Mid Wakool River, downstream Thule Creek). Five sample sites will be established in each zone at the same sites as the larval fish sampling.

Timing and frequency of sampling

Monitoring of percent cover and height of vegetation will be undertaken monthly and monitoring of diversity will be undertaken bi-monthly between September and March each year.

Responsibilities

- Field sampling: Sascha Healy (OEH), James Abell (CSU), Chris Smith (NSW Fisheries)
- Data entry and collation: Sascha Healy (OEH) and James Abell (CSU)
- Data analysis and reporting: Nicole McCasker (CSU), Robyn Watts (CSU) and Sascha Healy (OEH)

Field methods

Five sites within each zone will be surveyed monthly between September and March. At each site we will establish 5 permanent markers at surveyed locations along a transect running from within the water and up the riverbank. One of the locations will be in the water at base flows, three locations on the riverbank will be at heights that may be inundated during Commonwealth environmental watering, and one location will be above that height but may be occasionally inundated by high unregulated flows. These heights will be determined by examining the hydrograph from previous Commonwealth environmental watering actions. At each of these locations on each sampling date a 25 m tape measure will be laid out running horizontally along the riverbank. The type of cover at point quadrats at each 50cm point along the 25 m transect will be recorded along with the maximum height of any vegetation at that point. Riverbank vegetation will be classed as grasses (tall and short), herbs (tall and short), logs and litter, and bare ground. Aquatic vegetation will be classed as tall emergent, short emergent, broadleaf emergent, attached floating, or submerged. These data will be used to estimate percent cover of riverbank and aquatic vegetation over time. On a bimonthly basis the vegetation diversity will be identified to species where possible.

Overall river characteristics including surrounding land use, general assessments of the surrounding vegetation communities, soil type, aspect, and continuity of fringing vegetation and percent open water will also be recorded at each site.

Photopoints will be established at each transect and photos taken on every sample event.

Data analysis

For event-based analysis, data will be analysed with a BACI style approach comparing percent cover of riverbank and aquatic vegetation in hydrological zones that received environmental water to zones that did not receive environmental water; before, during and after environmental water releases.

For short and long term (1-5 year) analyses, data will be analysed over the period from September to March to answer the question: What did Commonwealth environmental water contribute to the percent cover and diversity of riverbank and aquatic vegetation?

Reporting

Reporting and data interpretation will be undertaken by OEH (Sascha Healy), CSU (Nicole McCasker and Robyn Watts).

Health and Safety

The Edward-Wakool Selected Area Health and Safety Plan (HSP) include an assessment of all identified potential risks and a plan on how these risks will be managed.

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6.7 Fish movement

6.7.1 Evaluation questions

This monitoring protocol addresses the Basin-scale and Selected Area evaluation questions listed in Table 21.

Table 21. Questions for fish movement that are relevant to the Edward-Wakool Selected Area. Zone refers to the hydrological zones outlined in section 3. Boxes shaded green will be monitored using Cat II methods.

Questions	Focal Area				Additional sites outside Focal Area		
	Zone 1	Zone 2	Zone 3	Zone 4	Source of Commonwealth environmental water (weir and canal)	Fish community assessment (15 sites)	Optional Carbon and water quality monitoring during adverse events (4 sites)
Basin-scale evaluation questions							
<i>Short-term (1 year) questions:</i>							
What did Commonwealth environmental water contribute to native fish dispersal?	✓	✓	✓	✓			
<i>Long-term (5 year) questions:</i>							
What did Commonwealth environmental water contribute to native fish populations?	✓	✓	✓	✓			
Selected Area evaluation questions							
<i>Short and Long-term (one to five-year) questions:</i>							
Were periodic species (golden and silver perch) present in the target reaches during Commonwealth environmental water delivery?	✓	✓	✓	✓			
Did periodic species remain within the target reaches during Commonwealth environmental water delivery?	✓	✓	✓	✓			
Did Commonwealth environmental water stimulate periodic fish species to exhibit movement consistent with reproductive behaviour?	✓	✓	✓	✓			
Does Commonwealth environmental water enable periodic species to disperse from and return to refuge habitat?	✓	✓	✓	✓			
Does Commonwealth environmental water protect periodic species from adverse water quality?	✓	✓	✓	✓			

Selected Area Hypotheses

H₁ Reproduction related movement responses occur as a result of Commonwealth environmental water delivery of bankfull and freshes.

H₂ Increased dispersal of adults and juveniles occurs as a result of improved longitudinal connectivity facilitated by Commonwealth environmental water delivery.

H₃ Movements to refuge habitats occur without stranding as a result of Commonwealth environmental water delivery.

6.7.2 Standard methods (Cat II)

This SOP is according to Hale et al. (2014), and includes adjustments (where relevant) to incorporate Edward-Wakool selected area methods and evaluation questions, with inclusions of Health and Safety Plan, Location for monitoring, and Responsibilities. It will be used to address both Basin-scale and Selected Area evaluation questions.

Overview and context

Freshwater fish make reproduction, dispersal and feeding movements in response to biotic and abiotic stimuli (Lucas et al. 2001)(Figure 20). The delivery of Commonwealth environmental water will affect the scale of fish responses to these stimuli, as the frequency, timing and magnitude of fish movements are strongly related to flow (Taylor and Cooke 2012). It is important that any fish movements are able to be quantified and related back to discharge (whether it is delivered by the Commonwealth or otherwise), to enable adaptive management of future flow events. For example, elevated flows increase longitudinal and lateral habitat connections, enabling fish to seek refuge to avoid disturbances such as hypoxic blackwater events or to recolonise following disturbances. Commonwealth environmental water objectives have, in the past, had ecological objectives which required monitoring of fish movements to determine outcomes. For instance, if fish reproduction (and thus changes in landscape fish diversity) is an objective, then tracking the movements of fish to breeding locations, or documenting behaviour consistent with reproduction, provides direct evidence that the delivery was successful. In addition, movement data can demonstrate whether fish survived during poor water quality events, or whether fish successfully moved into refuge habitat during periods of low flow. The strategic placement of acoustic receivers in the Edward-Wakool Selected Area will provide information on the timing, frequency and magnitude of movements related to Commonwealth environmental watering events. Importantly, data is logged on average every 90 seconds. With this level of precision, movement events can be linked to particular aspects of the hydrograph. Such information is important to determine whether the fish movement aspects of Commonwealth environmental water delivery are successfully achieved.

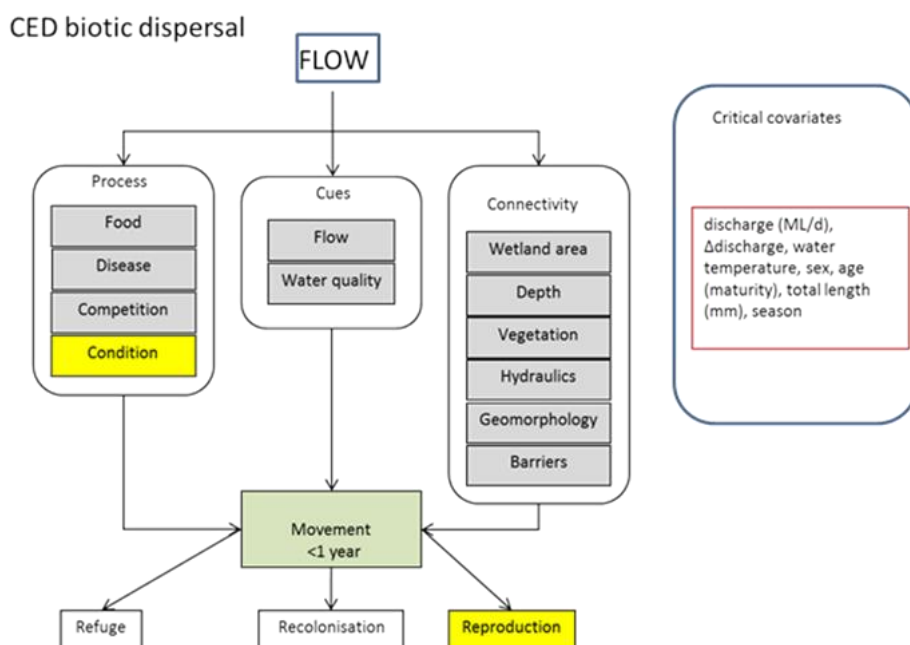


Figure 20. Modified biotic dispersal cause and effect diagram reflecting the biotic and abiotic influences on fish movement. Yellow boxes indicate other cause and effect diagrams. The critical reason biotic dispersal is important for fish is that it may be reproduction related in response to flow. (Modified from MDFRC 2013).

Given the climatic variability in Australia and the associated unpredictable hydrology, numerous species rely on in-channel flows, rather than off-channel connections, to complete their life cycle (Humphries et al. 1999). For example, golden perch reproduction can occur from early November to March (Roberts et al. 2008; King et al. 2009). In-channel reproduction has occurred in non-flood years for golden and silver perch, and rapid responses of reproduction to rising water levels and temperatures have been documented, often in conjunction with long-distance migrations (Reynolds 1983, Mallen-Cooper and Stuart 2003, O'Connor et al. 2005). This suggests that both species are in a state of 'reproductive readiness' over a specified season and are awaiting suitable environmental conditions to spawn. If these conditions are not achieved minimal reproduction may occur or the species will simply resorb gonads.

Telemetry is a useful method for obtaining detailed movement information on fish, as it enables quantification of the magnitude, timing and frequency of individual responses to abiotic stimuli such as flows (Taylor and Cooke 2012). In Australia, telemetry has been used to identify the reproduction related movements of golden perch in response to flow events (O'Connor et al. 2005). Leigh and Zampatti (2013) used telemetry to quantify the lateral movements of Murray cod during high discharge events. Using telemetry, Simpson and Mapleston (2002) identified a positive correlation between the distance moved by Mary River cod and discharge. Telemetry can also be used to quantify large scale dispersal, including movements to and from refuge habitats, and serves as a useful additional line of evidence to infer successful reproduction (e.g. Thiem et al. 2013, Walsh et al. 2013).

Acoustic tracking is a useful telemetry method for obtaining information on fish movements. The process involves implanting a transmitter into a fish, which is then detected by a series of stationary readers installed in a target stream. Acoustic monitoring can provide high resolution spatial information on fish location, and data can be graphically presented to identify specific movement patterns (Barnett et al. 2010). In the case of environmental water delivery, the strategic placement of acoustic receivers will provide information on timing of movements, distances travelled, residency, correlation of movements with flow delivery and evidence of reproduction behaviour. Such information is important to determine the delivery success of a particular Commonwealth environmental water volume, to provide additional evidence to support existing monitoring activities such as larval fish monitoring, and to inform the planning of future events.

These standard methods describe monitoring required for the Basin-scale evaluation and Selected Area evaluation of the response of river fish to Commonwealth environmental water. The methods describe the sampling design and protocol for large-bodied fishes in river channels for the LTIM Project.

This protocol describes equipment specifications and implantation procedures to measure:

- Dispersal rates and directions of target periodic life-history fishes

The process for evaluating Basin-scale questions is illustrated in Figure 21, with components covered by this protocol highlighted in grey.

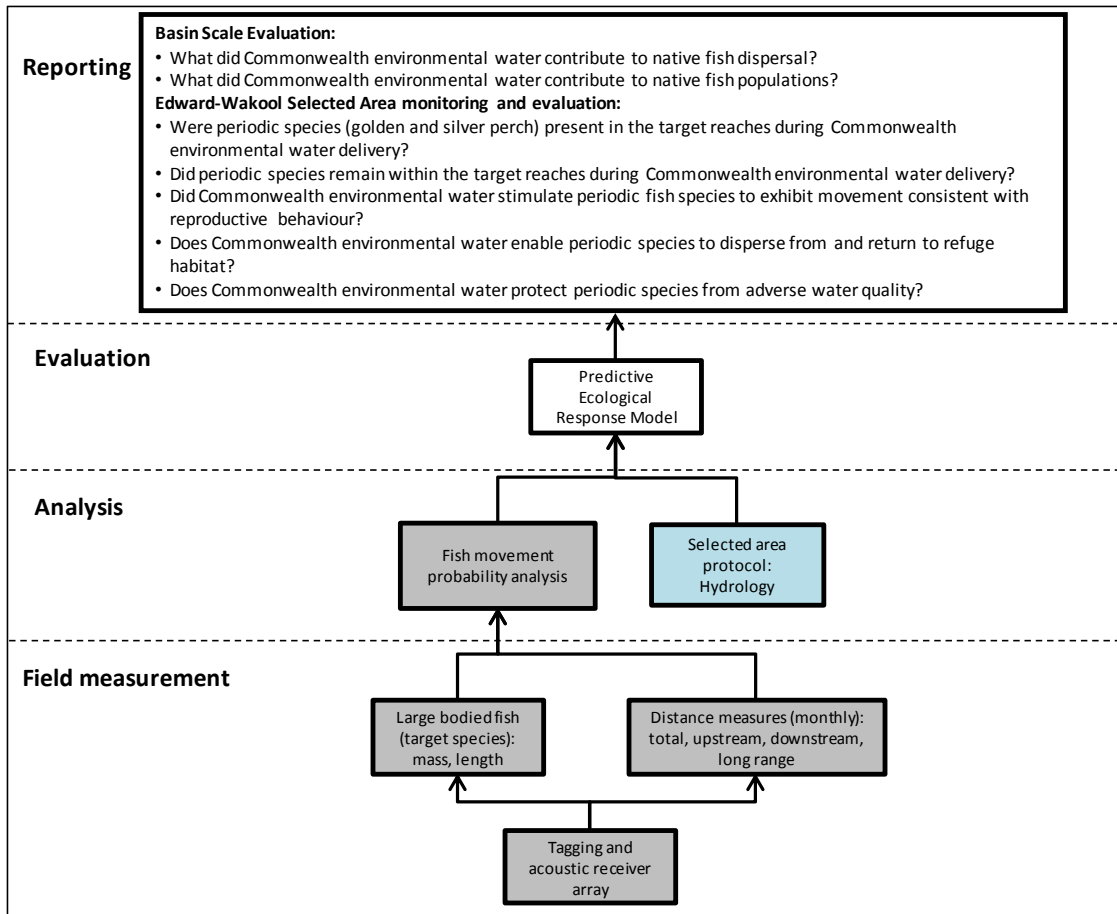


Figure 21: Schematic of key elements in LTIM Project Standard Protocol: Fish (Movement). Components covered by this protocol are highlighted in grey. Components highlighted in blue are also required for the predictive ecological response model

Establishing sites

Equipment

- Boat
- GPS

Protocol

LTIM Project for Basin-scale evaluation has adopted a hierarchical approach to sample design. The spatial hierarchy for fish (movement) monitoring is as follows:

- Selected Area
 - Zone
 - Site

Zone placement within Selected Areas

A 'zone' is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands.

For Basin-scale evaluation, we selected four zones for monitoring of fish movement in river channels based on the following recommendations of Hale et al. (2014):

- Different zones within Selected Areas represent spatially-, geomorphologically- and/or hydrologically-distinct units;
- Zones must be likely to receive Commonwealth environmental water at least once in the next five years;
- Zones must have an expected outcome related to the indicator in question (in this instance fish movement);
- The zones selected for monitoring fish movement responses to flows are to be the same as selected for monitoring fish population and community structure for Basin-scale modelling data (see LTIM Project Standard Protocol: Fish (River)). In this way we may achieve synergies amongst different forms of fish data collected.

Receiver design / placement within zones

The array and design of the telemetry study in the Edward-Wakool Selected Area (Figure 22) was established with respect to the following general requirements outlined in Hale et al. (2014):

- Receivers will span the length of channel defined by the ten sites established as part of the population/community monitoring; these are placed within Zone 3 (see LTIM Project Standard Protocol: Fish (River));
- Consistent spacing of acoustic receivers will occur within monitoring zones.
- Additional receivers will be deployed at major waterway junctions to determine the direction of movement into and out of these waterways.
- GPS coordinates of receiver locations will be recorded to facilitate calculation of distances moved by individual fish.

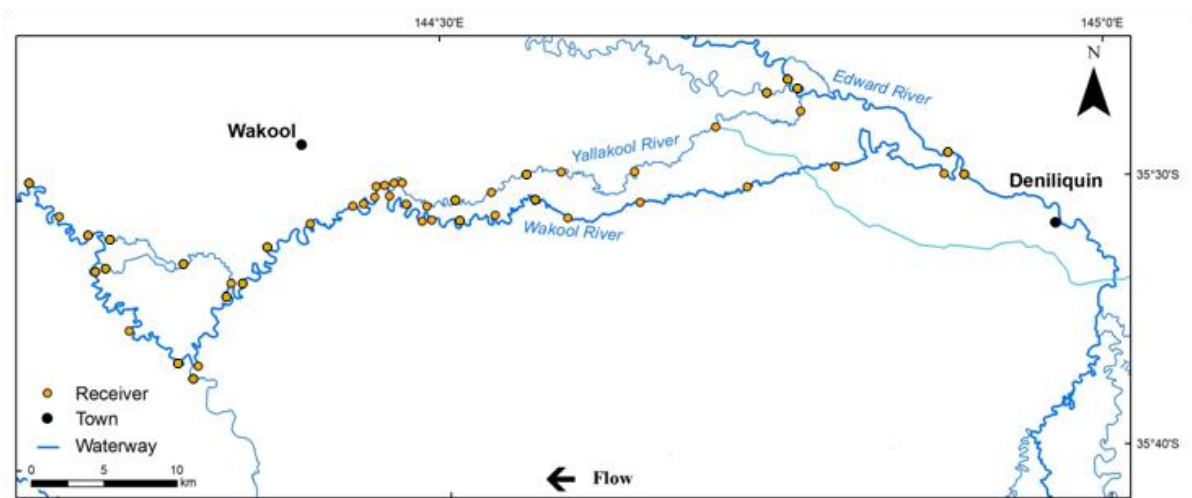


Figure 22. Proposed locations of acoustic receivers in the Edward-Wakool system.

Location of Monitoring

Fish (movement) Cat II will be monitored in zones 1 (Yallakool Creek), 2 (Upper Wakool River), 3 (mid Wakool River, upstream of Thule Creek) and 4 (mid Wakool River, downstream of Thule Creek). Placement of 48 individual receivers will be distributed at a 5 kilometre spacing within zones, and at the junction of major waterways also to provide the fish movement metrics requested to address Basin-scale evaluation Category II questions (Hale et al. 2014).

Knowledge of the dispersal paths in the system will enhance management of future Commonwealth environmental watering actions targeting native fish colonisation and dispersal. The scale of

movement exhibited by fish will likely vary depending upon the magnitude of Commonwealth environmental water that is delivered, and will be of the greatest magnitude during high flow events. Dispersal of tagged fish from the study area into the catchment will provide insight into resilience, emigration, immigration and blackwater related movements, informing Selected Area reporting. Movements by fish throughout the Selected Area result in increased population resilience, through dispersal into new habitats, by enabling greater access to breeding habitat, through colonisation of new or previously impacted habitat (e.g. drought or hypoxic blackwater affected areas) and avoidance of poor quality habitat (e.g. water quality). Large bodied fish communities in the mid and lower Wakool river system were significantly impacted by drought (2000 – 2010) and large scale fish kills caused by hypoxic blackwater following system wide flooding in 2010. The monitoring of flow related fish movement into and out of these zones from less affected 'refuge' areas will assist in interpretation of the role of Commonwealth environmental water in facilitating system-wide recovery. The data collected from the fish movement component will also be used to compliment fish community monitoring that will occur annually in these zones

Representative species from life-history guilds

Overview

Fishes belonging to different life history guilds may respond in different ways to managed and natural flows. Periodic species including golden and silver perch are considered to be flow dependent spawners and are expected to provide detectable responses to Commonwealth environmental water.

Protocol

The monitoring of fish movement in the Edward-Wakool Selected Area will be undertaken with respect to the following guidelines from Hale et al. (2014):

- Across all Selected Areas the periodic life-history species targeted will be golden perch. The basis for selection of a second, Selected Area-specific periodic species is at the judgement of the Selected Area team, and will be silver perch in the Edward-Wakool Selected Area.

Target species for the Edward-Wakool Selected Area

We propose to implant acoustic tags into two periodic species (golden perch and silver perch). We have included silver perch as an additional species as there is considerable stakeholder interest in this species' responses to Commonwealth environmental water delivery both nationally (as a state and federally listed threatened species which is known to require flow to recruit) and by stakeholders within the Edward-Wakool Selected Area due to strong recruitment, possibly in response to recent flooding. Further, it is anticipated that both species will be the focus of 'perch spawning flows' in the target reaches in future Commonwealth environmental watering events. Reproduction of the species is often preceded by synchronised movements of these species, typically in response to in-channel rises or overbank flows. Demonstrating that Commonwealth environmental water can be used to stimulate reproduction in these species would be a significant achievement.

Monitoring the location, timing and magnitude of movements exhibited by these species will enable a multiple lines of evidence approach to be undertaken that specifically compliments the existing M&E Plan for the Edward-Wakool Selected Area. For example, if perch spawning flows are delivered and no reproductive response is detected (via larval fish sampling), is this result due to the movement of focal species out of the target reaches in response to Commonwealth environmental

water delivery (i.e. are adults of these species even present to reproduce when suitable conditions occur?). Such information is necessary to determine the delivery success of a particular Commonwealth environmental water volume, to provide additional evidence to support existing monitoring activities such as larval fish monitoring, and to inform the planning of future events. Further, when focal species remain within the target reaches during water delivery we will employ a modelling approach whereby the type and scale of future movements will be able to be predicted based on past events.

Tag implantation procedures will be conducted in accordance with the standard methods as outlined by Hale et al. (2014). A target sample size of $n=30$ individuals has been set for each species at the commencement of the project (2015-16) and this is reflected in the detailed budget. In addition, given likely losses of fish from the acoustic array through emigration and angler removal (golden perch only) we propose to replenish tag numbers each year. Replenishment tags will be allocated between species based on the number of tagged fish present in the acoustic telemetry array prior to annual tagging events.

Sampling protocol

Equipment

- For reliability as well as consistency with current projects (Murrumbidgee, Gwydir and Goulburn) we will use Vemco (<http://vemco.com/>) VR2W acoustic monitoring receivers operating on 69 kHz; VR2Ws are a submerged, single channel, omni-directional receiver that record time, date and identity of fish fitted with acoustic transmitters. VR2W receivers are powered by a single “D” sized 3.6 Volt lithium battery, with a projected battery life of 15 months. Range testing of receivers in other Australian installations indicated 100% detection efficiency to 300 m which declines to 60% at 400 m. Receiver locations will be placed where channel widths are less than reliable detection ranges (< 600 m) and possess clear open substrate to eliminate detection shadows.
- Vemco tags will be used. Other ‘compatible’ tags are available on the market but cannot guarantee unique tag numbers. Duplicate tag numbers will be avoided;
- Tag size may vary with target species body size within the Edward-Wakool Selected Area. We will ensure that tag burden does not exceed 2% of the body weight of fish. Tag battery life will be maximised while considering transmission delays to reduce code collision, taking into account the following points raised by Hale et al. (2014):
 - Tag size is governed by battery size; larger tags = larger battery = longer tag life;
 - Tags with a 3 year life can be purchased but only implanted into large fish;
 - Tags transmit on a random delay. The delay is determined at the time of purchase and influences two things:
 - The chances of code collision. More tags in a location at any given time requires a longer transmission delay to reduce the risk of tags transmitting at the same time and collision of transmission codes (i.e. 2 tags transmitting at the same time in the same location will usually result in no detections)
 - Tag life. Longer delays = longer tag life. BUT increase the chance a fish can swim past a receiver and not be detected as receivers are passive and only detect tags when tags transmit.
 - Previous Edward-Wakool projects used Vemco model V9 tags (<http://vemco.com/products/v7-to-v16-69khz/>) on an average 90 second delay (i.e. transmission occurs randomly between 50 and 130 seconds) for small fish (tag weight 3.6 g, battery life ~225 days) and V13 tags on an average 90 second delay for larger fish

(tag weight 11g, battery life ~885 days). It is expected that these tags will continue to be used

Protocol

Which individuals to tag?

Species tagged for movement study will be golden perch and silver perch. A minimum sample size of n=30 individuals per selected species will be tagged, with adequate representation of size ranges within each species. As a very rough guide, 1/3 of the individuals tagged will be juvenile, with the remainder spread across a broad range of adult sizes.

Implantation

- Telemetry tagging will be conducted between March and August to avoid high water temperatures and reproductive events. Fish with advanced gonad development have little room in the coelomic cavity to accommodate a tag.
- Fish will be immediately tagged on-site following recovery from capture.
- All telemetry tags will be surgically implanted into the coelomic cavity whilst fish are under anaesthesia. Dose rates of anaesthesia will comply with animal ethics approval.
- Anaesthesia will be achieved through submersion of fish in an induction bath of either benzocaine or Aqui-S (<http://www.aqui-s.com/>).
- Stage 4 anaesthesia, characterised by total loss of equilibrium and no reaction to handling, is typically the stage required for surgical procedures on fish (Summerfelt & Smith 1990).
- Relevant total length (TL: mm) and fork length (FL: mm) as well as mass (g) will be recorded
- Fish exhibiting visible signs of disease, injuries and deformities will be excluded from tagging.
- Surgery will take place in a V-shaped cradle and fish are to have water continually pumped over the gills (containing a reduced concentration of anaesthetic where necessary).
- Mid-ventral incisions of 20–30 mm will be made through the body wall of the fish posterior to the pelvic girdle and anterior of the anal vent.
- Every possible effort will be made to determine the sex of fish by examining the gonads through the incision prior to transmitter insertion or by collecting a fin clip to retrospectively assign sex. It will be important for later interpretation of data and identifying possible reproductive behaviour during flow events.
- Use of antibiotics and disinfection of tags and surgical equipment will be a standard practice
- Incisions will be closed using 2–3 interrupted monofilament absorbable sutures (Ethicon PDS II sutures: <http://www.ecatalog.ethicon.com/sutures-absorbable/view/pds-ii-suture>) using multiple surgeons knots.
- A single surgeon will be used for all tag implantation where possible, or record kept if multiple surgeons are used.
- All tagged fish will be fitted with external, individually numbered dart tags in the dorsal musculature to aid angler identification and facilitate tag returns which is important to understand the fate of the fish if it is not detected in the future.
- Post-surgery fish will be recovered on-site and released within 24 hours of capture/surgery at the point of capture.

Data analysis and reporting

Receiver download schedule

- Acoustic receivers will be downloaded quarterly to reduce the possible risk of lost/stolen receivers

- Data will be filtered to remove single detections (Clements et al. 2005), false detections and orphan tags.
- Data files will be stored and managed appropriately.

Data outputs

Downloaded acoustic receiver data will be uploaded into a custom built SQL database. This database will comprise a distance matrix of receiver locations that account for river sinuosity so that movement paths of individual fish can be recreated and distances moved quantified. Single detections will be removed and false detections and orphan tags filtered by the database prior to any analysis.

Basin –scale individual fish metrics

With respect to population modelling, the following metrics will be available on request if a Basin-level assessment is undertaken:

- Total longitudinal Distance (TD) moved, stratified by month:
 - This is the sum of all distances (upstream and downstream) covered by an individual, within a receiver array.
 - These monthly statistics for each individual will be used to establish a TD probability distribution as a function of month, species and (approximate) age-class or stage-class.
- Total longitudinal Distance moved Upstream (TDU), stratified by month:
 - This is the sum of all distances moved upstream made by an individual, within a receiver array.
 - These monthly statistics for each individual will be used to establish a TDU probability distribution as a function of month, species and (approximate) age-class or stage-class.
- Total longitudinal Distance moved Downstream (TDD), stratified by month:
 - This is the sum of all distances moved downstream made by an individual, within a receiver array.
 - These monthly statistics for each individual will be used to establish a TDD probability distribution as a function of month, species and (approximate) age-class or stage-class.

Selected area indicators and analysis

Fish movement metrics and location data will be calculated including: linear range (the maximum upstream minus the maximum downstream location), mobility (the sum of all distances moved) and residency (the proportion of the tagged sample within any given location). These metrics will be relation to season and discharge for periodic species and will be queried on time-scales of days to months depending upon the question of interest.

Reproduction related movements

Analysis will be focussed around the following questions: 1) Did fish move in response to the delivery of Commonwealth environmental water? 2) If so, how far did they move? 3) Where did they move to and what was the direction of movement? A model selection approach using linear mixed effect (LME) models will be applied to address questions 1 and 2 incorporating key covariates discharge, Δ discharge, lagged discharge (number of days since flow event), Julian day, water temperature, sex and length of fish. If reproduction related movements do occur then the locations of fish during this time will be reported as displacement, defined as a representation of the geographical distance and direction that a fish moved. It is expected that the some reproduction related movements of golden perch may occur over a greater spatial scale than the fine scale array and subsequently a broad scale

array would be required to quantify reproduction movement for individuals that move outside the study area.

Dispersal from, and return to, refuge habitat

Movements to and from refuge habitats will be analysed using movement metrics including total linear range (maximum distance between upstream and downstream locations) and displacement (representation of the geographical distance and direction that a fish moved). We will quantify the rates of emigration from the focal reach, as well as any subsequent return movements. All movement metrics will be analysed for responses during Commonwealth environmental water delivery as well as outside of this time. It is expected that these movements will occur over a greater spatial scale than the fine scale array and will subsequently use data from the broad scale array.

Data management

All data provided for this indicator will conform to the data structure defined in the LTIM Project Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Project Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is the site (river section).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Project Data Standard and will be enforced by the MDMS when data is submitted.

Timing and frequency

Submerged Vemco autonomous receivers will record the time, date and identity of acoustic tagged fish swimming within detection range of the receiver units (~ 500 m). Logged receiver data will be downloaded quarterly, although there is potential to incorporate strategic downloads to inform adaptive management. Individually coded acoustic transmitters will be inserted into the peritoneal cavity of each fish and tags will have a programming-dependent battery life of up to 900 days depending upon fish size. Annual replenishment of a proportion of the tagged sample will account for tag loss through battery expiration, angler removal and emigration.

Complementary monitoring and data

This fish movement SOP provides an additional line of evidence to link Commonwealth environmental water delivery with fish outcomes (and ultimately 5+ year changes in native fish populations). For example, Commonwealth environmental water delivered to stimulate a golden or silver perch reproduction event is likely to trigger large scale synchronised movements of adults to suitable reproduction habitat. In the absence of the collection of eggs and larvae of these species, the location of key reproduction sites can provide insight into the possible timing of reproduction and critical reproduction habitat of these species. Further, data emanating from this fish movement SOP provides a proof of concept for the use of Commonwealth environmental water to increase longitudinal connectivity and promote dispersal from drought refugia locations. This SOP will also identify and quantify stranding that may occur between refuge locations as well as identifying critical refuge sites and thus links directly with the ecosystem recovery CED and resistance/resilience objective. Complimentary monitoring includes hydrology, water quality, and fish reproduction, recruitment and community monitoring. In addition, large datasets emanating from existing fish

movement projects within the Edward-Wakool Selected Area will be drawn upon during the analysis and interpretation of fish movement data collected as part of the LTIM Project.

Responsibilities

Fisheries NSW project staff based at Narrandera Fisheries Centre will perform receiver deployment, acoustic tagging, receiver downloads, data management, analysis and reporting. Fisheries NSW staff involved in the project (Thiem, Wooden and Smith have extensive experience with all aspects of telemetry – including tagging, data management, analysis and reporting)

Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for the Edward-Wakool Selected Area. QA/QC activities specific to this protocol include:

- Electrofishers will be experienced operators of units. They will be supervised by Senior Operators on-site, and have obtained their electrofishing certificates through a reputable course.
- Monitoring and Evaluation Providers will have relevant boat licenses.
- Monitoring and Evaluation Providers will have specific fisheries and ethics permits with them while sampling.
- Monitoring and Evaluation Providers will have appropriate experience in the surgical implantation of telemetry tags.

Health and safety

The Edward-Wakool Selected Area Health and Safety Plan (HSP) includes an assessment of all identified potential risks and a plan on how these risks will be managed.

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6.8 Fish (larvae)

6.8.1 Evaluation questions

This monitoring protocol addresses the Basin-scale and Selected Area evaluation questions listed in Table 22.

Table 22. Questions for fish larvae relevant to the Edward-Wakool Selected Area. Zone refers to the hydrological zones outlined in section 3. Boxes shaded red will be monitored using Cat I methods and boxes shaded grey will be monitored using Cat III methods.

Questions	Focal Area				Additional sites outside Focal Area		
	Zone 1	Zone 2	Zone 3	Zone 4	Source of Commonwealth environmental water (weir and canal)	Fish community assessment (15 sites)	Optional Carbon and water quality monitoring during adverse events (4 sites)
Basin-scale evaluation questions							
<i>Short-term (1 year) questions:</i>							
What did Commonwealth environmental water contribute to native fish reproduction?	✓	✓	✓	✓			
What did Commonwealth environmental water contribute to native fish survival?	✓	✓	✓	✓			
<i>Long-term (5 year) questions:</i>							
What did Commonwealth environmental water contribute to native fish populations?	✓	✓	✓	✓			
What did Commonwealth environmental water contribute to native fish species diversity?	✓	✓	✓	✓			
Selected Area evaluation questions							
<i>Short and Long-term (one to five-year) questions:</i>							
What did Commonwealth environmental water contribute to the spawning of 'Opportunistic' (e.g. small bodied fish) species?	✓	✓	✓	✓			
What did Commonwealth environmental water contribute to spawning in 'flow-dependent' spawning species (e.g. golden and silver perch)?	✓	✓	✓	✓			

Selected Area question hypotheses

- H₁ Spawning of opportunistic fish species, as measured by abundance of larvae, will increase either during or immediately following environmental water delivery, compared to nearby rivers not receiving environmental water (<1 year reporting).
- H₂ Successful spawning of flow-dependent spawners such as golden and silver perch will occur either during or immediately following the delivery of CEWO environmental water that is delivered as high spring flows, compared to nearby rivers not receiving environmental water (<1 year reporting).

- H₃ Total production of fish larvae during spawning season will be significantly greater in the rivers that received environmental freshes compared to those that did not (1-5 years reporting).
- H₄ The magnitude of spawning in opportunistic fish species will be significantly influenced by key hydrological and physical chemical parameters including the amount and duration of slackwater habitat, water depth, instream aquatic vegetation (1-5 years reporting).
- H₅ The successful spawning of flow-dependent spawners will be significantly influenced by key hydrological and physical chemical parameters including magnitude of discharge change, rate of discharge change, extent and duration of overbank flow, and temperature (1-5 years reporting).

6.8.2 Fish (larvae) standard methods (Cat I)

This SOP is according to Hale et al. (2014), with inclusions of Location for monitoring, responsibilities and Health and Safety Plan subsections. Fish (Larvae) – Cat I methods will be used to address Basin-scale evaluation questions. Some of the Cat I data will also be used to address Selected Area questions along with data collected through the Fish Reproduction – Cat III SOP.

The process for evaluating the Basin-scale evaluation questions for Fish (larvae) is illustrated in Figure 23, with components covered by this protocol highlighted in blue. Note that the boxes marked in red for otolith examination and daily age and growth will not be monitored for Basin-Scale evaluation in the Edward-Wakool Selected Area.

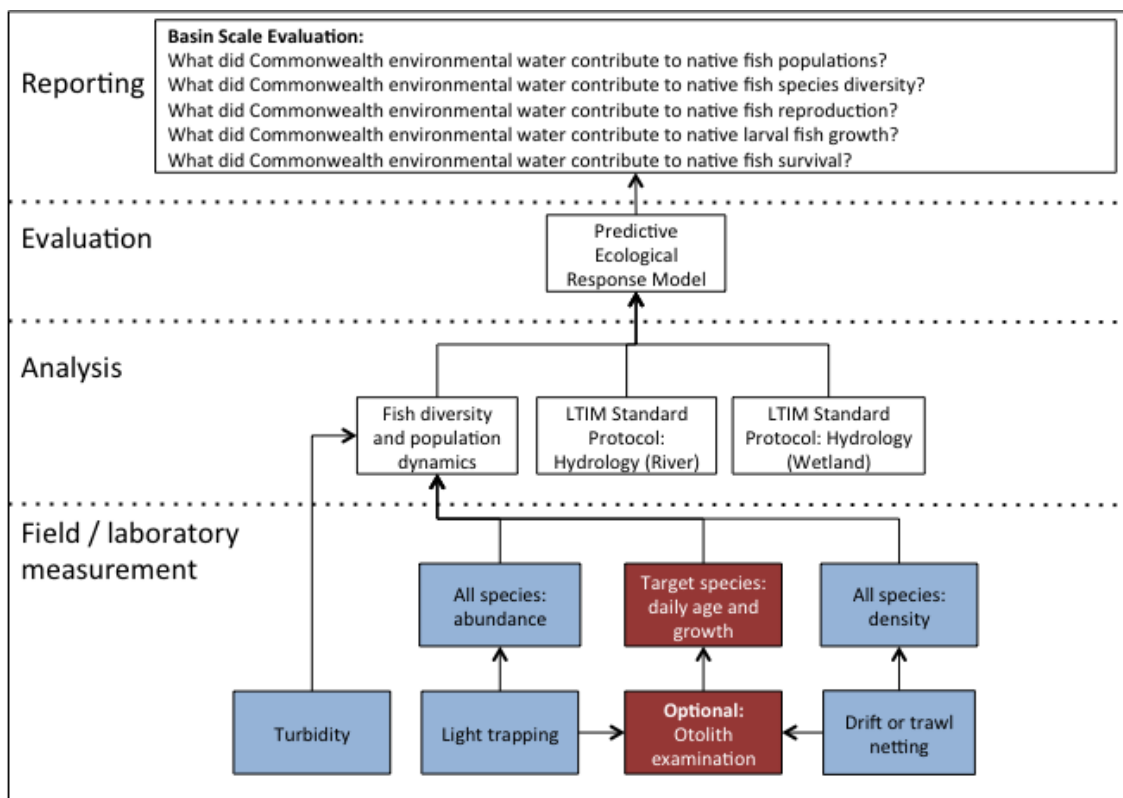


Figure 23: Schematic of key elements in LTIM Project Standard Protocol: Fish (larvae) – Cat I. Boxes marked in red for otolith examination and daily age and growth are optional (category II) and will not be monitored in the Edward-Wakool Selected Area.

Overview and context

These standard methods describe monitoring required for the Basin-scale evaluation of fish breeding in response to Commonwealth environmental water. The methods describe the sampling design and protocol for fish larvae in rivers for the LTIM Project.

This protocol describes sampling over five years, each year to measure:

- Catch-Per-Unit-Effort (CPUE) of each larval fish species in rivers and wetlands using:
 - Light traps
 - Fixed position drift nets
- And the *in situ* measurement of turbidity.

Site placement within zones

Larval fish monitoring for Basin-scale analysis will take place in Zone 3 (Mid Wakool River, upstream of Thule Creek). Three of the ten sampling sites specified for the monitoring of fishes in Zone 3 will be used (see Fish (River) standard methods (Cat I)). The rationale underlying this is to seek as much synergy as possible among the three different monitoring components for fishes.

Sample placement within sites

Two different larval sampling gears will be used at three sites in zone 3; light traps, and drift nets.

Ten light traps will be randomly allocated within each site. The same randomisation approach outlined in Fish (River) standard methods (Cat I) will be used, with the following caveat: light traps will be positioned within slackwater. A set of 10 random PS waypoints will be selected, and then the closest slackwater to that waypoint will be used to position light trap. If no slackwater is available within 20 m either side of the waypoint another random waypoint will be selected.

Light traps will be used for larval assemblage composition and potentially for relative abundance comparisons/contrasts among areas. Their efficacy is heavily dependent on turbidity, so any comparisons of relative abundance among areas will be dependent on the inter-area differences in turbidity levels.

Larval density will be measured using stationary drift nets for higher current areas. Three drift nets per site (total of nine per zone, per sampling event) will be positioned in water with a moderate velocity, preferably where the discharge is concentrated through a narrow section of the river (a funnel effect). Ideally, drift nets will not be closer than 100 m to each other.

Location for monitoring

Sampling for Fish Larvae (Cat I) will occur at three sites in Zone 3 (Mid Wakool River, upstream of Thule Creek).

Responsibilities

- Field sampling: field technicians from CSU and Fisheries NSW
- Larval identification and sample processing: Nicole McCasker and James Abell (CSU)
- Data analysis and reporting : Nicole McCasker (CSU)

Sampling protocol

Equipment

- Ethics and fisheries permits from relevant institutions;
- Light traps;
- Larval drift nets;
- Boat;
- Data sheets

Protocol

Timing of sampling

Larval sampling will occur over five sampling events that are timed to capture responses to watering events. For the Edward-Wakool Selected Area we anticipate that these watering events will take place between September and January each year. Sampling will take place at a weekly interval.

Sampling

At each site on each sampling event, turbidity will be measured *in situ* via an appropriately calibrated meter and recorded.

Modified quatrefoil light traps will be used to sample larval fish, the details of which can be found in Humphries et al. (2002). Mesh will be fitted around the light traps to eliminate larger fish from entering the trap, and eating the sample (3 mm knot-to-knot). The ten light traps set within each of the three sites will be set in the afternoon and retrieved the following morning. Set and retrieval times will be recorded, so that relative abundance can be expressed as catch-per-unit-effort (CPUE). Each light trap should be 'baited' with a yellow Cyalume® 12 h light stick (or equivalent manufacturer, but yellow in colour).

Drift nets will be constructed from 500 µm mesh, have an opening diameter of 50 cm, tapering over 1.5 m to an opening of 9 cm, to which a reducing bottle is fitted. Positioning of drift nets is explained earlier. Volume through the net will be estimated so that larval abundances in drift nets can be expressed as a density: number of individuals per m³. Volume sampled by the net is estimated as $\pi r^2 \cdot v \cdot t$, where r is radius in metres, v is mean velocity in m s⁻¹, and t is time set in seconds.

Processing

Entire samples will be preserved individually in 90% ethanol and returned to the laboratory for larval identification and enumeration.

Data analysis and reporting

Turbidity

Turbidity measures will be recorded as mean turbidity per site per sampling event and matched to Light trap abundance data.

Relative abundance estimation

Light-trap abundances will be expressed as 'catch-per-unit-effort' (CPUE), where the units are number of individuals per trap per hour of deployment. Drift net abundances will be expressed as densities; number of individuals per cubic metre of water filtered.

Community data

CPUE data at the level of the site (species by site abundance matrices) will be recorded. Abundance data will be reported for each species as the mean CPUE for the site. Data will be provided separately for light traps and drift nets.

Data management

All data provided for this indicator will conform to the data structure defined in the LTIM Project Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Project Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the site (river section or wetland).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Project Data Standard and will be enforced by the MDMS when data is submitted.

Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas. QA/QC activities specific to this protocol include that the specific fisheries, national park and ethics permits are carried with the monitoring team while sampling.

Health and safety

The Edward-Wakool Selected Area Health and Safety Plan (HSP) includes an assessment of all identified potential risks and a plan on how these risks will be managed.

References

Brooks S and Wealands S (2014) Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Data Standard. Report prepared for the Commonwealth Environmental Water Office by The Murray-Darling Freshwater Research Centre, MDFRC Publication 29.3/2013 Revised Jan 2014

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6.8.3 Fish (Larvae) standard methods (Cat III)

Overview

The delivery of environmental water is seen as a key way of enhancing the spawning and recruitment of native fish species (Murray-Darling Basin Commission 2004). The environmental and hydraulic conditions under which the spawning and recruitment of Murray-Darling fish takes varies across species (Humphries et al. 1999). These methods describe the monitoring approach for the Selected Area evaluation of fish breeding in response to Commonwealth environmental water, focussing on two broad groups of fish; small-bodied 'opportunistic' fish, and large-bodied 'periodic' flow-dependent species (Humphries et al. 1999).

For small-bodied 'opportunistic' fish, the prevalence of slackwater environments characterized by low flows, warm temperatures, high food resources and microhabitat such as aquatic vegetation are considered key environmental factors amenable for spawning and recruitment (Humphries et al. 2006)(see Figure 1). Monitoring the larval abundance and diversity of 'opportunistic' fish species will be undertaken across a gradient of rivers with differing hydrological variability, in order to assess the effect of CEWO delivered water on fish spawning. We hypothesize that environmental water delivery that seeks to increase the inundation of slackwater areas will increase the spawning and recruitment of native small bodied, opportunistic fish species.

For large-bodied 'periodic' flow-dependent species, high spring flows are considered to be key spawning cue (Figure 1). Monitoring of the eggs and larvae of silver and golden perch will be undertaken to detect the occurrence and magnitude of spawning in response to commonwealth environmental water. By monitoring the presence/absence and abundance of silver and golden perch eggs and larvae under a range of different hydraulic conditions, across rivers and across seasons, we aim to develop a predictive model that will look at what environmental factors trigger spawning in golden and silver perch in the Edward-Wakool Selected Area. These models will help to provide predictive capabilities for spawning success for these species under different environmental watering actions.

Basin plan objective and outcome

- Biodiversity (Fish species diversity)

The process for evaluating Fish (Larvae) Selected Area questions is illustrated in Figure 24, with components covered by the protocol highlighted in grey. Components highlighted in blue are also required for the predictive ecological response model.

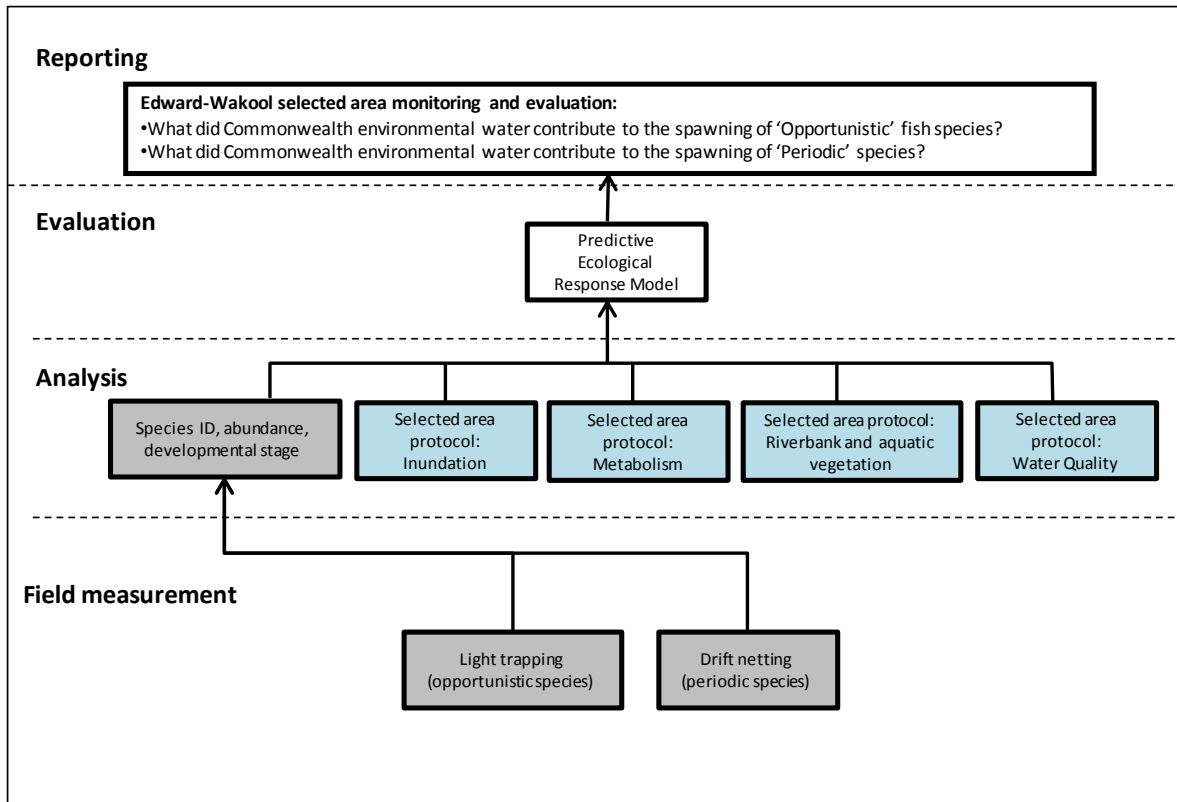


Figure 24. Schematic of key elements in Selected Area Monitoring and Evaluation - Fish larvae (Cat III). Components covered by this protocol are highlighted in grey. Components highlighted in blue are also required for the predictive ecological response model.

Indicators

- Abundance of small bodied ‘opportunistic’ larval fish
- Abundance of eggs and larvae of large bodied ‘periodic’ flow dependent fish

Critical covariates

- *For opportunistic fish species:* temperature, area of slackwater inundated, velocity, depth and discharge, and whether the zone received environmental water
- *For periodic fish species:* temperature, rate and magnitude of discharge change, extent of overbank flow and duration, whether the zone received environmental water.

Complementary monitoring and data

Data on the abundance of small bodied fish are available from previous short-term intervention monitoring in the Edward-Wakool system from 2011 to 2014.

Location for monitoring

Opportunistic fish species

Sampling for the fish larvae of opportunistic fish species will take place at 5 sites in 4 hydrological zones: zone 1 (Yallakool Creek), zone 2 (upper Wakool River), zone 3 (Mid Wakool River, upstream of Thule Creek), and zone 4 (Mid Wakool River, downstream of Thule Creek). Note: Only 2 sites in zone 3 will need to be sampled as per the Fish (Larvae) standard methods (Cat III). This is because a subset

of the data collected from the three sites used in Fish (Larvae) Basin-level-evaluation will be used to make up the full complement of data required from Zone 3.

Periodic fish species

Drift nets will be set at 1 site in each of the following hydrological zones: zone 1 (Yallakool Creek), zone 2 (upper Wakool River) and zone 4 (mid Wakool River, downstream of Thule Creek). In addition, data collected for Fish (Larvae) Basin Level evaluation (drift nets) from Zone 3 will be also used for Selected Area evaluation.

Timing and frequency

Opportunistic fish species

Light trap sampling for larvae of Opportunistic fish species will occur fortnightly, from September to February inclusive. Each zone will be sampled for 1 night on each sampling event. This type of sampling will also capture other species, including more 'Equilibrium' fish species (e.g Murray Cod, sensu Humphries et al. 1999), that spawn every year independently of flow conditions.

Periodic fish species

To compliment the sampling of Periodic larval fish species for the Basin-Scale evaluation, sampling for the Edward-Wakool Selected Area evaluation will also undertaken on two consecutive nights, weekly, over a five week period each year during specific environmental watering actions. It is anticipated that this sampling will occur between September and January of each year.

Responsibilities

- Field sampling: Field technicians from CSU and NSW fisheries
- Larval identification and sample processing: Nicole McCasker and James Abell (CSU)
- Data analysis and reporting: Nicole McCasker (CSU)

Field Methods

Opportunistic fish species

In alignment with the gear used in Fish (Larvae) standard methods (Cat I) for light trapping (Hale et al. 2014), modified quatrefoil light traps with 5 mm entrances and 3mm knot-to-know mesh will be used to sample fish larvae (as described in Humphries et al. 2002). Light traps will be deployed fortnightly at five sites in zones 1, 2, 3 and 4. Three light traps will be randomly allocated within each site, whereby 3 random GPS waypoints are used to locate the closest slackwater to each waypoint for the positioning of light traps. If no slackwater is available within 20 m either side of the waypoint, another random waypoint will be selected.

Light traps will be deployed late afternoon, and retrieved the following morning. Set and retrieval times will be recorded, so that relative abundance can be expressed as catch-per-unit-effort (CPUE). Each light trap will be baited with a yellow Cyalume 12 h light stick.

Because turbidity can influence light trap efficacy, turbidity levels will be measured at each site at the same time light traps are retrieved.

Upon retrieval, light traps will be rinsed down and entire samples will be preserved individually in 90% ethanol, and returned to the laboratory for processing.

Periodic fish species

In alignment with the gear used in Fish (Larvae) standard methods for Basin-Scale evaluation, drift nets constructed of 500 μm mesh, with an opening of 50 cm and tapering over 1.5 m to an opening of 9 cm will be used to collect eggs/larvae of golden and silver perch. Two, fixed station drift nets will be deployed over two nights, at 1 site within each zone (zone 1, 2 and 4).

Drift nets will be positioned in the water with a moderate velocity, at locations within each zone where the discharge is concentrated through a narrow section of the river (a funnel effect). Each drift net will be fitted with an Oceanic Flow Meter to estimate the volume of water that has passed through the drift net during its deployment. Volume through the net will be estimated so that larval abundances in drift nets can be expressed as a density: number of individuals per m^3 . Volume sampled by the net is estimated as $\pi r^2 \cdot v \cdot t$, where r is radius in metres, v is mean velocity in m s^{-1} , and t is time set in seconds.

Drift nets will be deployed late afternoon, and retrieved the following morning. Set and retrieval times will be recorded, so that relative abundance can be expressed as catch-per-unit- effort (CPUE).

Upon retrieval, drift nets will be rinsed down and entire samples will be preserved individually in 70% ethanol, and returned to the laboratory for processing.

Laboratory methods

All eggs/larvae collected in the light trap and drift net samples will be identified to species, and enumerated. The developmental stage of each individual will also be recorded according to classifications of Serafini and Humphries (2004). Here, ontogeny is classified into seven key developmental stages: egg, yolksac protolarvae, protolarvae, flexion, post-flexion, metalarvae and juvenile/adult.

Data analysis and reporting

Spawning in opportunistic fish species

Light trap abundance will be expressed as 'catch-per-unit-effort' (CPUE), where the units are number of individuals per trap per hour of deployment during the night (e.g. number of dark hours light traps are deployed). Abundance data will be analysed at the site level. To do this, data from the three light traps per site will be pooled.

For event-based analysis, data will be analysed with a BACI style approach comparing larval abundance in zones that received environmental water to zones that did not receive environmental water; before, during and after environmental water releases.

For short (<1 year analysis), data will be analysed using a traditional ANOVA approach, to answer the question: Was the magnitude of fish spawning over the spawning season greater in hydrological zones that received environmental water compared to those that did not. Here the total number of larvae collected in light traps across the entire season will be used as the dependent variable, and hydrological zone used as the treatment factor.

For longer term (1-5 year analysis) trends: a hierarchical model (continuous modelling) will be used to look at what environmental factors drive spawning magnitude in the Edward-Wakool area. Independent variables that will be assessed in this model include a mix of continuous variables including temperature, season, and hydrological variables such area of slackwater within sites, velocity, depth and discharge, and categorical variables such as (e.g. hydrological zone, and whether zone received environmental water). This model will be important for understanding the

mechanisms behind observed trends in spawning magnitude of small bodied fish, and thus help to provide predictive capabilities under different environmental watering actions.

Other uses: The magnitude of spawning in fish is an important variable influencing the amount of recruitment taking place in native fish populations. Therefore, the data gathered in this cat III component will be important data that is used in a larger fish recruitment model (see Cat III: Fish recruitment component).

Spawning in periodic fish species

Eggs and larvae collected from drift nets will be expressed as 'catch-per-unit-effort' (CPUE), where the units are density of eggs/larvae (number of individuals collected per drift net per volume of water passed through the net). Density data will be analysed at the site level, meaning that data from the two drift nets per site will be pooled.

For short (1 year) analysis, data will be analysed using a more traditional ANOVA approach, to answer the question: Was the spawning magnitude of golden and silver perch over the entire spawning season greater in hydrological zones receiving environmental water compared to those that did not. Here the total density of eggs/larvae collected in drift nets across the entire season is used as the dependent variable, and hydrological zone used as the treatment factor.

For longer term (1-5 year) analysis trends, a hierarchical model (continuous modelling) will be used to look at what environmental factors influence the successful spawning of golden and silver perch spawning in the Edward-Wakool area. Independent variables that will be assessed in this model include a mix of continuous variables including temperature, season, and hydrological variables such as rate of discharge change, magnitude of discharge change, extent of overbank flow and duration, as well as categorical variables such as hydrological zone, and whether the zone received environmental water. These models will be important for understanding the mechanisms behind both the success and magnitude of spawning in flow-dependent spawners like golden and silver perch, and help to provide predictive capabilities of spawning for these species under different environmental watering actions in the Edward-Wakool Selected Area.

Other uses: the magnitude of spawning in fish is an important variable influencing the amount of recruitment taking place in native fish populations. Therefore, the data gathered in this cat III component will be important data that is used in a larger fish recruitment model for golden and silver perch (see Cat III: YOY Fish recruitment methods).

Responsibilities

- Field sampling: field technicians from CSU and NSW fisheries
- Larval identification and sample processing: Nicole McCasker and James Abell (CSU)
- Data analysis: Nicole McCasker (CSU)
- Report writing: Nicole McCasker (CSU)

Health and safety

The Edward-Wakool Selected Area Health and Safety Plan (HSP) includes an assessment of all identified potential risks and a plan on how these risks will be managed.

References

Hale, J., Stoffels, R., Butcher, R., Shackleton, M., Brooks, S. and Gawne, B. (2014) Commonwealth Environmental Water Office Long Term Intervention Monitoring Project – Standard Methods. Final Report prepared for the Commonwealth Environmental Water Office by The Murray-Darling Freshwater Research Centre, MDFRC Publication 29.2/2014, January, 182 pp.

Humphries, P., King, A.J. and Koehn, J.D. (1999) Fish, flows and flood plains: Links between freshwater fishes and their environment in the Murray-Darling River system, Australia. *Environmental Biology of Fishes* 56, 129-151.

Humphries, P., Serafini, L.G. and King, A.J. (2002). River regulation and fish larvae: variation through space and time. *Freshwater Biology* 47, 1307-1331.

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6.9 Fish recruitment

6.9.1 Evaluation questions

This monitoring protocol addresses the Selected Area evaluation questions listed in Table 23.

Table 23. Questions for fish recruitment relevant to the Edward-Wakool Selected Area. Zone refers to the hydrological zones outlined in section 3. Boxes shaded grey will be monitored using Cat III methods.

Questions	Focal Area				Additional sites outside Focal Area		
	Zone 1	Zone 2	Zone 3	Zone 4	Source of Commonwealth environmental water (weir and canal)	Fish community assessment (15 sites)	Optional Carbon and water quality monitoring during adverse events (4 sites)
Selected Area evaluation questions							
<i>Short and Long-term (one to five-year) questions:</i>							
What did Commonwealth environmental water contribute to native fish recruitment to the first year of life?	✓	✓	✓	✓			
What did Commonwealth environmental water contribute to native fish growth rate during the first year of life?	✓	✓	✓	✓			

Selected Area Hypotheses

We will test two hypotheses:

H₁: Annual recruitment of YOY and 1+ Murray cod, golden perch and silver perch will be highest in years with increasing area and duration of inundation.

H₂: Growth rate of YOY and 1+ Murray cod, golden perch and silver perch will highest in years with increasing area and duration of inundation.

6.9.2 Standard methods (Cat III)

Overview

The early stage of the life of a fish is when the highest mortality occurs. Recruitment, or survival of eggs/larvae to young-of-year life-history stage, is a fundamental process required to sustain fish populations. Previous data from the Edward-Wakool system (Watts et al. 2012; 2013) demonstrate that recruit stages of large-bodied fish will not be sampled effectively under proposed Cat I boat electrofishing and larval fish sampling methodologies. The proposed monitoring aims to develop an annual index of recruitment for young-of-year (YOY) juveniles and age-class 1 (1+) fish, specifically targeting Murray cod, golden perch and silver perch. Daily and annual age-length curves developed from recruit stage fish will fill gaps contributing to Cat I otolith age requirements.

This component aims to develop a recruitment index for young-of-year (YOY) and age-class 1 (1+) fish across a range of species and will develop age-length growth models for target species including

Murray cod, golden perch and silver perch. The age-length data will contribute to Cat I age and growth requirements by providing aged samples of fish less than 2 years old and will provide an annual index of fish recruitment for large bodied species that will not otherwise be available as part of the proposed standard methodology.

A gap in the current proposed Cat 1 methodology is a targeted monitoring programme to understand changes in fish recruitment in response to Commonwealth Environmental Watering actions. The standard methodology for sampling larvae, an indicator of adult reproduction, does not target or effectively sample young-of-year fish of large-bodied species including Murray cod, golden perch and silver perch. Sampling methods using boat electrofishing are biased toward sampling large fish and these methods have failed to effectively sample young-of-year of large bodied species in the Edward-Wakool system (Watts et al. 2012; 2013). Recruitment monitoring during the past two years in the Edward-Wakool system, therefore, has been limited to answering question about how Commonwealth environmental water has affected carp gudgeon and Australian smelt (both small-bodied species) with virtually no information about the magnitude of recruitment of large-bodied species. This Cat III method addresses the limitations of the previous approach.

Basin plan objective and outcomes

- Biodiversity (Fish diversity)
- Resilience (Ecosystem resilience)

The process for evaluating YOY Fish Recruitment questions is illustrated in Figure 25, with components covered by the protocol highlighted in grey. Components highlighted in blue are required for the predictive ecological response model.

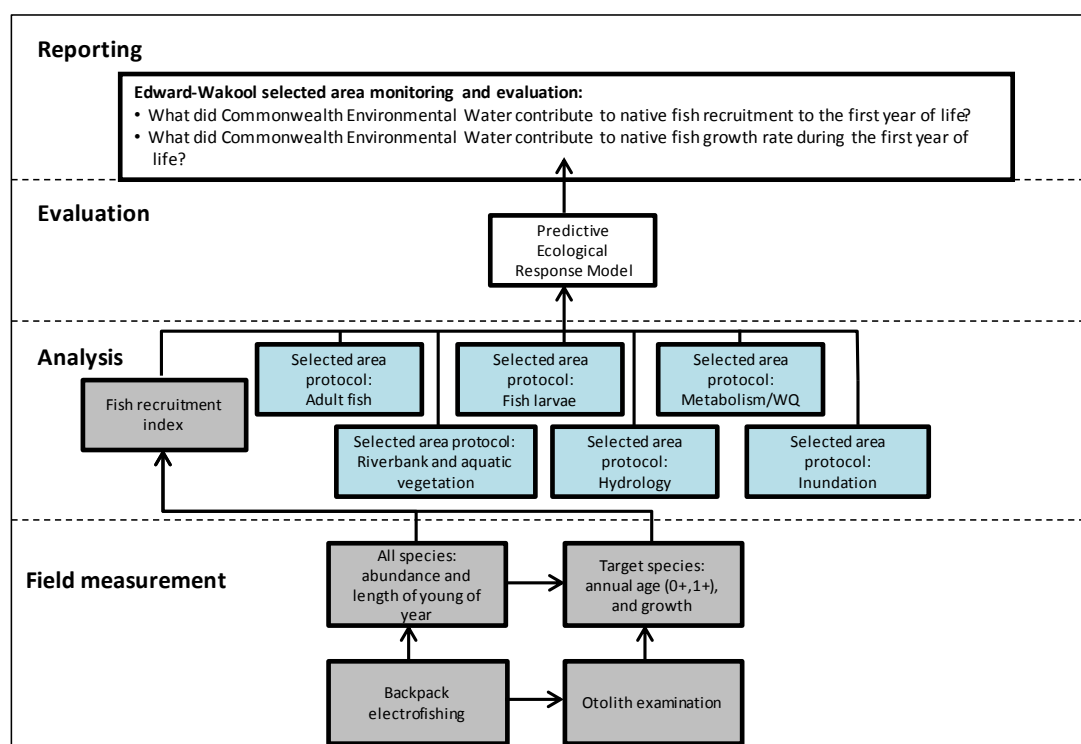


Figure 25. Schematic of key elements in Selected Area Monitoring and Evaluation – Fish recruitment. Components covered by this protocol are highlighted in grey. Components highlighted in blue are required for the predictive ecological response model.

Indicators

Two annual recruitment indices and one index of annual recruit growth will be developed for Murray cod, golden perch and silver perch in each zone

- Recruitment index 1: Annual relative abundance of YOY juveniles:
- Recruitment index 2: Annual relative abundance of 1+ fish
- Recruit growth: Annual variation in length of recruits (YOY and 1+)

Critical covariates

Species, area of inundation, year, zone, temperature, adult CPUE, ecosystem metabolism and annual flow parameters.

Locations for monitoring

Monitoring of YOY fish recruitment will be undertaken in zone 1 (Yallakool Creek), zone 2 (upper Wakool River), zone 3 (mid Wakool River upstream Thule Creek) and zone 4 (mid Wakool River downstream Thule Creek.) with five sites per zone.

Timing and frequency of sampling

Targeted sampling for recruits will occur between January and April at which point fish hatched in October-December that year (YOY) and the previous year (1+) will be targeted.

Responsibilities

- Otolith age estimates, analysis and reporting: Keller Kopf (CSU)
- Extracting and mounting otoliths: Lab technician (CSU)
- Lab processing of otoliths: Fish Aging Facility, Queenscliff
- Planning and organizing field trips, maintaining equipment, conducting fish sampling using backpack electrofishing fishing and light traps: Field Technicians (NSW DPI and CSU)

Field Methods

Five sites will be sampled in each zone between January and April. Sites will be sampled in random order among zones. Sampling will be targeted in shallow (< 1 m depth) water slow flowing habitat in and around coarse woody debris, overhanging vegetation and other physical structure that may provide cover for young fish.

Each sampling occasion and site will consist of backpack electrofishing, setting 10 light traps without exclusion mesh and potentially standardised angling to sample young individuals of large-bodied species.

Juveniles of all species will be identified enumerated and measured in the field. A sub-sample of 80 otoliths from estimated young-of-year, 1+ and 2+ fish of each species including Murray cod, golden perch and silver perch will be retained for annual aging.

Laboratory methods

Annual aged otoliths will be extracted and embedded in a polyester resin, sectioned to approximately 100 µm thick, mounted on a microscope slide and polished with lapidary film. Each sample will be aged once by an internal reader (R. Kopf) and twice by the Fish Ageing Facility. Digitized photographs of each otolith and each annulus reading will be recorded. The final age estimate will be determined by using the matching readings and samples with low reading precision will be discarded (Campana 2001).

Data analysis and reporting

Recruitment indices of YOY and 1+ juvenile Murray cod, golden perch and silver perch will be calculated from catch per unit effort of samples collected from backpack electrofishing, light traps without exclusion mesh.

Raw catch per unit effort for recruitment indices will be examined using a Generalized Linear Mixed Effects Model (GLMM) incorporating temporal, spatial and abiotic factors including flow related parameters and inundation area model estimates for each zone and year over the five year project duration. Factors influencing variation in recruit length after removing the effects of age will also be examined using a GLMM incorporating the same factors.

Estimates of recruit age will be derived from age-length models in individuals where otoliths were not extracted. The trajectory of change (positive, neutral, negative) in recruit growth will be estimated from GLMMs to evaluate effect of Commonwealth environmental water.

Reporting will include the three annual indicators (two annual recruitment indices and one index of annual recruit growth) for Murray cod, golden perch and silver perch within each zone.

- Recruitment index 1: Annual relative abundance of YOY juveniles
- Recruitment index 2: Annual relative abundance of 1+ fish
- Recruit growth: Annual variation in length of recruits (YOY and 1+)

Discussion will focus on whether annual recruitment and growth indices were affected by changes in flow conditions and to what extent Commonwealth environmental water contributed these changes.

Health and safety

The Edward-Wakool Selected Area Health and Safety Plan (HSP) includes an assessment of all identified potential risks and a plan on how these risks will be managed.

References

Campana, S.E. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. *J. Fish Biol.* 59(2): 197-242.

6.10 Fish (river)

6.10.1 Evaluation questions

This monitoring protocol addresses the Basin-scale and Selected Area evaluation questions listed in Table 24.

Table 24. Questions for fish (river) that are relevant to the Edward-Wakool Selected Area. Boxes shaded red will be monitored using Cat I methods and boxes shaded grey will be monitored using Cat III methods.

Questions	Focal Area				Additional sites outside Focal Area		
	Zone 1	Zone 2	Zone 3	Zone 4	Source of Commonwealth environmental water (weir and canal)	Fish community assessment (15 sites)	Optional Carbon and water quality monitoring during adverse events (4 sites)
Basin-scale evaluation questions							
<i>Short-term (1 year) questions</i>							
What did Commonwealth environmental water contribute to native fish community resilience?			✓				
What did Commonwealth environmental water contribute to native fish survival?			✓				
<i>Long-term (5 year) questions</i>							
What did Commonwealth environmental water contribute to native fish populations?			✓				
What did Commonwealth environmental water contribute to native fish diversity?			✓				
Selected Area evaluation questions							
<i>Long-term (5 year) questions</i>							
Does Commonwealth environmental water contribute to maintain or enhance existing levels of fish recruitment in the Edward-Wakool river system? (H4)	✓		✓			✓	
Does Commonwealth environmental water contribute to maintain or increase native fish diversity and abundance in the Edward-Wakool river system? (H1)	✓		✓			✓	
Does Commonwealth environmental water contribute to maintain or increase native fish biomass in the Edward-Wakool river system? (H2)	✓		✓			✓	
<i>Short and long-term (1-5 year) questions</i>							
Does Commonwealth environmental water contribute to maintain or enhance fish condition in the Edward-Wakool river system? (H3)	✓		✓			✓	
Does Commonwealth environmental water contribute to the recovery of fish communities following negative conditions within the Edward-Wakool river system?	✓		✓			✓	

Selected Area Hypotheses

H₁ Commonwealth environmental water contributes to the maintenance of native fish community structure (abundance and diversity) during drought through water replenishment and enhancement of water quality.

- H₂ Commonwealth environmental water contributes to maintenance of or increases in native fish biomass.
- H₃ Commonwealth environmental water contributes to the maintenance of or increases in native fish condition.
- H₄ Commonwealth environmental water contributes to maintain of or increases in fish recruitment in the Edward-Wakool river system?

The following sections 6.13.2 and 6.13.3 outline the SOP’s for fish (river) Cat I according to Hale et al. (2014) and also fish (river) Cat III, with inclusions of Location for monitoring, Responsibilities and Health and Safety Plan subsections. The fish (river) – Cat I SOP will be used for Basin-scale evaluations, however part of the data obtained will also be used to address Selected Area questions as part of the Fish (River) – Cat III SOP.

6.10.2 Fish (river) Standard methods (Cat I)

Overview and context

These standard methods describe monitoring required for the Basin-scale evaluation of the response of river fish to Commonwealth environmental water. The methods describe the sampling design and protocol for small- and large-bodied fishes in river channels for the LTIM Project.

The process for evaluating these questions is illustrated in Figure 26, with components covered by this protocol highlighted in blue.

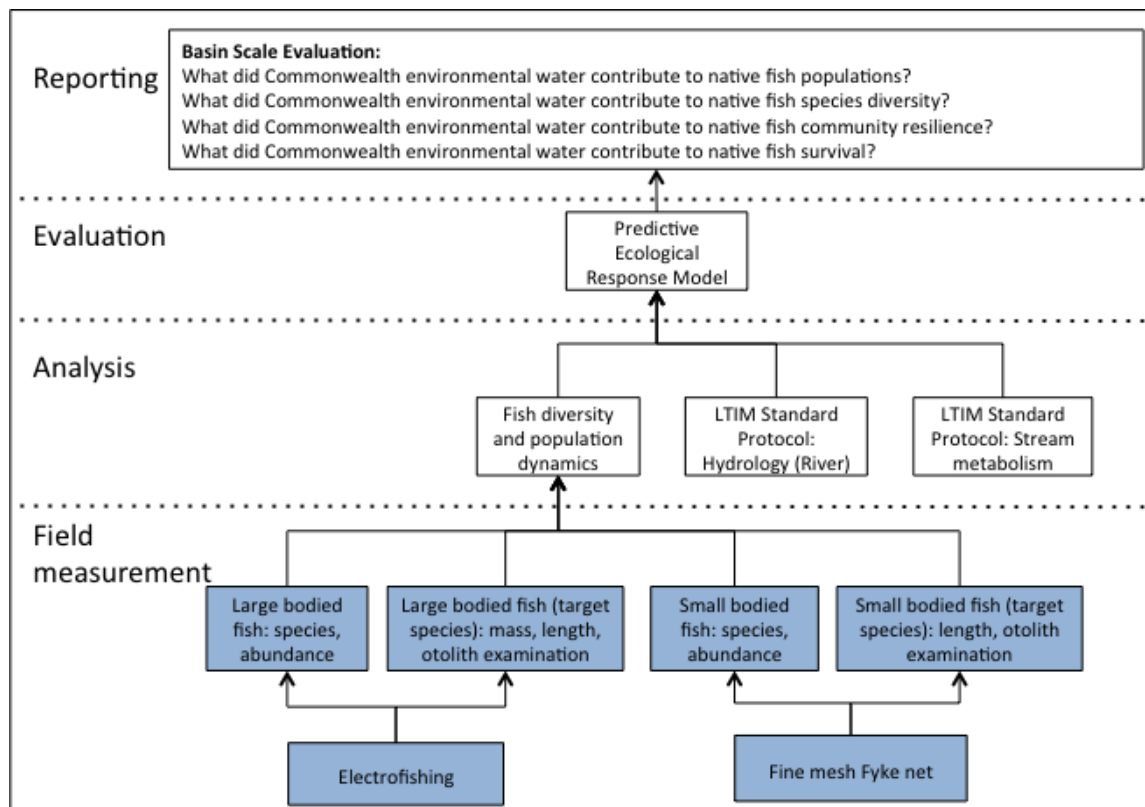


Figure 26: Schematic of key elements in LTIM Project Standard Protocol: Fish (River) – Cat I. Components covered by the Fish (river) Cat I SOP is highlighted in blue.

Overview and context

This protocol describes sampling once each year during autumn to measure:

- Catch-Per-Unit-Effort (CPUE) of each fish species for:
 - Electrofishing
 - Small-meshed fyke nets
- Population structure data for target species:
 - Length
 - Weight
 - Approximate age structure (from otolith examination)

Establishing sites

Equipment

- Boat
- GPS

Protocol

LTIM Project for Basin-scale evaluation has adopted a hierarchical approach to sample design (see Figure 27). The spatial hierarchy for fish (river) monitoring is as follows:

- Selected Area
 - Zone
 - Site

Zone placement within Selected Areas

A 'zone' is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands.

For Basin-scale evaluation, Zone 3 will be used. Following the recommendations of Hale et al. (2014):

- Different zones within Selected Areas represent spatially-, geomorphologically- and/or hydrologically-distinct units;
- Zones must be likely to receive Commonwealth environmental water at least once in the next five years;
- Zones must have an expected outcome related to the indicator in question (in this instance fish);

For Basin-scale analysis one zone (Zone 3) will be monitored within the Edward-Wakool Selected Area. The zone selected for Basin-scale data will have the following characteristics:

- The zone will be situated on a single river channel within a Selected Area, and the zone should contain channel habitat that is generally representative of the Selected Area as a whole;
- Within the channel of this zone there will ideally be a flow gauging station measuring height and discharge (otherwise a manual gauging station must be established (see LTIM Project Standard Protocol: Hydrology (River));
- The zone will contain relatively high abundances of the target species (Section 0), to maximise potential to obtain powerful age- or stage-structure data.

- This zone will be among the zones of an Selected Area most likely to receive Commonwealth environmental water, towards some significant change in river hydrology during that Commonwealth environmental water delivery event;
- The zone will contain channel habitat that can be readily accessed—either by boat or car—for sampling using the full suite of active and passive gears detailed below;

Site placement within zones

A 'site' is defined as follows:

- An 800 m reach of channel within a zone
- Site location for channel sampling will be fixed throughout the LTIM Project.
- Each site will be accessible and be representative of the zone.
- Ideally, each site will coincide with a pre-existing discharge and river height gauging station. In the event a site does not contain a gauging station, new gauging stations (and associated rating curves etc.) may have to be established.
- Each site will not be within 1 km of a significant tributary and/or distributary.

The below specifications for site number and distribution will be applied:

- Ten channel sites will be located within the zone targeted for Basin-scale monitoring/analysis.
- All ten sites for Basin-scale data will be located on a single channel.
- These sites will be distributed randomly throughout the zone selected for Basin-scale data collection, such that the samples collected are representative of that zone. However, they will not be spread over a distance farther than 100 km.

Sample placement within sites

A sampling grid will be established within each site to ensure individual samples can be randomly sampled from that site, and are therefore representative of that site as a whole. Sampling will be random with respect to the environment to avoid temporal and spatial biases.

Hale et al. (2014) propose that a totally random sampling design is most appropriate for detecting flow-induced temporal trends within zones and Selected Areas, and spatiotemporal trends among zones and Selected Areas. Each 800 m site is subdivided by fixed transects spaced 50 m apart. Points of intersection between transects and the river bank define the sampling grid (Figure 27).

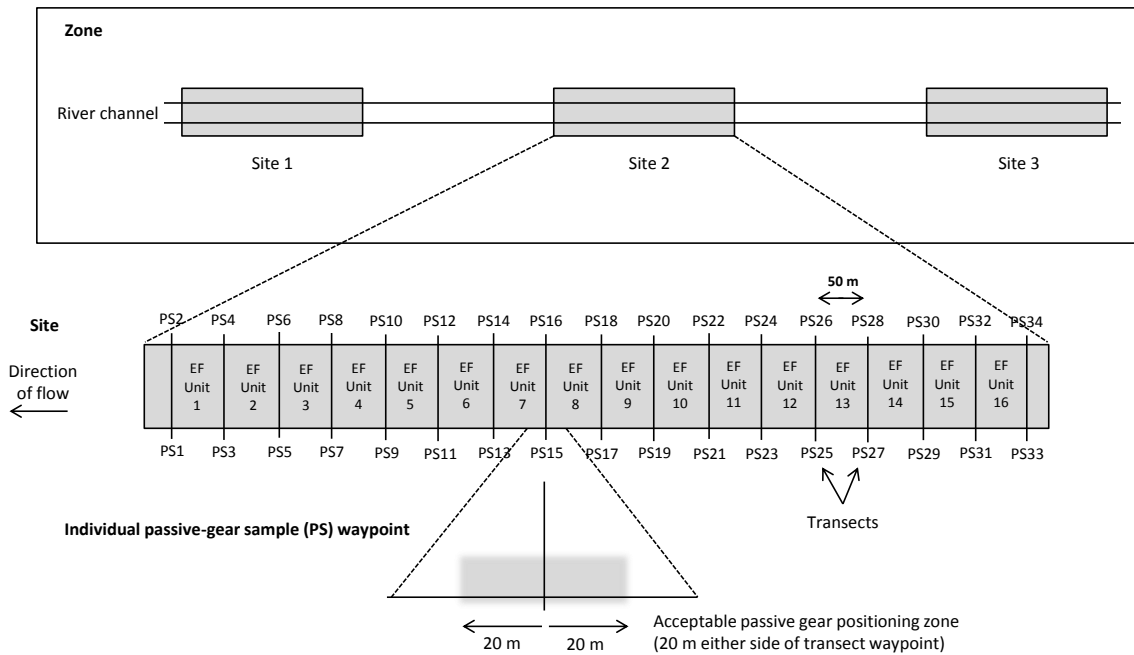


Figure 27: Diagram of hierarchical sample design illustrating zones, sites and sample locations.

The sample design defines two key sampling locations: electrofishing (EF) units (16 in total), and passive-gear sample (PS) waypoints (34 in total). Use of these EF units and PS waypoints will be explained below.

To establish the PS grid, each PS waypoint will be saved in a GPS, so that the GPS can be used to locate each PS waypoint over the monitoring period. That is, it is not necessary to establish visible transects and physically label each PS waypoint (e.g. a stake, floats or flagging tape).

Location for monitoring

Monitoring for Fish (River – Cat. I) will take place in Zone 3 (Mid Wakool River, upstream of Thule Creek).

Responsibilities

Fisheries NSW project staff based at Narrandera Fisheries Centre (Thiem, Smith, Rehwinkel) will coordinate and schedule the sampling, data management, analysis and reporting for this component; with assistance from other team members as required.

Representative species from life-history guilds

Overview

Fishes belonging to different life history guilds may respond in different ways to managed and natural flows. Towards a more complete knowledge of fish population response to flows, monitoring will target representatives of the three primary life history guilds: equilibrium, periodic and opportunistic. Additional data will be collected from these target species.

Protocol

The following protocol from Hale et al. (2014) will be followed:

- Within the Selected Area we will identify six target species, two from each guild. Within each guild, one of the two species will be fixed, and common to all Selected Areas (as much as practicable), while the identity of the other species will be flexible across Selected Areas.
- The equilibrium life history species targeted for detailed data collection will be Murray cod. The second equilibrium species to be used in the Edward-Wakool Selected Area is unknown and will depend on captures, although could be trout cod, freshwater catfish or river blackfish.
- Across all Selected Areas the periodic life-history species targeted will be golden perch. The second, Selected Area-specific periodic species will be bony herring.
- Across all Selected Areas the opportunistic life-history species targeted will be carp gudgeon, *Hypseleotris* spp. The second opportunistic species within Selected Areas will be Australian smelt

Sampling protocol

Equipment

- Backpack or boat electrofisher, including nets, storage and processing equipment;
- Ethics and fisheries permits from relevant institutions;
- GPS;
- GPS coordinates of site structure (PS waypoints and EF units)
- PS waypoints determined using random number generator (sample locations within sites);
- 12 fine-mesh fyke nets (10 for use; 2 spare) per site;
- Anchoring devices for fyke nets (stakes, chains, etc.);
- Large (1000 mm) and small (300 mm) measuring boards;
- Scales, either quality hanging scales with bag or bench scales with bucket/tray for fish;
- Data sheets

Timing of sampling

The channel sites of each Selected Area will be sampled once each Autumn (March-May inclusive).

Large-bodied species

Sampling

Large-bodied species will be sampled using either boat or backpack electrofishing, depending on the river height.

Sustainable Rivers Audit (SRA) electrofishing protocol will be a subset of what is described here, so that data collected as part of the CEWO LTIM Project can be compared and contrasted with SRA large-bodied fish data. We will not collect small-bodied species for processing using electrofishing, but collect all stages (including juveniles) of large-bodied species for processing.

Herein, 'small-bodied' species are those belonging to the following families:

- Galaxiidae;
- Retropinnidae;
- Atherinidae;
- Melanotaeniidae;
- Ambassidae;
- Nannopercaidae;
- Eleotridae;
- Gobiidae;
- Poeciliidae;

All other fish families of the Basin are considered 'large-bodied'.

The following methods are suggested by Hale et al. (2014) and will be followed, with some adjustments to standard protocol (as described in a section below).

- The entire 800 m site will be electrofished. Within each electrofishing unit of a site (EF unit; Figure 28) two 'shots' of 90 s 'on-time' should be carried out. This results in a total of 2880 s (48 min on-time) for each site. No more than 180 s of shocking will be allocated to each EF unit, such that electrofishing effort is spread out across the entire site, thus giving a more random sample with respect to the (site's) environment. Note that, *within* EF units the location of shots is left to the discretion of the service provider.
- If boat electrofishing alone results in a sample biased towards larger and/or older individuals, then effort may be split in half, across both boat and backpack methods. For example, 50% of the EF units might be shallow enough to be intensively fished (still 180 s) with backpack electrofishing, thus enabling fishers to target the shallower (< 40 cm deep), more structurally complex habitats where 0+ and 1+ individuals might reside. Alternatively a certain proportion of the 16 (EF units) x 2 (90 s shots per EF unit) = 32 shots may be allocated to backpack electrofishing the shallow margins.
- It is difficult to standardise electrofishing across areas towards meeting the objective of a robust sample that is representative of the population present. Once a certain 'balance' or partitioning of boat and backpack electrofishing is devised—within the constraints of the general 'shot structure' laid out above—the design will be maintained over the entire five years.

Processing - electrofishing

For every individual belonging to a target large-bodied species, the following will be obtained or implemented:

1. Identified to species;
2. Total (TL; round or square caudal fin species) OR fork (FL; fork-tailed species) lengths, in millimetres (mm);
3. Mass in grams (g) (use scales that have been recently calibrated);

If > 20 individuals are obtained within a 90 s shot, the above information will be recorded on a random sub-sample of 20 individuals only. The random sub-sample will be the first 20 individuals sampled during a 90 s shot. That is, if 20 individuals from a target species are obtained in less than 90 s, sampling will cease until the above statistics are obtained, or we will separate the first 20 individuals from those caught subsequently during that 90 s shot.

Non-target species will be identified and enumerated; lengths and masses of these non-target species will not be measured. All individuals (including alien species) will be returned to the water.

Fine-mesh fyke net setting

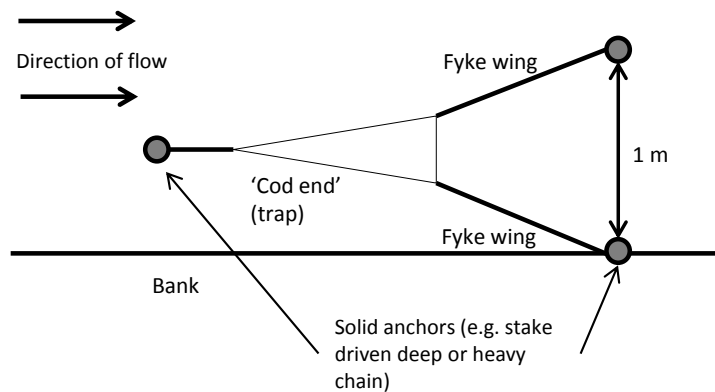


Figure 28. Diagram indicating the positioning of fine-mesh fyke nets in river channels, relative to the bank and direction of water flow. Cod-end should face upstream so as to not collect debris and act as a water velocity 'parachute'.

Small-bodied species

Sampling

Small-bodied species will be sampled using a passive technique only; fine-mesh fyke nets. The fine-mesh fyke nets (2 mm mesh) should be double wing (each wing: 2.5 m × 1.2 m), with a first supporting hoop covered by a plastic grid (5 cm × 5 cm) to keep large aquatic vertebrates out of the trap.

A random number generator will be used to randomly select a subset of 10 PS waypoints from the total of 34. A waypoint encompasses a total of 40 m of bank (20 m either side of specific waypoint), so we will endeavour to find the point on the bank as close to the exact waypoint as possible. The purpose of this system is to ensure sampling is random with respect to the environment. If it is impossible (in the strict sense, not just inconvenient) to set a fyke net at a certain waypoint (current is too fast; bank is far too steep; water too deep; too many emergent macrophytes to be an effective fish sample), then an adjacent, unoccupied waypoint will be used.

Fine-mesh fyke nets will be set in the afternoon and retrieved the following morning. Set and retrieval times will be recorded for each individual net/trap, so that abundances can be expressed as rates.

Past monitoring programs have not used fine-mesh fyke nets in the channel. In many cases, however, fine-mesh fyke nets can be set in certain locations within river channels. Fine-mesh fyke nets sample a much broader subset of the overall fish community than minnow traps, and are effective for estimating relative abundances of active, pelagic species such as smelt and hardyhead. Furthermore, use of fyke nets in the river channel and in wetlands may allow comparisons of community and population structure among these two major habitat types.

Fine-mesh fyke nets will be set with the cod end facing the current, so that water velocity is deflected around the net and wings. For the net to be effective both wings and the cod end need to be anchored to the bottom very well using steel stakes. So that sampling effort is held constant across nets, the wings will have an aperture of 1 m.

Processing

The following measurements will be made for non-target, small-bodied species:

1. Identify (to species) and enumerate all individuals. Random sub-samples will be used if nets capture too many fish for complete processing, as long as proportion of total sample sub-sample represents is recorded;

Further measurements are required for those small-bodied species targeted as part of the opportunistic guild:

2. Obtain total (TL; round or square caudal fin species) OR fork (FL; fork-tailed species) lengths, in millimetres (mm), of up to the first 10 individuals from both target species, from each net. We will ensure the first ten are randomly selected from the overall sample. This may be achieved, for example, by using an aquarium net to 'blindly' sub-sample from a bucket until 10 individuals have been measured.

Example approach to a typical site

Electrofishing will interfere with passive sampling as little as possible. Fyke nets will not be set while electrofishing is taking place (and vice versa). Accordingly, we will adopt a 'per site' itinerary similar to the following:

1. Day 1 morning – travel to site;
2. Day 1 afternoon – set fine-mesh fyke nets;
3. Day 2 – retrieve and process fyke nets;
4. Day 3 – electrofish.

Adjustments to standard protocol

Annual sampling for Basin-scale analysis within zone 3 will follow the standard methods for riverine fish as specified by Hale et al. (2014). However, in order to improve comparability with historical data (SRA, NSW DPI) and increase sampling effectiveness for target species the following additional protocols and augmentations at each site have been proposed;

1. The amount of sampling effort per 90 second electrofishing 'shot' is to be partitioned between littoral/structural and open water habitats at a ratio of 5:1 in order to maintain comparability with CPUE data generated using the standard SRA protocol. This means that within any single electrofishing operation, 75 seconds should be used to sample littoral/structural habitats and 15 seconds of sampling should be undertaken in open-water habitats < 4 m deep.
2. Length data from all species is recorded for all operations of every gear type (with sub-sampling of 20 individuals per shot/net/trap) to allow generation of SRA metrics. This includes alien and both large and small bodied species.
3. The individual weight of the first 50 individuals measured for length of each non-target species will also be recorded.
4. Ten unbaited bait traps will be set for the duration of the electrofishing operations (minimum of 1.5 hours) to maintain consistency with SRA protocol.

Otolith collection and analysis

Otoliths will be collected from target species populations for the following purposes:

1. Estimation of von Bertalanffy (vB) growth parameters, such that we have a vB model for each target species, for each area. These models will be used to coarsely approximate the age distribution (in years) of target species, based on their lengths, within each of the monitoring years. Age distributions will subsequently be used to coarsely approximate survivorships, hence year-class strength, in the absence of capture-mark-recapture data. Furthermore, otoliths may be used to back-calculate temporal variance in growth rates, in response to changes in flow.
2. For periodic and equilibrium targets, determine the relationship between age and length of (approximate, or what one assumes to be) 0+ and 1+ individuals within each year, to reduce uncertainty of age prescription during early life history.
3. For opportunistic species, determine the age composition (in years) of the populations within each area.

The otolith collection and reading protocol is dependent on which life-history guild the species belongs to:

Opportunistic species

During each annual census, a minimum of 6 individuals of each of the two species (*Hypseleotris* sp. + one other) will be retained from each of the 10 sites, giving a minimum of 60 pairs of otoliths for each opportunistic species, each year, per area. The 6 individuals collected within each site will, as much as practicable, span the entire length range observed at that site, for that species.

Otolith removal, storage, mounting and reading methods are now very broadly tested and used (e.g. Campana 2001; Secor et al. 1992, and references therein). We will utilise published protocols for these procedures.

Periodic and Equilibrium species

Two comprehensive otolith samples from these target species will be taken over the course of the 5-year program; one at the beginning of the program (Year 1) and one at the end of the program (the winter of Year 5, following autumn censuses). The Advisors will use these data to obtain two vB growth curves for each of the four target species of an area: one at the beginning of the program and one at the end of the program. The vB curves from Year 1 will give the modelling team some idea of how variable length-age relationships are between areas, and this will, in turn, improve their ability to progress population models as annual census data arrives. The vB curves from Year 5 will improve our area-specific vB curves, while also enabling service providers to explore the possibility of back-calculating growth rates in response to flow events over the 5-year period.

We will obtain otoliths from at least 50 individuals of each target species. Samples for estimating the parameters for vB curves will not be random with respect to the structure of the population. We will collect samples containing representatives across the full range of lengths within the population (ideally), and approximately equal numbers of individuals within each length-class.

We may use the following strategy as suggested by Hale et al. (2014) to achieve this: Suppose we are to obtain a sample size of $n = 50$ individual fish. If l_{min} and l_{max} are the approximate minimum and maximum lengths (mm) of individuals obtainable within a zone, respectively, then $w = (l_{max} - l_{min})/50$ defines an increment (mm) that can be used to define intervals within which one sample should be sought. For example, the first approximate length we then should try to obtain falls in the first bin, $b_1 = [l_{min}, l_{min} + w)$. The second sample should then be sought within the interval $b_2 = b_1 + w = [l_{min} + w, l_{min} + 2w)$; the third sample from within $b_3 = b_2 + w = [l_{min} + 2w, l_{min} + 3w)$; the i th sample (i goes from 1 to 50) from within $b_i = [l_{min} + (i-1)w, l_{min} + iw)$, such that for the last bin, $b_{50} = [l_{min} + 49w, l_{min} + 50w) = [l_{min} + 49w, l_{max})$.

Otolith samples will be obtained from within the zone 3 targeted for Basin-scale data collection, but not at the same 10 sites selected for annual censuses. If that zone does not yield an appropriate sample, sample may be obtained from within the broader monitoring area, noting location of capture.

A suite of alternative sampling techniques will be required to collect opportunistic and equilibrium species and as such we have budgeted for additional sampling in years one and five. To ensure a broad range of size classes are sampled we will use both active (electrofishing) and passive sampling (nets, traps, angling). Both techniques will be used during night and day sampling to maximise collection probability of all size classes. All required information will be entered into the LTIM Project central database as required under standard methods.

Data analysis and reporting

Relative abundance estimation

Abundances will be recorded as ‘catch-per-unit-effort’ (CPUE). Data will be structured in spreadsheets by individual ‘samples’, which are individual net hauls, or abundances within discrete electrofishing shots. Units will depend on sampling method—electrofishing versus trapping. Electrofishing CPUE will have units number of individuals per unit on-time for each shot. Passive trap CPUE units will be number of individuals per net per hour.

Population structure data for target species

Additional data will be collected for target species:

- Total length or fork length (mm), depending on species.
- Mass (gm).
- Length-age data:
 - Year 1 and Year 5 data sets for the four species belonging to the Periodic and Equilibrium guilds;
 - Annual data sets for the opportunistic species;
 - Raw data, not just von Bertalanffy parameter estimates, since we need to devise a stochastic model of age at length to accommodate strong inter-individual variation in growth, common in fish populations, particularly those with protracted reproduction seasons in Mediterranean climates.
 - Yearly ages of fish (0+, 1+,...x+), should be tagged by their species identity, place and date of capture, total or fork length (mm), and mass (g).

Community data

The Advisors will also be conducting Basin-scale analyses of community response to Commonwealth environmental water. For these analyses they require CPUE data at the level of the site (species by site matrices) corresponding to each sampling method.

Data management

All data provided for this indicator will conform to the data structure defined in the LTIM Project Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Project Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an ‘assessment unit’. The assessment unit for this indicator is: the site (river section).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Project Data Standard and will be enforced by the MDMS when data is submitted.

Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas. QA/QC activities specific to this protocol include:

- Electrofishers will be experienced operators of units. They will be supervised by Senior Operators on-site, and have obtained their electrofishing certificates through a reputable course.
- Monitoring and Evaluation Providers will have relevant boat licenses.
- Monitoring and Evaluation Providers will have specific fisheries and ethics permits with them while sampling.
- Fyke nets will be checked for holes in either wing- or cod-ends prior to every field trip. Any net with a hole will be repaired or replaced.

Health and safety

The Edward-Wakool Selected Area Health and Safety Plan (HSP) includes an assessment of all identified potential risks and a plan on how these risks will be managed.

References

Brooks S and Wealands S (2014) Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Data Standard. Report prepared for the Commonwealth Environmental Water Office by The Murray-Darling Freshwater Research Centre, MDFRC Publication 29.3/2013 Revised Jan 2014

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6.10.3 Fish (river) Standard methods (Cat III)

Overview

Detecting valley-scale native fish benefits from environmental water delivery

River regulation reduces habitat complexity, alters the timing and magnitude of flows necessary for critical life stages for fish, reduces in- and off-channel connectivity and promotes invasion of generalist alien species (Bunn and Arthington 2002). The use of Commonwealth environmental water to restore more natural flow characteristics can benefit native fish by increasing reproduction opportunities, stimulating in-stream migration to trigger a reproduction response or improving food availability which can translate to improved condition and larval survival (Humphries et al. 1999, Humphries et al. 2002, King et al. 2003). Further, many native fish species have been known to opportunistically use wetlands and floodplains for nursery habitat and to benefit from increased food availability (Lyon et al. 2010), and the delivery of Commonwealth environmental water can promote connectivity with these off-channel habitats.

It is important that any monitoring program is sufficient to detect valley-scale benefits for native fish from Commonwealth environmental water delivery. The Edward-Wakool Selected Area presents an opportunity to understand flow-related outcomes because delivery options are flexible and controlled. We have designed a monitoring program that will enable 1) in-channel fish community comparisons among two hydrological zones, and 2) in-channel long-term broad scale trends in fish community composition. In each of two zones we will relate changes in fish condition and recruitment to Commonwealth environmental watering. In addition, a broad scale fish community monitoring program will be undertaken in years 1 and 5 that will report on changes in native and alien species abundance and biomass using Sustainable Rivers Audit health indices. The design will be strengthened by having access to long term data collected (at some sites up to 20 years of data) and will extend the existing five-year datasets at each of these sites.

Background

Dryland rivers in Australia are characterised by unique ecological communities that have adapted to extreme hydrological regimes, such as extensive flooding interrupted by long periods of low flow and drought (Humphries et al. 1999, Thoms and Sheldon 2000). Following European settlement, the majority of fish communities within these systems have undergone severe declines, and the alteration of natural flow regimes has contributed significantly. Flow regulation reduces habitat complexity, alters the timing and magnitude of flows necessary for critical life stages for fish, reduces in- and off-channel connectivity and promotes invasion of generalist alien species (Bunn and Arthington 2002). The use of Commonwealth environmental water to restore more natural flow characteristics can benefit native fish by increasing reproduction opportunities, by stimulating in-stream migration to trigger a reproduction response (Humphries et al. 1999, Humphries et al. 2002, King et al. 2003) or improving food availability which can translate to improved condition and larval survival. Further, many native fish species have been known to opportunistically use wetlands and floodplains for nursery habitat and to benefit from increased food availability (Lyon et al. 2010), and the delivery of Commonwealth environmental water can promote connectivity with these off-channel habitats.

Environmental water delivery has previously provided detectable short-term changes in fish communities in the Edward-Wakool system. For example, Gilligan et al. (2009) examined changes to the fish community before, during and after a 30 GL environmental flow. The objective of the flow

was to sustain existing populations by improving water quality in deteriorating conditions during an extreme drought. Reproduction was triggered in Murray-Darling rainbowfish (*Melanotaenia fluviatilis*) and un-specked hardyhead (*Craterocephalus stercusmuscarum fulvus*), although there was no change detected in the abundances of Murray cod or silver perch (*Bidyanus bidyanus*) (Gilligan et al. 2009). Following the environmental water release, the abundance of golden perch and carp gudgeon (*Hypseleotris* spp) was found to decline (Gilligan et al. 2009). These outcomes were all based on a short-term before and after comparison. Whether these benefits contributed to overall long term changes was not determined.

It is likely that short term changes in fish community redistribution during environmental water delivery are driven by movement, localised changes in hydraulic and structural habitat availability and food resources. However, changes in fish community composition at the reach and valley scale are also likely to occur in response to environmental water delivery as indicated in the landscape fish diversity CED (MDFRC 2013). These landscape-scale changes are manifested by increasing biomass across the system, overall improvements to fish condition, the presence of recruitment, positive changes in native fish abundance and increased species richness. For example, landscape fish diversity over longer time scales (>10 years) is influenced by available habitat, connectivity and disturbance, which are mainly influenced by the interactions between flow and geomorphology. Providing greater access to habitat through connectivity is achievable using environmental water and will lead to a detectable change, at the valley scale, over the medium-long term. These are expected and measurable changes. The ability to detect change is often influenced by the overall objective of water delivery. Changes in landscape-scale fish condition are generally only applicable if environmental water delivery occurs to drive these impacts, and that only occurs when water holdings are high.

During periods when holdings are low, Commonwealth environmental water can be used to prevent deterioration of fish condition, to encourage dispersal to refuge sites and to sustain populations already present within refuge areas. For instance, a previous Commonwealth environmental water allocation in the Edward-Wakool river system successfully prevented a hypoxic blackwater event and protected many fish when water was released from irrigation escapes into the upper Wakool River and Yallakool Creek. Many fish survived in the area where water delivery took place, whilst many thousands of fish perished elsewhere.

The delivery of Commonwealth environmental water can also influence native fish reproduction directly by providing cues that stimulate reproductive behaviour or provide access to suitable available habitat. Likewise, the delivery of Commonwealth environmental water to drive fish recruitment outcomes can therefore be influenced indirectly by:

1. The provision of food,
2. Increasing available habitat,
3. Promoting suitable water quality,
4. Facilitating connectivity and dispersal

We have designed a monitoring protocol capable of detecting the changes likely to occur to the fish community structure in the Selected Area as a result of Commonwealth environmental water delivery. The design enables the evaluation of fish community changes over:

- Medium term (1-5 years; recruitment and young of year abundance, fish condition, redistribution); and
- Long-term (5+ years; species richness, abundance and biomass).

The design will also enable comparison of the community structure with long term trends by including existing long term sites. Within the focal zone (Zone 3), sites will overlap with larval fish

sampling, water quality, and primary productivity sampling. The primary purpose of this overlap is to determine how fish improvements are linked to other critical ecosystem components. For instance,

1. Did adult fish move in response to the Commonwealth environmental water delivery?
2. Were the movements consistent with reproductive behaviour?
3. At the same time did the abundance of microinvertebrates increase?
4. Did the presence of fish larvae occur at the same time?
5. Were young of the year fish caught later that season?
6. Did the age of young of the year fish correspond to the Commonwealth environmental water delivery?

Structuring a monitoring program with this conceptual basis in mind will help determine the critical linkages among ecosystem components. For instance, if only larval sampling were conducted, there would be little mechanism to determine if there was sufficient food for survival, or if these fish grew to young of year. Similarly, if larvae were not collected, was it because adults were not present in the study reach or because they simply did not spawn? Determining the answer to these questions using a multiple lines of evidence approach is critical to ensure the contribution of environmental water to native fish outcomes can be discussed with increased certainty.

Basin plan objective and outcome

- Biodiversity (Fish species diversity)
- Resilience (Individual survival and condition)

The process for evaluating these questions is illustrated in Figure 29, with components covered by the protocol highlighted in grey. A modified CED is presented in Figure 30 and 31.

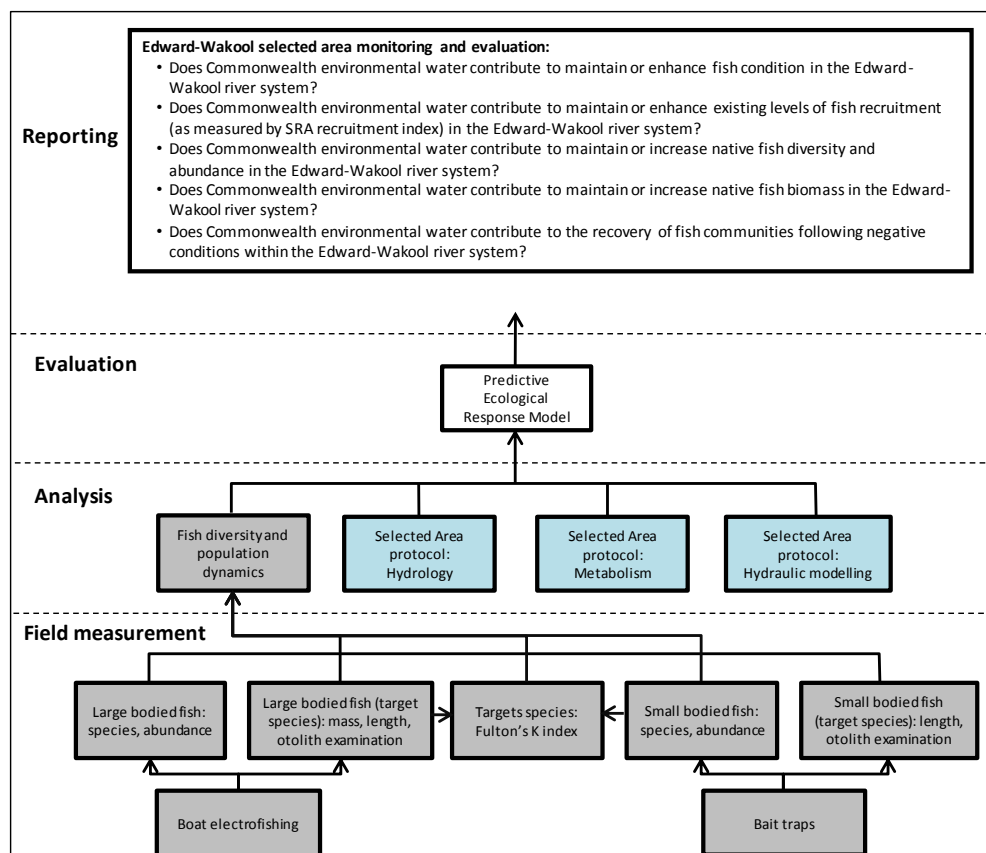


Figure 29. Schematic of key elements in Selected Area Monitoring and Evaluation – Fish (river) – Cat III. Components covered by this protocol are highlighted in grey. Components highlighted in blue are also required for the predictive ecological response model.

CED landscape fish diversity

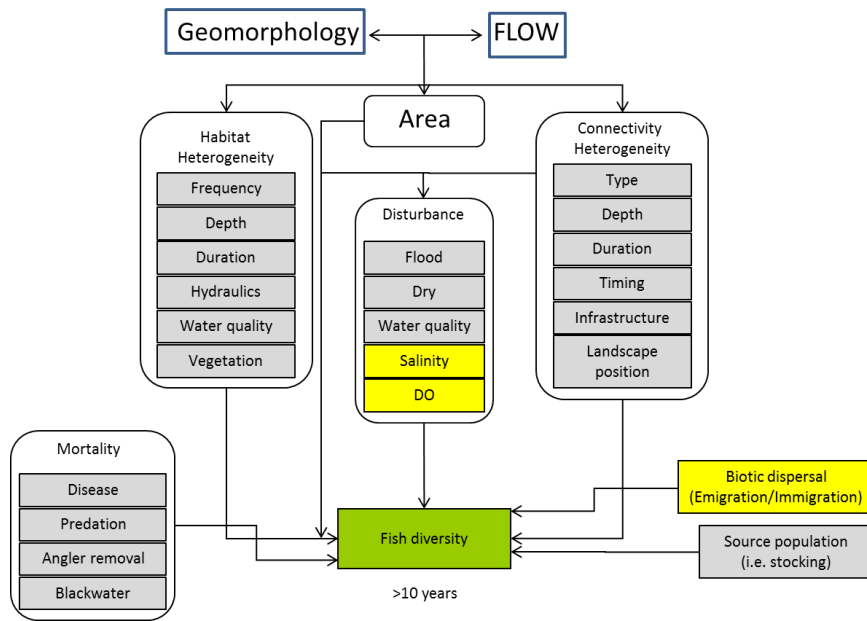


Figure 30. Modified landscape fish diversity cause and effect diagram. Yellow boxes indicate other CED's.

CED fish condition

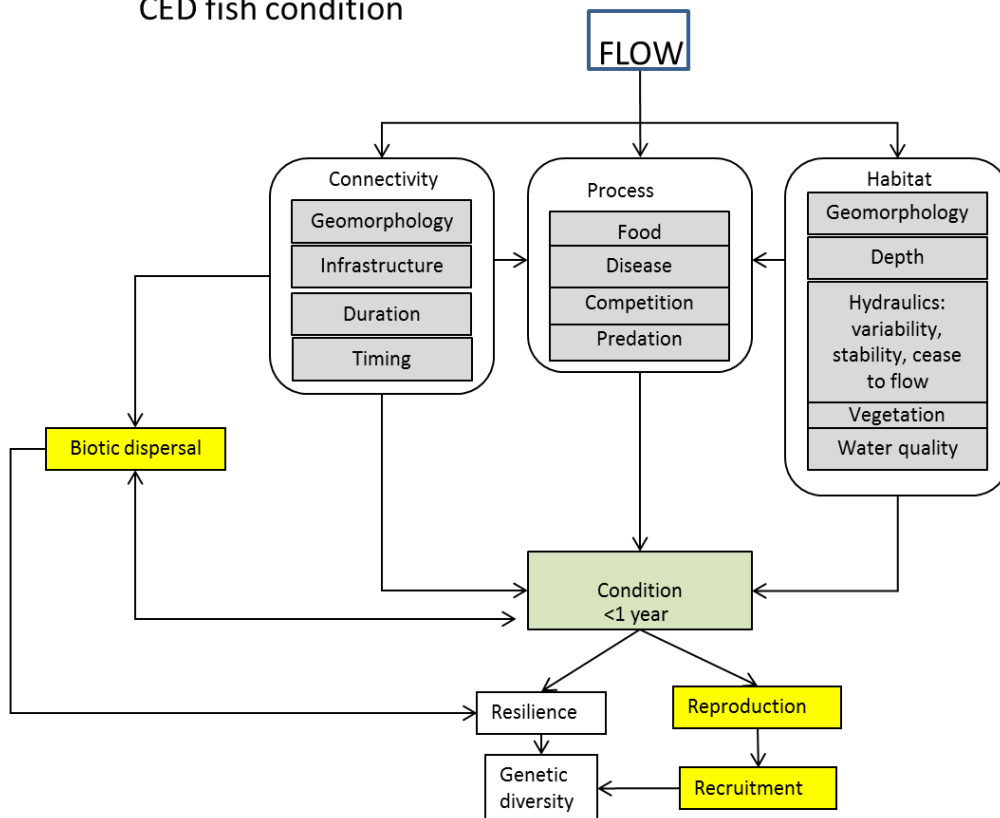


Figure 31. Modified Fish condition cause and effect diagram depicting the influences of flow. Yellow boxes indicate other CED's.

Indicators

CPUE of fish, length of fish, weight of fish, spatial distribution

Covariates

Hydrology: (discharge, Δ discharge, height/level, wetted area, connectivity); water quality: temp, DO

Complimentary monitoring and data

Existing long term fish community data exists at numerous sites within the Edward-Wakool Selected Area and was collected as part of other projects including short-term intervention monitoring, Edward-Wakool Fish and Flows, SRA, and NSW rivers survey. Where possible, sites with long term data sets will be retained.

Locations for monitoring

In addition to the Cat 1 sampling undertaken in zone 3, annual sampling will occur at a total of five sites in zone 1 to address Selected Area questions. Analyses will be reported at the zone scale. This design will provide an indication of how the delivery of Commonwealth environmental water is providing fish diversity outcomes across the Selected Area.

Sampling of an additional 15 sites distributed throughout the Edward-Wakool system will occur in years 1 and 5. These will all be in-channel sites, have a minimum of five years of continuous data collected as part of a previous project, and will be located outside the Focal Area. Use of data from these additional sites coupled with data collected from a subsample of sites in the Fish (River) Cat I will enable long-term change trajectories of the native fish population to be determined using SRA health indices.

Timing and Frequency of sampling

Annually, between March and May following flow recession.

Responsibilities

Fisheries NSW project staff based at Narrandera Fisheries Centre (Thiem, Smith, Rehwinkel) will coordinate and schedule the sampling, data management, analysis and reporting for this component; with assistance from other team members as required.

Field methods

Sampling will be conducted annually from March-May. In the interests of cost-efficiency and comparability with data generated by previous projects within the study area, the area scale assessment of the status of fish populations and assemblages will be conducted using Sustainable Rivers Audit (SRA) protocol (Davies et al. 2010). Within zone 1 fish will be collected from 5 sites using a combination of boat or backpack electrofishing (12 x 90 second shots) and unbaited bait traps (n = 10). Additional augmentations to the standard SRA protocol will be:

1. The LTIM Project subsampling procedure of measuring the first 20 individuals per shot/net/trap will be utilised in place of the SRA's subsampling procedure.

2. The individual weight of the first 50 individuals measured for length of each species will be recorded.

Important points of difference to LTIM Project Fish (river) Cat I sampling methods are that:

- Small-meshed fyke nets will not be used
- Only 18 to 20 minutes of electrofishing sampling effort will be used per site (depending on electrofishing equipment used).
- No otolith samples will be retained.

All fish community data will be entered onto the Fisheries NSW database. Data analysis will occur at two scales: 1) at the zone scale annually, and 2) at the system-scale in years 1 and 5.

Data analysis and reporting

Raw catch and effort data for each sampling operation (electrofishing shot or net/trap set) will be recorded. Processed data for fish abundances will be reported as standardised catch-per-unit-effort (CPUE) per site.

Condition: The collection of length and weight data at all sites will enable calculation of a condition index (Fulton's K) for each fish. This data will be analysed after five years generalised linear models to identify the differences in fish condition in relation to watering regimes among zones and over time.

Recruitment: Fish length structure will be evaluated for each species (where sample sizes permit) using Kolmogorov-Smirnov tests to examine changes in length distribution. Increased recruitment would be expected in years where the hydrological regime facilitated successful reproduction and provided suitable conditions conducive to growth and survival of larvae.

Native fish diversity and abundance, native fish biomass, recovery of the fish community: Fish community data will be summarised to compare results to four main SRA Indicators (see Robinson (2012)). The SRA derived Indicators will be; 1) Expectedness (provides a comparison of existing catch composition with historical fish distributions), 2) Nativeness (combination of abundance and biomass describing the proportion of the community comprised of native fish), 3) Recruitment (provides a proportion of the entire native fish population that is recruiting within a zone) and 4) Native and alien Biomass. Recruitment will be further divided; recruiting taxa (proportion of native species present recruiting), and recruiting sites (proportion of sites where recruitment occurs). These indicators produce a score that is related to Reference conditions, and receive a condition rating (Extremely Poor (0-20), Very Poor (21-40), poor (41-60), Moderate (61-80), Good (81-100). Changes to SRA condition ratings will be examined in year 1 and then again in year 5, with an overall expectation that condition ratings will improve over time as a result of Commonwealth environmental water. In addition, fish community structure (species specific abundance and biomass at each site) will be analysed using permutational multivariate analysis of variance (PERMANOVA), with year as a fixed factor.

Health and safety

The Edward-Wakool Selected Area Health and Safety Plan (HSP) includes an assessment of all identified potential risks and a plan on how these risks will be managed.

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7 Selected Area schedule of monitoring

This section describes the monitoring schedule for the Edward-Wakool Selected Area. The location of zones and indicators in the Edward-Wakool Selected Area was previously described in Section 4.4. The timing of reporting is summarised in Section 9. Details on the timing of sampling activities were described in each of the SOPs (Section 6).

The monitoring schedule was developed to ensure it is in line with the expected environmental watering in this system (Section 3). As the majority of the watering actions are likely to occur between September and February, this is when the routine monitoring will occur. In addition, there is flexibility in the schedule to allow for event based monitoring of water quality associated with blackwater events or monitoring of fish larvae and frogs/tadpoles during inundation events that occur outside these months.

The Edward-Wakool Project Team designed the field monitoring schedule to utilise staff time efficiently and to ensure value for money. Field costs were kept to a minimum by incorporating several indicators into a single field trip where possible. At the same time, the schedule allows for field work to be completed on a Monday to Friday basis to ensure staff are able to spend weekends at home and thus be rested for subsequent field trips and laboratory work.

Tables 25 to 29 provide an overall summary of the field and reporting activities for this M&E Plan. In The hatched boxes indicate approximate timing of event-based monitoring (this may vary from year to year). Activities vary slightly from year to year. Examples of variation in activities between years include:

- In 2015-16 the receivers for the fish movement indicator will be deployed, but this activity will not be required in subsequent years.
- The Acoustic Doppler Current Profiler field work will be undertaken in 2014-15 and 2015-16 but not in subsequent years
- No field monitoring will be undertaken in 2018-19 after June 2019, as this will be the period in which the final evaluation report is prepared.

Table 27. Timeline for 2016-17 Edward-Wakool LTIM Project. The different colours represent different teams of staff undertaking field work. Activities shaded the same colour are undertaken on the same field trip. Hatched shading indicates approximate timing of event-based surveys (this may vary from year to year). Light blue shading indicates continuous logging, while darker blue indicates the time when downloads of loggers will occur.

					2016-2017																																																	
Indicator	Cat	zone	Basin evaluation	Selected Area evaluation	Notes	July		Aug				Sep				Oct					Nov				Dec				Jan				Feb				Mar					Apr				May				Jun				
						1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Monitoring activities																																																						
River hydrology	1	1,2,3,4	✓	✓	hydrological data	[Hatched shading]																																																
	1	1,2,3,4	✓	✓	depth loggers	[Darker blue shading]																																																
	3	1,2,3,4		✓	reading staff gauges	[Hatched shading]																																																
Stream metabolism	1	1,2,3,4	✓	✓	D-opto & light loggers	[Darker blue shading]																																																
	1	1,2,3,4	✓	✓	nutrients and carbon	[Darker blue shading]																																																
Carbon & water quality (core)	3	1,2,3,4		✓	carbon characterisation	[Darker blue shading]																																																
Riverbank and aquatic veg	3	1,2,3,4		✓	transects	[Hatched shading]																																																
Fish (larvae) ¹	3	1,2,3,4		✓	Light traps	[Hatched shading]																																																
	3	1,2,3,4		✓	drift nets	[Hatched shading]																																																
Fish (larvae)	1	3	✓	part	Light traps and drift nets	[Light blue shading]																																																
Fish (river)	1	3	✓	part	fish population surveys	[Hatched shading]																																																
	1	3	✓		otolith collection	[Hatched shading]																																																
Fish (river)	3	1,2,3,4		✓	fish population surveys	[Hatched shading]																																																
Fish (Movement)	2	1,2,3,4	✓	✓	tag fish, download receivers	[Darker blue shading]																																																
Evaluation activities																																																						
Area evaluation report						[Hatched shading]																																																
Progress reports						[Hatched shading]																																																
Monitoring data entry						[Hatched shading]																																																
Face-to-face team meeting						[Hatched shading]																																																
Team teleconference						[Hatched shading]																																																
Auditing						[Hatched shading]																																																

¹To be monitored in 2014-15 and 2015-16. At the end of 2015-16 an assessment will be made to determine whether monitoring for recruitment (Cat 3) or fish larvae (Cat 3) will continue (i.e. budget provides for only one of these indicators to be monitored in 2016-17, 2017-18 and 2018-19. Only fish (larvae) shown here.

Table 28. Timeline for 2017-18 Edward-Wakool LTIM Project. The different colours represent different teams of staff undertaking field work. Activities shaded the same colour are undertaken on the same field trip. Hatched shading indicates approximate timing of event-based surveys (this may vary from year to year). Light blue shading indicates continuous logging, while darker blue indicates the time when downloads of loggers will occur.

					2017-2018																																																		
Indicator	Cat	zone	Basin evaluation	Selected Area evaluation	Notes	July		Aug			Sep			Oct					Nov			Dec			Jan			Feb			Mar			Apr			May			Jun															
						1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Monitoring activities																																																							
River hydrology	1	1,2,3,4	✓	✓	hydrological data	[Hatched shading]																																																	
	1	1,2,3,4	✓	✓	depth loggers	[Dark blue shading]																																																	
	3	1,2,3,4		✓	reading staff gauges	[Hatched shading]																																																	
Stream metabolism	1	1,2,3,4	✓	✓	D-opto & light loggers	[Dark blue shading]																																																	
	1	1,2,3,4	✓	✓	nutrients and carbon	[Dark blue shading]																																																	
Carbon & water quality (core)	3	1,2,3,4		✓	carbon characterisation	[Hatched shading]																																																	
Riverbank and aquatic veg	3	1,2,3,4		✓	transects	[Hatched shading]																																																	
Fish (larvae) ¹	3	1,2,3,4		✓	Light traps	[Hatched shading]																																																	
	3	1,2,3,4		✓	drift nets	[Hatched shading]																																																	
Fish (larvae)	1	3	✓	part	Light traps and drift nets	[Light blue shading]																																																	
Fish (river)	1	3	✓	part	fish population surveys	[Hatched shading]																																																	
	1	3	✓		otolith collection	[Hatched shading]																																																	
Fish (river)	3	1,2,3,4		✓	fish population surveys	[Hatched shading]																																																	
Fish (Movement)	2	1,2,3,4	✓	✓	tag fish, download receivers	[Hatched shading]																																																	
Evaluation activities																																																							
Area evaluation report						[Hatched shading]																																																	
Progress reports						[Hatched shading]																																																	
Monitoring data entry						[Hatched shading]																																																	
Face-to-face team meeting						[Hatched shading]																																																	
Team teleconference						[Hatched shading]																																																	
Auditing						[Hatched shading]																																																	

¹To be monitored in 2014-15 and 2015-16. At the end of 2015-16 an assessment will be made to determine whether monitoring for recruitment (Cat 3) or fish larvae (Cat 3) will continue (i.e. budget provides for only one of these indicators to be monitored in 2016-17, 2017-18 and 2018-19. Only fish (larvae) shown here.

8 Evaluation

The data collected during the monitoring will be used to assess the Basin-scale and Edward-Wakool Selected Area evaluation questions identified in section 5.

Three types of analysis are used to support the evaluation of environmental outcomes from Commonwealth environmental watering (Gawne et al. 2014):

- Aggregation, where outcomes or results are either listed or added together;
- Qualitative analysis, where predictions of outcomes are descriptive and/or based on conceptual models that enable only qualitative predictions; and
- Quantitative analysis, where there is sufficient data to develop and test quantitative predictions.

8.1 Basin-scale evaluation

The Basin-scale evaluation will be undertaken by the M&E Advisors as outlined in the Evaluation Plan. The Edward-Wakool Selected Area Monitoring and Evaluation Team would like the opportunity to be involved in the Basin-scale evaluation for those indicators that are monitored in the Edward-Wakool system.

8.2 Edward-Wakool Selected Area evaluation

The Edward-Wakool Selected Area evaluation will be undertaken by the Edward-Wakool Monitoring and Evaluation team (M&E Providers).

We envisage three main ways by which the ecosystem responses to Commonwealth environmental watering will be assessed in the Edward-Wakool system.

1. Monitoring zones have been selected to allow a control-treatment analysis to be undertaken, especially for event-based hypotheses. The creeks and rivers that comprise the Edward-Wakool system provide a unique opportunity to undertake this type of evaluation of ecosystem responses to the delivery of Commonwealth environmental water because in a single watering year it is likely that one of the rivers will not receive environmental water and can thus serve as a study 'control', with rivers receiving environmental water serving as 'treatment' systems. Such opportunities are relatively rare in testing the effectiveness of environmental flows as control systems are often difficult to find (Konrad 2011). This makes the Edward-Wakool system an important test case for this sort of analysis. This type of analysis will facilitate an assessment of the marginal benefit of Commonwealth environmental water.
2. In addition to a simple control/treatment type analysis, we also intend to employ data from additional zones within the Edward-Wakool system to undertake a gradient analysis, in which variation in the hydrologic conditions at individual sites are included in a regression model. For this type of analysis, rather than treating the occurrence of watering as a binary event (as in the treatment/control analysis), the outcomes of Commonwealth environmental water will be

inferred by relating ecosystem responses to hydrological and other independent variables measured at each site (and as appropriate for each indicator). For this analysis we will employ hierarchical mixed-effects models, which allow the integration of both continuous and categorical variables, as well as measurements that vary at different scales (e.g. from rivers, zones or sites). The creeks and rivers that comprise the Edward-Wakool system provide the ideal situation in which to undertake this type of evaluation because a wide range of flow types are experienced in this system within a single year, which strengthens the modelling capability and reduces the risk of having to wait for many years to sample a wide range of flows. The range of flow types and environmental watering options that will be considered range from low base flows, to small freshes and possibly bankfull or overbank flows with connections to floodplain. Using this modelling approach, the effects of Commonwealth environmental watering decisions can be tested directly, but also can be inferred in a post-hoc fashion by using the resultant predictive models to answer 'what-if' type questions about the outcomes of alternative watering scenarios, or, for example what would have been expected in the absence of watering.

The complex channel arrangement within the Edwards-Wakool system creates a considerable diversity in the flow regimes experienced among individual zones, even when those zones are in close proximity to one another. This also includes diversity in where, and what types of managed flows can, or are likely to be delivered in particular zones. This diversity provides opportunities to examine responses across a hydrologic gradient within a Selected Area, thereby overcoming some of the confounding factors that might influence a whole-of-basin analysis. The strength of the regression approach is that rather than treating zones in a categorical sense (i.e. control vs treatment), the conditions experienced within each individual zone can be described more explicitly in terms of the local environmental conditions. Thus, for example, the response of fish could be considered in terms of the area of slackwater habitat, or the specific timing of a flow event, rather than just in terms of whether a flow event occurred or not. By extending the sampling to a number of zones within the system it becomes further possible to adopt (at least to some degree) a space for time substitution approach in examining the effects of hydrologic variability. Furthermore, by extending the linear regression framework to the use of hierarchical mixed effects models, it becomes possible to not only consider data collected within a nested spatial hierarchy (e.g. zones within rivers), but also to consider a range of predictor variables (e.g. continuous/categorical and fixed/random effects), and ways in which those predictors influence the response variables of interest (e.g. see Zuur et al. 2009). Overall, the combination of emerging statistical modelling approaches with a diverse set of sampling zones will enhance the ability to make inferences about the effectiveness of environmental watering within the life of this project.

This approach will facilitate cumulative evaluation against 5 year expected outcomes. The models will assist with the prediction of responses under different watering actions and over time.

3. As well as using statistical models to test hypotheses and generate quantitative predictions, the responses measured across multiple indicators will be used to evaluate competing hypotheses about underlying mechanisms driving or limiting the outcomes from environmental water delivery. For example, if watering achieves increases in production and fish spawning, but not recruitment, it would be possible to identify potential bottlenecks and strategies for overcoming

those as part of an adaptive management cycle. This accords with the qualitative approach outlined in the LTIM Project Draft Evaluation Plan.

Within the focal zone, monitoring sites for fish (river) will overlap with fish larval sampling, water quality, nutrients, and primary productivity sampling. The primary purpose of this overlap is to determine how Commonwealth environmental water benefits fish in the context of ecological linkages with other critical ecosystem components. For instance, if only larval sampling were conducted, there would be little mechanism to determine if these fish grew to young of year. Similarly, if larvae were not collected, was it because adults were not present in the study reach or because they simply did not spawn? Determining the answer to these questions using a multiple lines of evidence approach is critical to ensure the contribution of environmental water to native fish outcomes can be discussed with increased confidence.

9 Communication and engagement

9.1 Stakeholder engagement

Recognition of the importance of local communities to effective Natural Resource Management (NRM) has led to natural resources being defined and managed as ‘social ecological systems’ (Chapin et al. 2009). Environmental flows are being increasingly used to restore riverine ecosystems but have the potential to be viewed both positively and negatively by the community (e.g. Murray Catchment Action Plan 2013-2023). Public (social) acceptance and involvement is being increasingly recognised as critical to the overall success of NRM, including that related to environmental flows (Carpenter and Biggs 2009). This project provides an excellent opportunity to incorporate effective engagement to support e-water delivery.

The Edward-Wakool system has a very diverse and active community that are concerned about the future of their region. The area was identified as a significant natural resource asset in a series of community workshops held by Murray Catchment Management Authority (the now Murray Local Land Services) in 2010 and also by the Murray-Darling Basin Authority in the Basin Plan (MDBA 2010).

The Murray Catchment Community (which includes landholders, technical experts, Aboriginal people, government agency staff, industry representatives and the general public) identified key values, goals and priorities for the Edward-Wakool system during the development of the Murray Catchment Action Plan (CAP; Murray CMA 2013). There is broad support for the use of environmental flows in this system, but the community has expressed the desire to be involved, particularly in decision-making related to system management (Murray CMA 2013).

The aim of the engagement program for the Edward-Wakool system is to ensure that the community is informed and accepting of the project and are able to contribute to adaptive management of the system.

Stakeholder Analysis

The first step in effective engagement is to identify the relevant stakeholders and determine the level of engagement each requires. Stakeholders of the Edward-Wakool River system were identified and the level of engagement determined by a Stakeholder Analysis Matrix modified from Effective Community Engagement: workbook and tools (DSE 2002; www.dse.vic.gov.au/engage) (Table 30).

Once identified, each stakeholder was scored and assigned to a particular engagement level based on their importance to, and influence on the project according to the IAP2 Spectrum of Public Participation (www.iap2.org.au, accessed 11/10/2013), i.e. Inform, Consult, Involve, Collaborate and Empower.

A range of engagement activities outlined in the communication and engagement plan (Table 31) will be conducted with stakeholders depending on the level of engagement assigned in the stakeholder analysis (Table 30).

Table 30. Stakeholders of the Edward-Wakool River system were identified and the level of engagement determined by a Stakeholder Analysis Matrix modified from Effective Community Engagement: workbook and tools

Edward-Wakool Stakeholder Analysis							
Stakeholder relation to project							
Stakeholder	Needs at stake in relation to project	Attitude/ Effect on project outcomes	Importance to our work	Degree of influence over our work	Score	Engagement Level	Notes
Name	Description	(+, -, 0)	(U, 1, 2, 3, 4, 5)	(U, 1, 2, 3, 4, 5)			
Murray LLS Investors (C40C)	Efficiency and effectiveness of investment Potential impacts on reputation	+	5	5	25	EMPOWER (25)	Ask to sit on SC
LLS	Implementation of CAP, incorporation of community values, delivery partner	+	5	5	25	EMPOWER (25)	Ask to sit on SC
CEWO	Water holder	+	5	5	25	EMPOWER (25)	Ask to sit on SC
CSU	Key Delivery partner - represents other partners for monitoring component	+	5	4	20	EMPOWER (20)	Ask to sit on SC
OEH	Water holder/manager	+	5	4	20	EMPOWER (20)	Ask to sit on SC
NOW	Water manager	+	5	4	20	EMPOWER (20)	Ask to sit on SC
Landholder groups (Wakool Rivers Assoc, WMLIG, etc)	Water and land holders, vested interest in local outcomes for environment, community and economy	plus and minus	5	4	20	EMPOWER (20)	Ask to sit on SC
Aboriginal representation	Delivery partner for some components, key community sector, input into cultural flows	+	2 - 5	2 - 4	4 - 20	INFORM - EMPOWER	Depends on proposed activities, but if likely to include eventually, should ask to participate from the beginning
MIL	Water Manager - Private	plus and minus	4	4	16	COLLABORATE (16)	Due to the reliance on MIL infrastructure to deliver water they will be asked to sit on the SC
DPI Fisheries	Delivery partner - monitoring	+	4	4	16	COLLABORATE (16)	Delivery partner - represented by CSU on SC
Monash Uni	Delivery partner - monitoring	+	4	4	16	COLLABORATE (16)	Delivery partner - represented by CSU on SC
Rec angler groups (EWAA and other groups)	Potential impact on their hobby/ perceptions/ activities, partner in some activities (re-stocking, instream hab enhancement works) Potential focus group/ communication avenue	+	4	4	16	COLLABORATE (16)	Delivery partner not otherwise represented - Ask to sit on SC
EWAG	Water advisory group	+	4	4	16	COLLABORATE (16)	Already covered by OEH, MDBA, LLS, etc
MDBA	Water storage manager	+	3	4	12	COLLABORATE (12)	
State Water Corp	Infrastructure owners/ managers and operators	plus and minus	3	3	9	COLLABORATE (9)	
NPWS and Forestry NSW	Own/manage the land around several sites	+	3	3	9	COLLABORATE (9)	
Irrigation farmers	Impact on source water	plus and minus	3	2	6	INVOLVE (6)	
Other universities and Research orgs	Scientific interest in outcomes of work	+	2	3	6	CONSULT (6)	
Rec fishers (not in group)	Potential impact on their hobby/ perceptions	+	2	3	6	CONSULT (6)	
Deni Council	Potential provider of approvals for some works Potential PR impacts	+	2	2	4	INFORM (4)	
MATG	Aboriginal values, some members are land managers - representatives for other Aboriginal groups	+	2	2	4	INFORM (4)	
General public	Potential impact on their values - social, economic, env	plus and minus	1	2	2	INFORM (2)	
Deni Chamber of Commerce	Input into local economic diversification - local knowledge bank, entrepreneurial skills, etc	+	1	1	1	INFORM (1)	
RDA	Project delivery partner - economic diversification	+	1	1	1	INFORM (1)	
LALC's (Deni, Moama, Wamba Wamba) and traditional owner	Aboriginal values, some members are land managers	+	1	1	1	INFORM (1)	
Private industry	May have an interest in project components related to local economic diversification	+	1	1	1	INFORM (1)	
Other LG's	Interest in project approach and roll-out Potential provider of approvals for some works Potential PR impacts	+	1	1	1	INFORM (1)	

Empower - Edward-Wakool Stakeholder Committee (EWSSC)

Due to the various natural resource activities occurring in the Edward-Wakool system, a single stakeholder group is being established to avoid the need for multiple stakeholder groups with a similar focus. All stakeholders that scored in the 'empower' level of engagement (Table 30) were invited to be a member of the committee chaired by Murray Local Land Services. Membership of the group was discussed at the first meeting in February 2014 and it was agreed that an additional member, Murray Irrigation Limited should be invited to join the committee.

The EWSC will provide guidance on the planning, implementation, review, evaluation and communication of 'Locally Identified Projects' relevant to the Edward-Wakool system. The group will help facilitate local input and information exchange to support delivery and adaptive management by key agencies such as the NSW Office of Water, the Office of Environment and Heritage and other relevant agencies. The group will help support local implementation of the projects listed below:

- Commonwealth Environmental Water Office - Long Term Intervention Monitoring Project for the Edward-Wakool 'Selected Area'
- Murray Local Land Services - Edward-Wakool Social-Ecological System Project
- Environmental watering actions conducted by the Commonwealth Environmental Water Office and NSW Office of Environment and Heritage. The Working Group will assist the Murray Lower Darling Environmental Water Advisory Group in community consultation on environmental water in the Edward-Wakool local area.
- Aboriginal programs relevant to the Edward-Wakool region overseen by the Murray Aboriginal Program Steering Committee
- Edward-Wakool Community Water Quality Monitoring program coordinated by the Wakool River Association
- Relevant projects and activities of the Western Murray Land Improvement Group (e.g. Retired Irrigation Lands Project)
- Edward-Wakool Angling Association community fish re-stocking and coordinated recreational fishery data collection programs

A Terms of Reference is being developed for the EWSC that will outline the roles and responsibilities of each member. The Terms of Reference will also outline how the roles and responsibilities of the Committee will differ for some of the Locally Identified Projects. The draft Terms of Reference was discussed at the first meeting and comments are being incorporated and will be presented at the next meeting. All members must agree to abide by the final EWSC Terms of Reference.

Collaborate

The Project Team will collaborate with stakeholders through the EWSC. Several projects funded by Murray LLS in the Edward-Wakool Region will be led by Edward-Wakool stakeholder groups. These groups have been asked to decide what level of involvement they would like the EWSC to have but we expect that the level of engagement through this group will fall under the collaborate level of engagement. The projects and Stakeholder Groups include: Coordinated restocking program led by EWAA and the Community Water Quality Monitoring Program led by Wakool Rivers Association.

Involve

A 'lessons learnt' workshop will be held by Murray Local Land Services in August each year to review the success of project activities conducted in the previous year and to implement improvements as part of the adaptive management cycle. Representatives of all stakeholder groups will be invited to participate and the information generated used to inform planning by the project team in future years.

Consult

As environmental flow delivery in the Edward-Wakool is a new area for all stakeholders, there is a degree of uncertainty around the outcomes and potential impacts of certain flow scenarios. Landholders in the treatment streams will be contacted to discuss proposed environmental watering actions and to obtain insight into the extent of inundation expected from different delivery scenarios. Follow up contact will be made after each watering action to ground-truth predictions made by landholders and the project team and to document any issues that arose.

Inform

A range of activities will be conducted during the project to inform the community about the project. Activities include: large-scale diverse audience events such as 'Native Fish Awareness Week'; more focused engagement events such as the Deniliquin RSL Fishing Classic; updates and information via the Murray LLS website and email newsletter; media releases; individual contacts with interested people such as the landholders with monitoring sites on their properties. A minimum of three targeted community engagement events will be used to interact with stakeholder groups on an annual basis. Factsheets and/or other information will be distributed during these events, with members of the project team available to present the overall monitoring plan and objectives, methods, areas, results and way forward.

The following types of events will be supported each year:

- An event to align with native fish awareness week in November each year. This will involve the general community and school groups. Members of the project team will present results from the monitoring of environmental flows within the system. This event will be held at the Deniliquin RSL or at the Deniliquin Boat Club.
- An event to be held during the Deniliquin RSL Fishing Classic in February each year. The project team will set up an information booth to disseminate information and demonstrate some of the sampling techniques used in the monitoring. The event attracts recreational fishers and the general community with attendance of over 1000 people each year.
- An event to be held during the Wakool Fishing Classic in late March or early April each year. The event is held at the Wakool Reserve. An information booth will be set up to disseminate information on the project and staff will be available to answer questions from the public. This event is attended by recreational fishers and the general community with attendance of over 700 people each year.

Members of the project team will also attend meetings of key groups including the Wakool River Association, Edward-Wakool Angling Association, Wakool Landholder Association as required and with other groups upon request. At these meetings members of the project team will give presentations on the project. These meetings can also be used as a conduit for information from the CEWO and to get input and feedback from the community in relation to monitoring.

Where possible, the following questions on stakeholder engagement related to Commonwealth environmental watering will be addressed by complementary projects:

- How did Commonwealth environmental water delivery contribute to community engagement in natural resource management?
- How did Commonwealth environmental water delivery contribute to community understanding of aquatic ecosystems?
- How did Commonwealth environmental water delivery contribute to community acceptance of and support for environmental water purchase, allocation and management?
- How did Commonwealth environmental water delivery contribute to the maintenance of Aboriginal cultural values of aquatic ecosystems?

References

- Chapin, F.S., Folke, C. and Kofinas, G.P. (2009) A framework for understanding change. In 'Principles of ecosystem stewardship – resilience-based natural resource management in a changing world'. (Eds F.S. Chapin, C. Folke, and G.P. Kofinas) pp. 3-28. (Springer Science + Business Media, New York)
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- Murray CMA (2013) Catchment Action Plan 2013-2023. Murray Catchment Management Authority, Deniliquin NSW.
- DSE (2004) Effective community engagement: workbook and tools (Version 1 and 2). Victorian Government Department of Sustainability and Environment, Melbourne.
- MDBA (2012) Basin Plan. Adopted by minister for sustainability, Environment, Water, Populations and Communities under subparagraph 44(3)(b)(i) of the Water Act 2007, Canberra.

Table 31. Communication and engagement plan for the Edward-Wakool Selected Area

Tools/Activities	Detail	Timeframe	Responsibility
Reporting to CEWO	Reporting requirements for LTIM Project activities as per Project Operations Manual e.g. project updates, annual reports (see section 9.2 in bid document)	Continuous	LTIM Project Leader
Edward- Wakool Stakeholder Committee	Forum for stakeholder input and strategic-level guidance on project direction	Continuous (Quarterly meetings and some 'out of session' inputs)	Chair of EWSC
Edward- Wakool Operations Advisory Group	CEWO, LLS Project Officer, MIL, MDBA, OEH, SWC, NPWS, Forestry Corp of NSW	Monthly before and fortnightly during eflow delivery	CEWO
At least 3 Public events per year: - Edward-Wakool Fish and Flows Forum - Deni Fishing Classic - Wakool Fishing Classic	Invitations sent to MDBA and AG	Nov Feb Mar/Apr	LLS Project Officer
Direct contact with potentially affected landholders	During e-flow planning and during and after e-flow events	Mar/Apr Sep-Apr	CEWO LEO (LLS to cover in interim)
Media release (e.g. article for newspaper, radio interview)	Content provided by CEWO, OEH, NOW, LTIM Project Leader. Approved by CEWO and OEH Audience = Rec fishers, Local Govt, General public	following quarterly reporting to CEWO	LLS Project Officer to coordinate with approved content from OEH and CEWO.
LTIM Project Presentation at EWAG meeting	Presentation by LTIM Project Leader on project activities and outcomes	Annually	LTIM Project Leader

Table 31 (continued). Communication and engagement plan for the Edward-Wakool Selected Area

Tools/Activities	Detail	Timeframe	Responsibility
Project presentation at Landholder Group AGMs	Presentation by delivery partners on project activities and outcomes	Annually	LLS Project Officer
LLS Website Updates	Updates on project activities and outcomes uploaded to LLS (and any other interested delivery partner) website	following quarterly reporting to CEWO	LLS Project Officer
Lessons Learnt Workshop	Annually	Annually (Jul/Aug)	LLS Project Officer
Presentation of project at MATG meeting	Presentation by LTIM Project Leader on project activities and outcomes	Annually	MATG member on EWSC
Reporting to other investors	Inclusion of project activities and outcomes in reports to investors (e.g. AG, CA NSW)	Annually or 6-monthly	LLS Project Manager
Present findings at Scientific conferences	Presentation of project activities and outcomes from various delivery partners	various	All project delivery partners
Information booths/ materials at other public events	Eg. Carp-O-Mania, BioBlitz, Henty Field Days, Deni Innovation Expo, Ag Shows, Wonga Wetlands Open Day, Three Rivers Run, Murray Meander	various	LLS Project Officer LLS Event Coordinator
Internal email updates	Updates developed by delivery partners to inform their own organisations of project activities and outcomes	following quarterly reporting to CEWO	CEWO Project Staff
			MATG member on EWSC
			LLS Project Officer
			Team leaders for each partner organisation
LLS Board Updates	Update to LLS Board on project delivery	Bi-monthly	LLS Project Manager

9.2 Reporting

The following forms of reporting and information transfer activities that will be undertaken as part of this project include:

- Project reporting (progress),
- Submission of data in correct format and according to defined protocols; and
- Outcomes reporting.

A summary of reporting and information activities (Table 32) and requirements (Table 33) that will be undertaken as part of this project including frequency and timing is presented below. These tables are based on information provided in Project Operations Manual.

Table 32. Summary of reporting and information transfer activities that will be undertaken as part of the project.

Document/Information	Timing	Description
Monitoring data (including context information)	Ongoing	We will collect and process monitoring data for the Edward-Wakool Selected Area, in accordance with the M&E Plan
Operational information (observed)	Ongoing, following actions	We will note and report any incidental observations made during field visits that may contribute to or support Evaluation (Area or Basin) or Adaptive Management. This will include observations reported to team members by stakeholders. This will contribute to Watering Action Acquittal Reports written by CEWO.
Annual monitoring workplan	Annually, August	We will produce an annual monitoring workplan in August each year that outlines which elements of the M&E Plan will be implemented over that coming water year, based on the M&E Plan and environmental watering actions(s) that is likely to be undertaken. This should be based on information available at the time on area condition, water available and water use options.
Annual evaluation plan	Annually, August	Following on from the annual monitoring workplan, we will provide an annual evaluation plan in August each year that outlines what evaluation activities will be undertaken over the coming year, based on anticipated environmental watering actions and monitoring data availability.
Area evaluation report	Annually, Draft Aug 30 Final Oct 31	We will provide an evaluation of the outcomes of Commonwealth environmental water for the Edward-Wakool Area, based on the outcomes framework of the seven Selected Areas'.
Relationship with delivery partners to support evaluation	Ongoing	We will maintain a good working relationship with delivery partners. This relationship will provide contextual information on environmental watering activities to support Area monitoring and evaluation activities.
Relationship with M&E Advisors to support evaluation	Ongoing	We will maintain a good working relationship with the M&E Advisors. We will provide important contextual information on watering activities (including observations and interpretations of raw monitoring data to support Basin evaluation activities.
Relationship with CEWO to support Adaptive Management	Ongoing	We will maintain a good working relationship with the CEWO. This relationship will provide a pathway for lessons learned from monitoring to inform future water use planning, decision and use through the Annual Watering and review process.

Table 33. Summary of reporting and information transfer requirements for the LTIM Project (Source LTIM Project Operations Manual)

Activity Type	What	Frequency	Timing / Due date	Responsibility	Receiver	Description and high level requirements	Inputs
Reporting	Monitoring and Evaluation Plan	One-off	Draft – Feb 28 2014 Final – 17 April 2014	M&E Providers	CEWO	A plan for monitoring and evaluation in each Selected Area over the five year period from 2014-15 to 2018-19. M&E Providers are responsible for developing M&E Plans during 2013-14, in collaboration with the CEWO. See the M&E Plan specifications for more information.	See Monitoring outline and Evaluation outline
Reporting	Area evaluation report	Annual	Draft – Aug 30 Final – Oct 31 First report – 2015 Final report - 2019	M&E Providers	CEWO	A cumulative evaluation of the outcomes of Commonwealth environmental water at each Selected Area prepared in accordance with the M&E Plan. The report must be prepared in plain English with simple science and be suitable for publication on CEWO website.	M&E Plan Monitoring data for the Selected Area
Reporting	Basin evaluation report	Annual	Draft – Aug 30 Final – Oct 31 First report – 2015 Final report - 2019	M&E Advisors	CEWO	A cumulative evaluation of the outcomes of Commonwealth environmental water at the Basin-scale, based on the Evaluation Plan. The report must be prepared in plain English with simple science and be suitable for publication on CEWO website.	Evaluation Plan Monitoring data for all Selected Areas
Reporting	Progress reports - 2013-14	Monthly	Nov 2013 to June 2014 (last business day of the month)	M&E Providers	CEWO	A written progress report, summarising tasks completed since the last report, tasks planned for the upcoming period, emerging issues etc	Progress report template
Reporting	Project progress reports - 2014-15 onwards	Quarterly	Sep, Dec, Mar and June (last business day of the month) for the duration of the LTIM Project	M&E Providers	CEWO	A written progress report, summarising tasks completed since the last report, tasks planned for the upcoming period, emerging issues etc	Progress report template
Information Transfer	Monitoring data entry	Monthly	Monthly for the duration of the LTIM Project	M&E Providers	Monitoring and Data Management System	Processed monitoring data uploaded to the Monitoring Data Management System in accordance with data management protocols, as outlined in the M&E Plans.	Data management protocols

10 Project management

To ensure the delivery of projects in accordance with its objectives and to monitor progress, a formalized project management framework and methodology will be used, in accordance with best practice project management. This process facilitates the clarification of, and agreement to, goals, identify resources needed, ensure accountability for results and performance and focus on the final benefits to be achieved. The process will focus on developing specifically defined outputs to be delivered on time, to a defined quality, to the defined budget and with a level of resources, so that planned outcomes/benefits are achieved.

The following will take place to monitor progress against project objectives:

- Establish a clear governance process and organizational responsibilities and accountabilities
- The Project Team will report on progress to the Edward-Wakool Stakeholder Committee comprising key stakeholders
- The Project Team will develop a set of Key Performance Indicators in the area of quality, time performance, finance, communications and risk management.
- The Project Team will establish a clear reporting framework including a reporting and monitoring schedule to monitor project success in accordance with the head agreement. This may include the following:
 - Quality reporting and contract management – To present performance and compliance of outputs with project specifications; this includes the management of sub-contractors
 - Time performance reporting – To present milestones progress completion against milestone schedule and impact of delay on other project areas (Milestone History Monitor and Gantt Charts)
 - Financial reporting – outlines of actual expenses against budget allocation, forecast and impact of non-compliance
 - Communications reporting – outlines progress in stakeholder and community engagement (residents & business) versus plan
 - Risk management reporting – outline of status of major risks to the project and progress of mitigation action implementation
- The Project Team will hold regular teleconference call with their sub-contractors (at least monthly); an initial inception meeting with each contractor will confirm deliverables and timelines, schedule of payments and reporting and for completion of deliverables as well as clear scope and specifications. The Project Team will hold an annual 2 day face to face meeting (July) to collaborate on writing the Annual Evaluation Report and contribute to the development of the Annual Monitoring Workplan and Annual Evaluation Plan
- The Project Team will present the draft Annual Area Evaluation report to CEWO in August in advance of providing the final report in October of each year.

10.1 Project governance

The project governance structure for the broader LTIM Project is summarised in Figure 32. This shows the relationship of the M&E Provider (ie Edward-Wakool Project Team) to the M&E Advisors, the CEWO and the Selected Area Working Group ('Edward-Wakool Stakeholder Committee').

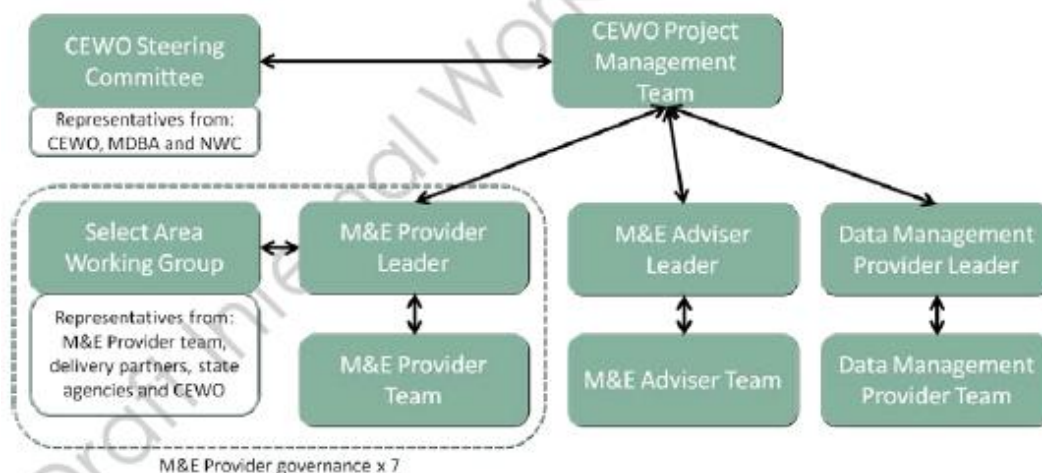


Figure 32. Project governance structure for the LTIM Project (Source: LTIM Project Operations Manual)

It is proposed that the project will operate under the following governance:

- *Corporate Client* – The government body that is funding the project –Australian Government through the Commonwealth Environmental Water Holder (CEWO)

The corporate client is the champion of the project with ultimate authority; promotes the benefits of the project to the community and may be viewed as the 'public face' of the project (involvement in most high profile media activity); lends support by advocacy at senior level and ensure that necessary resources are available for the project.

- *Edward-Wakool Stakeholder Committee* – High level representatives of relevant organizations including Project Manager, LLS Board Member, representatives of CEWO, landholder representatives, OEH representative, NSW Office of Water representative, and Aboriginal and industry representation. The anticipated meeting frequency is three to four times per year.

The EWSSC will provide advice on the planning, implementation, review, evaluation and communication of the project.

- *Project Manager* – Associate Professor Robyn Watts is the Project Manager. She will lead the project team and will be the key contact for communication with CEWO and the Advisors. She will follow the strategic direction set by CEWO and consult with the Edward-Wakool Stakeholder Committee

The Project Manager will be responsible for all the operational aspects of the project. Project Manager is responsible for organizing the project into one or more sub-projects, managing the day-to-day aspects of the project, maintaining the project schedule, resolving planning and implementation issues and monitoring progress towards budget. The Project Manager will: manage and monitor the project activities through detailed plan and schedules; report to CEWO according to the schedule of activities; and manage (client/partners/stakeholder) expectations

through formal specification and agreement of goals, objectives, scope, outputs, resources required, budget, schedule, project structure, role and responsibilities.

- **Team Leaders** – The Team leaders are representatives from partnering organisations, who are leading specific elements of the project; Team Leaders are expected to work closely with the Project Manager to deliver on project outcomes. The Team Leaders are Associate Professor Robyn Watts (Charles Sturt University), Dr Jason Thiem (DPI NSW), Dr Patricia Bowen (LLS), Associate Professor Michael Grace (Monash University), Ms Sascha Healy (NSW OEH) and Dr Nick bond (Griffith University).

The Team Leaders will be coordinated by the Project Manager, working to the delivery of the project outputs; composition of the team may change as the project moves through its various phases; the assessment and selection of people with the requisite skills required for each phase of the project is critical to its overall success; the skills should be explicitly identified as part of the project planning process; the project team is responsible for completing tasks and activities required for delivering project outputs.

The proposed governance arrangements for the project are demonstrated in Figure 33. A summary of responsibilities of the project team members is provided in Table 34 and a list of members of the Edward-Wakool System Stakeholder Committee is presented in Table 35.

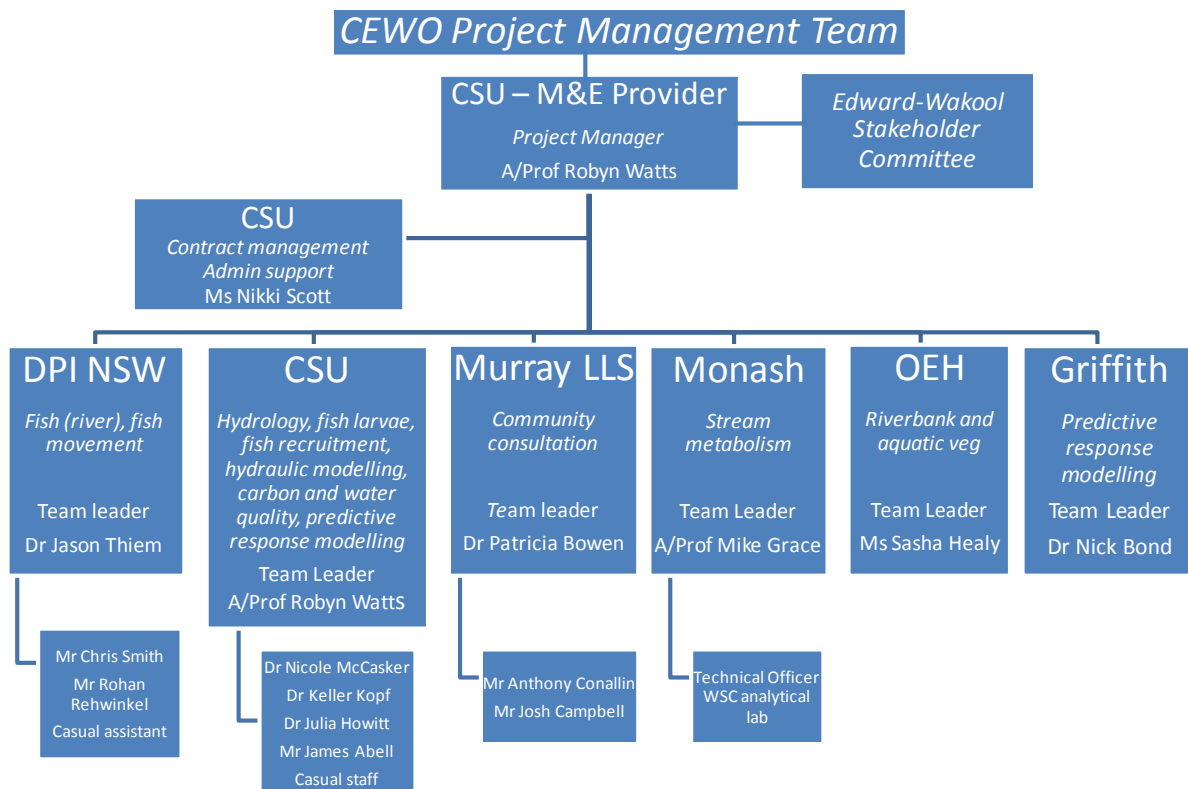


Figure 33. Proposed project governance structure of the Edward-Wakool LTIM Project Team.

Table 34. Summary of roles of Project Team members

Name	Organisation	Main Roles
A/Prof Robyn Watts	CSU	Project Manager, Team Leader for CSU, project planning, coordination of CSU staff, coordination and contribution to reporting, attend and present at EWSSC meetings, maintain relationship with M&E Advisors and delivery partners, lead project team meetings and annual planning
Ms Nikki Scott	CSU	Administration and contract management
Dr Nicole McCasker	CSU	Field work, laboratory processing of fish larval samples, data analysis and reporting of fish larvae data, coordination of field sampling team, participate in environmental watering teleconferences, contribute to predictive response modelling and reporting, contribute to project team meetings and annual planning
Dr Richard Kopf	CSU	Laboratory work, evaluation and reporting for fish recruitment, contribute to project team meetings and annual planning
Dr Julia Howitt	CSU	Analysis and reporting of targeted monitoring of carbon and water quality, contribute to project team meetings and annual planning
Mr James Abell - Technical Officer	CSU	Fieldwork, purchase of equipment/consumables, organisation of CSU field equipment, laboratory processing of fish larval samples under guidance of Dr McCasker, data entry
Casual RA level 4	CSU	Assistance with field work
Casual RA level 6	CSU	Processing of water samples
Dr Patricia Bowen	LLS	Team Leader for Murray LLS, Project planning, , reporting, Chair EWSSC meetings, contribute to project team meetings and annual planning
Mr Anthony Conallin	LLS	Attend EWSSC meetings, coordinate and attend community engagement activities, communicate with landholders potentially impacted by watering actions., contribute to project team meetings and annual planning
Mr Josh Campbell	LLS	Water quality monitoring, fish larval sampling, community consultation
A/Prof Michael Grace	Monash	Team Leader for Monash University, whole stream metabolism, data analysis and reporting, contribute to project team meetings and annual planning
Technical Officer	Monash	Processing water quality samples
Dr Jason Thiem	DPI NSW	Team Leader for DPI NSW, staff supervision, budgeting and project management, undertake monitoring, evaluation and reporting for fish (river) and fish movement components, contribute to project team meetings and annual planning
Technical Officer Mr Chris Smith	DPI NSW	Performing fieldwork, assisting with data entry for fish (river). Undertake fish movement field work. Assist with fish larvae fieldwork.
Technical Officer Mr Rohan Rehwinkel	DPI NSW	Assist with fieldwork
Casual assistants	DPI NSW	Required for all DPI field trips where three staff are needed.
Ms Sascha Healy	OEH	Team Leader for OEH, Fieldwork for riverbank and aquatic vegetation assessment, assist with data analysis and reporting, contribute to project team meetings and annual planning
Dr Nick Bond	Griffith	Lead predictive response modelling and reporting, contribute to project team meetings and annual planning

Table 35. Summary of roles of members of the Edward-Wakool Stakeholder Committee

Name	Position	Organisation	Role
Dr Trish Bowen	Project Team Leader	Murray LLS	Chair
Jennie Hehir	Board Member	Murray LLS	Deputy Chair
Mr Anthony Conallin	Project Team member	Murray LLS	Observer, administrative support
A/Prof Robyn Watts	Project Team Leader	Charles Sturt University	Member
Dr Nicole McCasker	Project Team member	Charles Sturt University	Observer
Dr Tim Wyndham	Director, Long term Intervention Monitoring Project	CEWO Monitoring and Evaluation	Member
TBA	CEWO staff member	CEWO	Observer
Paul Childs	Senior Environmental Water Manager	Office of Environment and Heritage	Member
	Executive Officer	Murray-Lower Darling Edward-Wakool Advisory Group	
Digby Jacobs	Team Leader	NSW Office of Water	TBC
John Lolicato	Chairman	Wakool River Association	Member
	Spokesperson	Wakool System Advisory Group	
	Representative	Wakool Landholder Association	
Dennis Gleeson	Representative	Colligen and Niemur Landholder group	Member
Rick Ellis	Secretary and Project Officer	Western Murray Land Improvement group	Member
Roger Knight	Community Support Officer	Western Murray Land Improvement Group	Member
	Community delegate	Koondrook-Perricoota Alliance	
Ian Fisher	President	Edward-Wakool Angling Association	Member
TBA	Representative	Aboriginal people of the Edward-Wakool region	Member
Perin Davy	Representative	Murray Irrigation Limited	Member

10.2 Data management

All data collected as part of this project will conform to the data structure defined in the LTIM Project Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Project Monitoring Data Management System (MDMS).

Data Management protocols will be followed as outlined in the Edward-Wakool Quality Management Plan (Watts et al. 2014a) and will be subject to annual audit. This includes document Management, record keeping, data storage and management.

CSU has a well-established document management system 'Total Records and Information Management' (TRIM). TRIM is an Electronic Document and Records Management System software solution for managing records of all formats. All controlled copies of accepted documents and reports are to be recorded in TRIM. In addition such documents and reports will also be recorded in Research Master. Financial data is recorded on Banner Finance, which in turn feeds financial information into Research Master. Data stored on Banner Finance is used to generate the relevant financial reports and acquittal for both internal and external purposes.

The Edward-Wakool Project team will store and manage access to primary data for the duration of the LTIM Project. The Project Leader will be responsible for ensuring the team members all comply with the management and storage of all primary data. All field and laboratory primary data sheets will be scanned and stored within the CSU Interact data management system as image files using tagged image file format at a minimum 300 dpi resolution. All monitoring information and data files will be uploaded onto the CSU Interact site for the project. This will include trip reports, audit reports and any other relevant data or documents.

The Edward-Wakool Project Team anticipates that the MDMS may not provide all the needs of selected area and has proposed that an online 'cloud' database be developed in addition to the MDMS. The proposed cloud database will provide the ability to link different indicators by spatial data, which will be important for the predictive response modelling component of the evaluation.

All derived data that supports shared evaluation will adhere to LTIM Project data standards and be traceable to primary data sets held on the Interact site. The Edward-Wakool team will submit data that supports shared evaluation into the LTIM Project Monitoring Data Management System within one month of collection and according to protocols established by CEWO.

10.3 Risk assessment

The Risk Management Plan for the Edward-Wakool Selected Area (Watts et al. 2014b) was prepared in accordance with:

- CSU Risk Management framework
- CSU Risk Management Policy
- CSU guidelines on How to complete a CSU Risk Assessment
- Australian Standard AS/NZS 4360:2004 Risk Management and revised AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines.

The Project Risk Management Plan follows the CSU Risk Management framework, including policies, guidelines and procedures, identifies major risks that are considered to have potential adverse effects or provide potential opportunities to meet the project objectives, risks to the environment and individuals and records the outcomes of the risk management process undertaken with the use of the Project Risk Register.

10.4 Quality plan

The Quality Management Plan for the Edward-Wakool Selected Area (Watts et al. 2014a) documents quality control and quality assurance procedures for all activities undertaken for the Edward-Wakool system under this M&E Plan. The plan is in accordance with relevant standards such as AS/NZ ISO 10005:2006 Quality management systems – Guidelines for quality plans as well as ANZECC and ARMCANZ (2000) Australian Guidelines for Water Quality Monitoring and Reporting.

The Quality Assurance Plan features the three following components:

- Quality assurance – to ensure quality management processes; this includes methodologies and standards (including LTIM Project Standard Methods and specific Standard Operation Procedures (SOPs))
- Quality control - to establish standards for acceptance of outputs, monitoring against the criteria to determine if quality has been achieved
- Quality improvement - review points to assess and improve quality where possible

10.5 Health, safety and environment plan

The Workplace Health, Safety and Environment Plan (HSEP) for the Edward-Wakool Selected Area (Watts et al. 2014c) has been developed in line with the current M&E Plan, but will be revised after indicators to be monitored in the Edward-Wakool Selected Area have been finalised. The HSEP is in line with Charles Sturt University policy and existing frameworks, including Work Health and Safety (WHS) Act 2011, Occupational Health and Safety Regulation, 2001 (NSW), Occupational Health and Safety Act, 1989 (ACT) and Occupational Health and Safety Regulations, 1991 (ACT). The plan describes the procedures and requirements for minimizing the risk of injury to persons and harm to the environment in relation to the LTIM Project.

Work Health and Safety (WHS) at CSU supports the identification, development and implementation of strategically based health and safety programs. These programs aim to ensure compliance with relevant health and safety legislation, as well as to assist managers and employees to maintain a workplace that is free from risk to health, safety and welfare and promotes staff health and wellbeing. These programs focus responsibilities and resources in the areas of accident and injury prevention, hazard removal and control, health and welfare preservation, the development of safe and healthy work practices, the promotion of health and safety awareness, the provision of training in safe and healthy work practices, the compliance with health and safety legislation and regulations, the rehabilitation of injured employees and consultative mechanisms.

All staff and students have a general responsibility in terms of the WHS Act (2011) to ensure a safe and healthy work environment. The broad parameters of these specific responsibilities are set out in the policy document Occupational Health, Safety and Welfare Objectives and Responsibilities.

To monitor and assist with the implementation of this policy, Occupational Health and Safety Committees have been established at each Campus pursuant to the provisions of the WHS Act 2011. Each Committee reports to the Executive Director, Division of Human Resources. The Presiding Officers of each OH&S Committee represent these committees on the University-wide Environment and Safety Management Committee established to coordinate occupational health and safety matters across the University.

Where Charles Sturt University has a presence at sites other than a designated campus, it is the responsibility of the management of that site, or the coordinating senior officer of the University in

regard to joint ventures, to ensure the operations at that site are compliant with applicable health and safety legislation.

The CSU Safety Management System and framework is centered on a number of policies, procedures and induction/training modules, including:

- Driving hours policy and Guidelines
- First aid policy
- Occupational Health & Safety Consultation Statement
- Occupational Health, Safety and Welfare Objectives and Responsibilities
- Occupational Health and Safety Policy
- Occupational Health, Safety and Welfare Objectives and Responsibilities
- Safety Management Plan Policy
- Accidents and incidents reporting
- CSU Risk Management Policy and Risk Register
- OH&S Induction and ELMO OHS Online Training

Charles Sturt University also has specific policies and procedures relating to the management of OH&S related risks including:

- New staff safety induction processes (ELMO)
- Ergonomics
- Manual Handling
- Electrical Safety
- Thermal comfort
- Accidents and incidents reporting

All persons in charge of workplaces at CSU coordinate the production of an annual Safety Management Plan by the commencement of May each year. This Plan details all planned WHS activities and targets for the current financial period. Longer term planning can also be incorporated where management of safety, needs to be staged over a number of years.

The HSEP includes information relating to the provision of safety information, the need for instruction, and the need for generic, specialist or on-the-job safety training in the coming year. The Plan includes objectives and targets to minimise risks resulting from hazards identified through observation, inspections, hazard reports, incident investigations and where changes occur to facilities or processes or through identified non-compliance with legislation, policies or standards. The planning and programming of risk assessments and risk control measures, including the production of administrative controls such as operating procedures are also included in the Plan when required. Emergency and contingency planning may also need development or improvement within the Plan.

Safety Management Plans form an essential part of the safety system at each workplace and active records of these plans are kept for the current plan and the previous four plans. Archived records to cover a span not exceeding 5 years are also kept.

The CSU team operates under the auspice of the Faculty of Science and will follow a number of faculty specific WHS policies and procedures through the delivery of this project. These include:

- Faculty of Science Risk Assessment Procedure (outlining the formal risk assessment process used by the Faculty of Science to ensure all activities conducted in on campus and off campus localities used for work, research or study implement controls to mitigate and/or reduce the risks of incidents, injury or damage

- Laboratory safety and standard operating procedures.
- Field work procedures, including the completion of project safety risk assessments to be completed and approved prior to any project field work being undertaken; in particular the project safety risk assessment covers potential hazards relating to field sites and their access as well as well as field activities (e.g. night trawls) and the controls in place to minimize risks
- Emergency response; the field work procedure includes a subset relating to the procedure that is to be followed in case of an emergency and will be detailed in the final HSEP; whilst working in the laboratory, staff are to follow existing building emergency procedures (these are detailed as part of new staff induction processes)
- More specific Job Safety and Environment Assessment (JSEA) for all laboratory and field activities if not covered under existing Faculty of Science procedures; specific standard operating procedures are developed for the project and will include a safety aspect component
- First aid training; the final HSEP will include a list of first aid training requirements, in particular for field work, as well as a record of staff first aid qualification; training records will be reviewed and updates on a quarterly basis as a minimum
- Incident reporting; the project team will follow CSU Incident Reporting and Management procedures which will be detailed in the final HSEP

All organisations sub-contracted by CSU with operate under CSU HSEP, with the exception of Fisheries NSW, which has developed a separate HSEP. Fisheries NSW will submit their HSEP to the project manager for review. As a requirement of CSU sub-contracting procedures Fisheries NSW HSEP is to be approved by the CSU project manager prior to NSW DPI commencing work on the project.

11 Budget

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Table 36. Summary of budget for Monitoring and Evaluation Plan for Edward-Wakool system LTIM Project 2014-15 financial year to the 2019-20 Financial Budget. Values shown are GST exclusive, except in final row and final column.

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Table 37. In-kind contributions of partner organisations

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Table 38 Schedule of Rates

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12 References

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13 Appendix B. Glossary

ADCP	Acoustic Doppler Current Profiler
ANAE	Australian National Aquatic Ecosystem Classification
ANOVA	Analysis of variance
CED	Cause and effect diagram
	Commonwealth environmental water
CEWH	Commonwealth Environmental Water Holder
CEWO	Commonwealth Environmental Water Office
CPUE	Catch-per-unit-effort
CSU	Charles Sturt University
DBH	Diameter at breast height
DO	Dissolved oxygen
DOC	Dissolved organic carbon
EWSSC	Edward-Wakool System Stakeholder Committee
EC	Electrical conductivity
ER	Ecosystem Respiration
FRP	Filterable reactive phosphorus
GLMM	Generalized Linear Mixed Effects Model
GPP	Gross Primary Production
HSP	Workplace Health and Safety Plan
LBA	Live Basal Area
LTIM Project	Long-Term Intervention Monitoring Project
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
MDMS	LTIM Project Monitoring Data Management System
M&E Plan	Monitoring and Evaluation Plan
Murray LLS	Murray Local Land Services
NATA	National Association of Testing Authorities
OEH	NSW Office of Environment and Heritage
PIA	Plant Area Index
SRA	Sustainable Rivers Audit
TN	Total nitrogen
TP	Total Phosphorus
YOY	Young-of-year