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UNIVERSITY OF CANBERRA

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# Commonwealth Environmental Water Office Long Term Intervention Monitoring Project

# Lower Lachlan river system

December 2015

UNIVERSITY OF CANBERRA

# Commonwealth Environmental Water Office

# Long Term Intervention Monitoring Project

# Lower Lachlan river system 2015 Annual Report

## Final: December 2015

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## Acronyms and abbreviations

| Accepted Acronym | Standard Term (capitalisation as specified) |
|---|---|
| ANAE | Australian National Aquatic Ecosystem |
| CEWH | Commonwealth Environmental Water Holder |
| CEWO | Commonwealth Environmental Water Office |
| CPUE | Catch per unit effort |
| GS | General Security |
| HS | High Security |
| IMEF | Integrated Monitoring of Environmental Flows |
| LLS | Local Land Services |
| LTIM Project | Long Term Intervention Monitoring Project |
| MDBA | Murray-Darling Basin Authority |
| M&E | Monitoring and Evaluation |
| MDMS | Monitoring Data Management System |
| SOP | Standard Operating Procedure |
| QA/QC | quality assurance / quality control |

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# Executive Summary

A single environmental watering action of 5,821 ML of Commonwealth (5000 ML) and NSW (821 ML) environmental water was monitored in the Lower Lachlan river system in 2014-15. The watering action protected natural tributary inflows from the mid Lachlan River through the river channel to Booligal Weir in spring 2014 (the target reach). The objectives of the watering action were to:

- preserve the integrity of small to medium unregulated flows through the Lachlan river system through spring-summer to provide natural cues for native fish to migrate and spawn.
- contribute to habitat access, fish condition, spawning and larval survival.

These contribute to the Basin Plan's environmental watering plan objectives by supporting natural tributary flows to provide outcomes for native fish communities in the mid to lower Lachlan River and the 2014-15 Basin annual environmental watering priority '*Enhance and protect refuge habitat: Native fish in the northern Basin'.* Two other planned actions targeting wetland vegetation in Murrumbidgil swamp and waterbirds in Booligal wetlands did not go ahead because the catchment and climate conditions were not appropriate for their delivery.

Stream flows (hydrology), stream metabolism and water quality (temperature, pH, dissolved oxygen, turbidity, conductivity, concentrations of nitrogen and phosphorus), fish (including larval fish), and the condition and diversity of vegetation were monitored to evaluate the outcomes of Commonwealth environmental watering actions. Monitoring effort was focussed on the target reach with the monitoring of vegetation extending across the entire Lower Lachlan river system.

Over the past five years, the Lower Lachlan river system experienced severe drought which resulted in a widespread decline in environmental conditions, particularly the native fish and vegetation communities. This was followed by whole of system flooding which, combined with environmental watering, lead to some observed improvements in environmental conditions. More recently, a return to dry conditions has prevailed with the most recent eighteen months providing below average rainfall accompanied by declining water in storage and flow in the river. At the beginning of the 2014-15 water year a combined total of almost 115 GL of environmental water entitlements (Commonwealth, NSW Riverbank and Rivers Environmental Restoration Program) was held for the Lachlan River Valley. The volume of Commonwealth environmental water in accounts at the start of 2014-15 was 43.5 GL.

The 5,821 ML of Commonwealth and NSW environmental water was delivered over 10 days starting on the 4th September 2014, as a small in-channel fresh. The flows peaked at Willandra Weir on the 7$^{th}$ September and the fresh reached as far as the Great Cumbung Swamp (Cumbung Swamp hereafter) on the 5$^{th}$ October. The timing of the fresh was determined by tributary inflows and it was expected that further spring flows would have supported the delivery of subsequent watering actions. This did not occur and there was only one small event in 2014-15. We would not have expected a stand-alone event of 5,821 ML delivered over 10 days in early September to be sufficient to fully meet many of the watering objectives. Early spring water temperatures are too cold to trigger spawning of flow cued fish species and the single flow event was too short to meaningfully contribute to fish condition and larval survival. We would have expected the event to preserve the integrity of small unregulated flows through the Lachlan river system, provide a small short term increase in habitat access, contribute to a flow regime (providing flow variability and hydraulic diversity) that is suitable for non flow cued fish species to spawn, and provide water to the central reed beds of the Cumbung Swamp.

The watering action resulted in the water level rising by up to 1.5 m between Willandra Weir and Booligal with smaller water level rises occurring between Booligal and the Cumbung Swamp. The integrity of the flow was preserved with natural patterns of flow occurring as the water moved through the system. Natural temperatures were also maintained with no noticeable increase or decrease in temperatures as the flows passed monitoring sites. Approximately 80% of the fresh in the river during early spring was Commonwealth environmental water and therefore the responses associated with this fresh are attributable to the Commonwealth environmental watering action.

Environmental watering had no discernible effect on water quality in the target reach. The delivery of environmental water was associated with a reduction in gross primary production (GPP) and ecosystem respiration (ER) in the target reach. GPP and ER provide an indication of the basal (primary) resources of the local food web. Both GPP and ER increased in the weeks following the environmental watering event and peaked in late October by which time the river had returned to relatively low flow conditions. It is likely that the response of GPP and ER is caused by the dilution of phytoplankton and organic matter as well as a reduction in light reaching the photosynthetically active surfaces in the channel. However the flow independent increase in both GPP and ER following the environmental watering event means that data from more flow events will be required to address the effects of environmental flows on these parameters in any definitive way.

Riverine fish communities were surveyed at ten in-channel sites between Wallanthery and Hillston during autumn 2015. Seven native species and three alien species were captured. The most abundant species were bony herring, eastern gambusia, common carp, Murray cod and golden perch. New recruits (juveniles) were detected in two native longer-lived species at multiple sites (bony herring and Murray cod), and three native short-lived species (Australian smelt, carp gudgeon and un-specked hardyhead). No golden perch or freshwater catfish new recruits were captured. New recruits of all alien species were captured (common carp, goldfish and eastern gambusia). Our data show that the target reach supports a greater proportion of native fish than do other reaches in the Lower Lachlan river system.

Although there was a healthy proportion of native species captured within the target reach, the Overall Condition of the fish community, calculated using three indices (Nativeness, Expectedness, Recruitment) according the Sustainable Rivers Audit (SRA) protocol in the target reach is rated as 'Very Poor'. This rating is because a number of native species predicted to have historically occurred within the area were absent and because recruitment within the population (the number of juvenile fish) was observed to be very low.

Targeted monitoring of larval fish occurred fortnightly at three sites between October and December 2014. Larval Murray cod, flat headed gudgeon and Australian smelt were caught during the sampling period with all three species exhibiting signs of growth. Freshwater catfish and carp gudgeon were the other native fish larvae detected, but only a few individuals were caught at a few sites. The species which had larval fish caught are generally thought to spawn independently of flow. No larvae were caught for species known to spawn in response to flow events (such as golden perch). Interestingly, larval common carp were not caught in most of the larval fish sampling which is a positive outcome for the reach. The larval fish data suggests that the environmental watering event produced conditions that were suitable for a number of native fish to spawn but did not trigger a flow-driven spawning event. To encourage spawning of flow cued species under similar conditions (i.e. where further tributary flows do not occur), it would be worth considering delivering water of a suitable temperature from storage as a follow up watering event.

The contribution of Commonwealth environmental water to native fish communities in the Lachlan River cannot be quantified based on a single year of data. Nonetheless, the presence of small individuals in the size structure of the native fish populations in 2015 indicates that the conditions in spring 2014 had been suitable for the spawning and recruitment of some non-flow cued spawners.

Vegetation health and diversity were surveyed at 12 sites in November/December2014 and in May 2015. The 2014-15 environmental watering action did not specifically target vegetation but the water reached the central reed beds of the Cumbung swamp and is likely to have been beneficial. A second planned watering action was not delivered because the natural triggers did not occur. The vegetation data provides baseline data against which the outcomes of future watering events can be compared. At the end of the 2014-15 water year, the flood-dependent vegetation communities within the floodplains, wetlands and billabongs of the Lower Lachlan river system in 2014-15 were dominated by terrestrial species. There were very few amphibious species (species that are adapted to a range of water levels, from damp to flooded) observed in the surveys. The Lower Lachlan river system oscillates between dry and wet phases and the vegetation community adapts to the prevailing conditions. Our data show that the flood dependent vegetation communities are currently in a dry phase.

There appeared to be a consistent general improvement in the condition of floodplain trees between summer and autumn with the canopy showing less dead material and canopy foliage cover generally increasing. These patterns are likely to be driven by factors such as the change to a cooler season and rainfall just before the May sampling. Future analysis with longer term Long Term Intervention Monitoring (LTIM) project data is expected to separate these effects from the outcomes of environmental flow.

More than 60% of understory plant species recorded were native, indicating a reasonably high degree of vegetation nativeness across sites. Recruitment of trees was observed at most sites, but a noticeable pressure on the success of recruitment was observed to be grazing by both stock and feral animals. This will affect the ability of environmental watering to achieve outcomes for vegetation regeneration in the catchment.

The key findings from the 2014-15 monitoring that can be used to inform future management of environmental water in the Lower Lachlan river system were:

- The small fresh delivered as the environmental watering action in the Lower Lachlan river system protected tributary inflows and provided part of the flow regime that was suitable for a number of native fish species to spawn. The event was not sufficiently large enough, nor timed correctly (the water was too cold and it was too early in the season), to encourage spawning of flow cued spawning species. For future management where specific species are targeted, a larger volume would be required within an ideal temperature range to encourage spawning of flow cued spawning species. This is likely to require a release from storage unless tributary inflows are matched to the requirements. For example flows targeting spawning of golden perch in the Lower Lachlan river system Selected Area should occur from late October onwards and ensure that water temperature is suitable (i.e. above 23°C) and flow variability and suitable increases in river height are achieved.

- It is acknowledged that there is a risk of the potential to promote a common carp spawning event in response to the release of fish flows in warmer months. Continuing to restrict the flow from inundating wetlands during the warmer months, would most certainly continue to contribute to the low level of spawning response of common carp observed in 2014.
- The vegetation communities throughout the Lower Lachlan river system are dominated by terrestrial species at the end of the 2014-15 water year. This indicates that the flood-dependent vegetation communities are currently in a dry phase. Future monitoring of watered sites may provide insight into the presence of other flood dependent vegetation species and for the capacity of the vegetation communities to return to a healthy wet phase. This information will contribute to the development of future watering options for wetland vegetation outcomes.
- Grazing presents a significant pressure on the recruitment of trees. This will affect the ability of environmental watering to achieve outcomes for long lived vegetation species in the catchment.

# 1 Introduction

A single environmental watering action of 5,821 ML of Commonwealth (5,000 ML) and NSW (821 ML) environmental water was delivered to the Lower Lachlan river system in the 2014-15 water year. The watering action protected natural tributary inflows from the mid Lachlan River through the river channel to Booligal Weir (the target reach) in spring 2014. The objectives of the watering action were to:

- preserve the integrity of small to medium unregulated flows through the Lachlan river system through spring-summer to provide natural cues for native fish to migrate and spawn.
- contribute to habitat access, fish condition, spawning and larval survival.

These contribute to the Basin Plan's environmental watering plan objectives by supporting natural tributary flows to provide outcomes for native fish communities in the mid to lower Lachlan River and the 2014-15 Basin annual environmental watering priority '*Enhance and protect refuge habitat: Native fish in the northern Basin*'. Two other planned actions targeting wetland vegetation and waterbirds did not go ahead because the triggers for their delivery were not met.

The Long-Term Intervention Monitoring Project (LTIM Project) is the primary means by which the Commonwealth Environmental Water Office (CEWO) undertakes monitoring and evaluation of the ecological outcomes of Commonwealth environmental watering. Monitoring activities implemented within the LTIM Project to evaluate the outcomes of Commonwealth environmental watering actions in the Lower Lachlan river system in 2014-15 included the monitoring of stream flows (hydrology), stream metabolism and water quality (dissolved oxygen, temperature, pH, electrical conductivity, turbidity and nutrients), fish (including larval fish) and the condition and diversity of vegetation.

This report documents the first of five years of monitoring and evaluation of Commonwealth environmental watering in the Lower Lachlan river system. It describes the context in which the water was delivered, the environmental objectives of the watering action, the monitoring activities undertaken, and an evaluation of the outcomes of the watering action. These are presented in separate sections (Sections 2 to 5) of the report. The results of the monitoring and evaluation are used to inform future management of watering actions in the Lower Lachlan river system (Section 6). Technical reports covering each monitoring activity are included (Section 7).

This is the first year of a five year monitoring program and the first formal ecosystem monitoring program in the Lower Lachlan river system for more than 10 years. The analysis and interpretation of indicator data in this first year is qualitative, descriptive and reliant on graphics and field observations.

# 2 Lower Lachlan river system – Selected Area

The area of the Lower Lachlan river system (referred to as the Selected Area) identified as the focus for the LTIM Project is the western end of the Lachlan River, and extends from the outlet of Lake Brewster to the terminal Cumbung Swamp (Figure 1). It encompasses anabranches, flood runners, billabongs and terminal wetlands, such as Merrowie Creek, Booligal Wetlands and Lachlan Swamp but excludes Middle Creek and other creeks to the north. The river system is complex, with a diversity of in-channel and floodplain features that provide a variety of habitats for the species in the region. Flows and water levels are naturally variable and unpredictable providing a temporal complexity of habitats.

The Lachlan River catchment supports many flora and fauna listed as vulnerable or endangered under federal or NSW state legislation, including the Sloane's froglet, Australian painted snipe, osprey, blue-billed duck and the fishing bat. The Selected Area comprises the majority of the Lachlan River endangered ecological community (NSW Fisheries Scientific Committee, 2003). In addition, the Cumbung Swamp is one of the most important waterbird breeding areas in eastern Australia, and supports one of the largest stands of river red gums in NSW.

The Lower Lachlan river system has previously been identified as being in poor ecosystem health as part of the Murray-Darling Basin Authorities Sustainable Rivers Audit (SRA) in both 2012 and 2008 (Murray–Darling Basin Authority, 2012;  Murray–Darling Basin Commission, 2008). This evaluation was primarily driven by an extremely poor native fish community (with low native species richness and poor recruitment) and poor hydrological condition. Macroinvertebrate communities were assessed as being in moderate condition whereas the physical form of the river and the vegetation were assessed as being in poor to moderate condition, depending on the timeframe of assessment.

The millennium drought resulted in large areas of river red gums becoming stressed and the wetland vegetation community shift to one dominated by terrestrial, drought tolerant species (Barma Water Resources, Thurtell & Wettin, 2011). Some recovery of the wetlands and rivers has been observed since 2010, attributed to natural flow events and environmental watering actions.

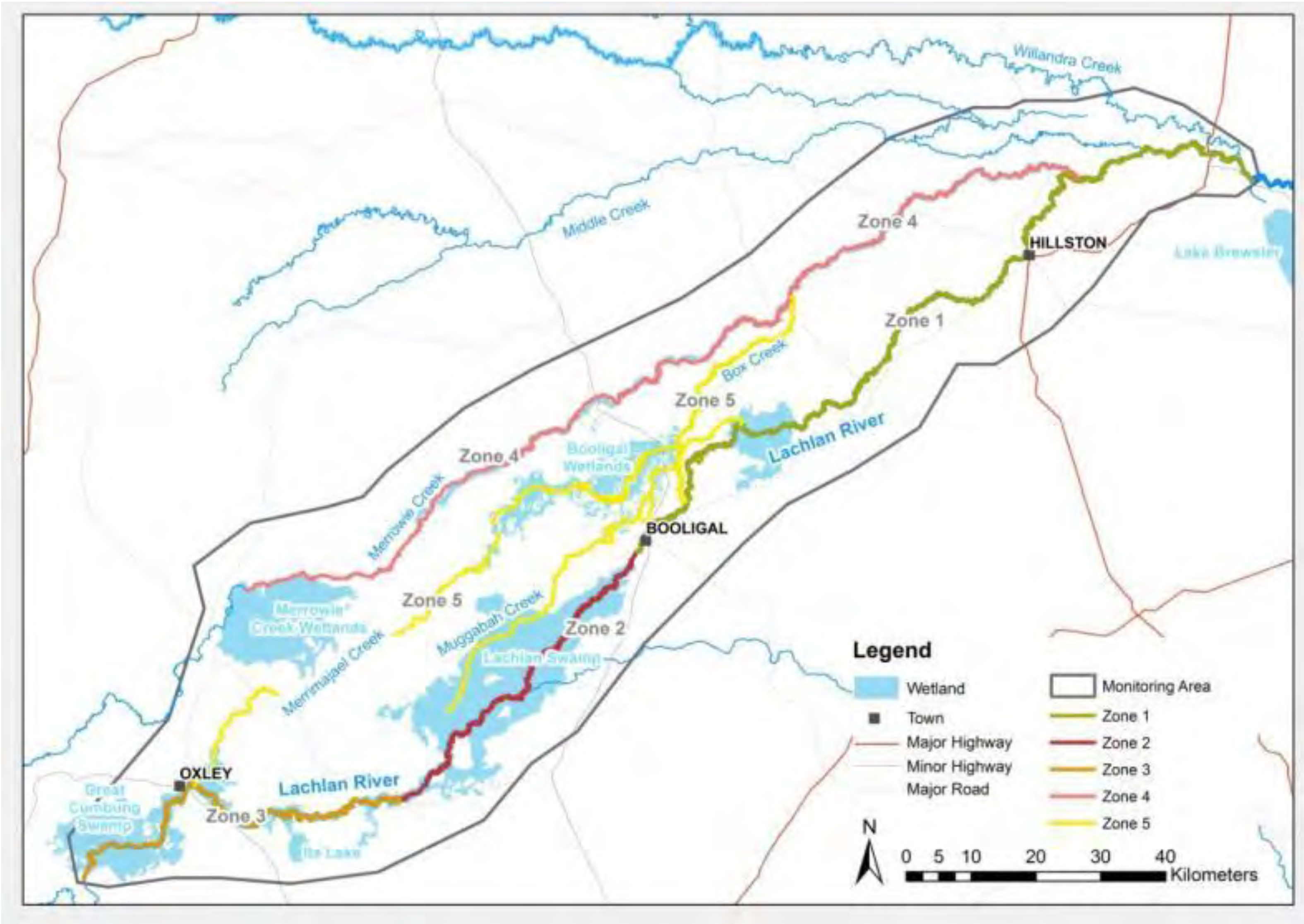


*Figure 1. Map of the Lower Lachlan river system showing the region that is the focus for the LTIM Project*

# 3 Commonwealth environmental watering actions 2014-15

## 3.1 Climate and water context

Environmental watering actions are determined by a combination of catchment and climate conditions as well as the volume of water holdings. These also provide the context in which the ecosystem responses to watering can be evaluated. Environmental conditions experienced in the Lachlan River catchment for the five years preceding the 2014-15 watering season included a long period of drought followed by regional floods. The hydrograph for the Lachlan River at Booligal (Figure 2) illustrates the climatic conditions experienced in the catchment prior to the 2014-15 watering season. The end of the Millennium drought produced extreme drought in which the river ceased to flow. The drought was broken by widespread rain and wet conditions prevailed in 2010-11. A return to drier conditions in 2011-12 saw flows decline in the river. In 2012 significant catchment-wide rain led to localised flooding and filling of floodplain wetlands and depressions. This was followed by whole of system flooding, dam spills, translucent releases following floods, and over-bank flows in the Lower Lachlan over a nine month period. The most recent eighteen months have provided below average rainfall accompanied by declining water in storage and flow in the river.

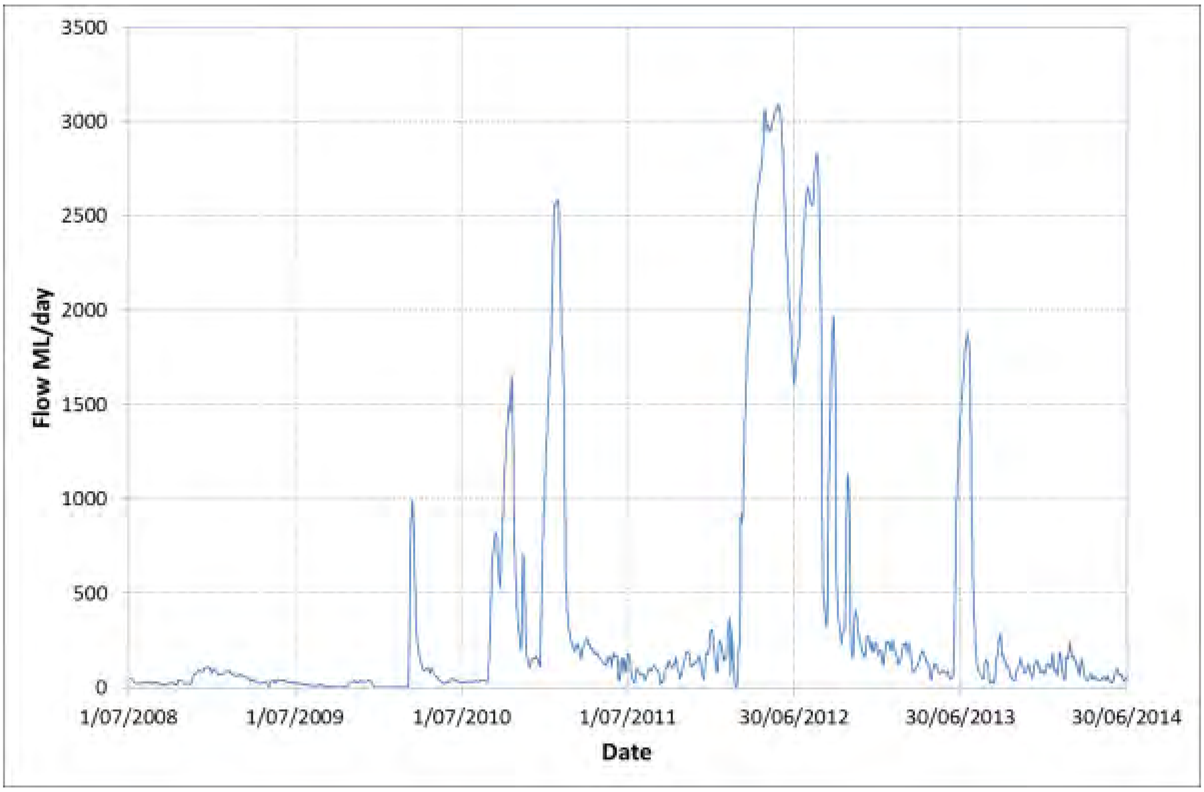


*Figure 2. Hydrograph for the Lachlan River at Booligal illustrating the climatic conditions experienced in the catchment between January 2009 and June 2014 prior to the delivery of the 2014-15 environmental water.*

Environmental water in the Lachlan River comprises both Commonwealth government holdings of water entitlements (Commonwealth environmental water) and NSW Government-held licensed environmental water (NSW Environmental Water Holdings). At the beginning of the 2014-15 water year the total Commonwealth environmental water entitlements held for the Lachlan River Valley was 87.8 GL (Table 1), with the Long-Term Average Annual Yield of these entitlements being 37.4 GL. The volume of Commonwealth environmental water in accounts at the start of 2014-15 was 43.5 GL.

*Table 1: Environmental water holdings in the Lachlan River Valley as at 1 July 2014*

| | WATER HOLDINGS (GL) BY ENTITLEMENT TYPE | | |
|---|---|---|---|
| **WATER HOLDER** | **HIGH SECURITY** | **GENERAL SECURITY** | **UNREGULATED** |
| CEWH | 0.90 | 86.92 | |
| NSW Riverbank | 1.0 | 24.10 | |
| Rivers Environmental Restoration Program | 0.93 | 0.47 | 0.18 |
| **TOTAL** | **2.8** | **111.39** | **0.18** |

## 3.2 2014-15 Watering Actions

Three watering actions were planned for the 2014-15 water year. These were:

1) Up to 2,500 ML of Commonwealth and NSW environmental water for Merrimajeel Creek and Murrumbidgil Swamp. This joint action was designed to support the survival and growth of wetland vegetation and habitat values for waterbirds and other water dependent species (Water Use Minute 10012).
2) Up to 5,000 ML of Commonwealth and NSW environmental water for Booligal Swamp to support waterbird breeding. This joint action was designed to support a bird breeding event to completion if a significant colonial nesting waterbird event occurred as a consequence of water delivery to Merrimajeel Creek/Booligal wetlands (Water Use Minute 10012).
3) Up to 5,821 ML of Commonwealth and NSW environmental water for the Lachlan River from Forbes to below Booligal to protect unregulated tributary inflows to provide natural cues to native fish communities (Water Use Minute 10013).

The first two planned watering actions did not go ahead because the triggers for delivery were not met; the progress of replenishment flows were not sufficient to trigger the delivery of water to Merrimajeel Creek and Murrumbidgil Swamp and a bird breeding event did not occur. Only the third planned watering action was delivered.

### 3.2.1 Design and Objectives

The 2014-15 Commonwealth environmental watering action was designed to protect small to medium sized natural tributary flows in spring-summer from extraction in the mid Lachlan River downstream to Booligal Weir. Thus flow from the Boorowa River, Belubula River and Mandagery Creek would be kept within the river channel providing natural cues to native fish communities. The objectives of the action were to:

- preserve the integrity of small to medium unregulated flows through the Lachlan river system through spring-summer to provide natural cues for native fish to migrate and spawn.
- contribute to habitat access, fish condition, spawning and larval survival.

These contribute to the Basin Plan's environmental watering plan objectives by supporting natural tributary flows to provide outcomes for native fish communities in the mid to lower Lachlan River and the 2014-15 Basin annual environmental watering priority '*Enhance and protect refuge habitat:*

*Native fish in the northern Basin'*. The action (as proposed) is described in Water Use Minute 10013 and summarised in Table 2.

*Table 2. The planned 2014-15 Commonwealth environmental watering actions as described in Water Use Minute 10013 (8 August 2014) and subsequent revisions (10013-02 and 10013-03).*

| DESCRIPTION | DETAILS |
|---|---|
| **Location** | Lachlan River from Forbes to below Booligal |
| **Action** | Protect small to medium tributary inflows from extraction in the mid Lachlan River downstream to Booligal weir |
| **Objective** | To protect the integrity of natural chemical signals from the unregulated tributaries (Boorowa, Belubula and Mandagery) to provide natural cues to native fish communities |
| **Flow component** | Fresh |
| **Volume** | 5,000 ML Commonwealth environmental water and 821 ML NSW environmental water |
| **Trigger** | natural inflows of between 3,000 and 15,000 ML over 3-14 days at Forbes |
| **Ecological outcomes** | Natural cues for native fish to migrate and spawn<br>Contribution to habitat access, fish condition, spawning and larval survival. |
| **Proposed hydrograph** | Event dependent. No flow shape specified because the flow is a protection of tributary inflows |
| **Accounting location** | Debited from the environmental accounts at Willandra Weir (412038)<br>Delivered to Booligal (412005) |

### 3.2.2 Implemented Watering Action

The total volume of environmental water delivered to the Lower Lachlan river system in 2014-15 was 5,821 ML made up of 5,000 ML of Commonwealth water and 821 ML of NSW water. According to the water accounts, environmental water delivery commenced on the 4$^{th}$ September 2014 and ceased on the 14$^{th}$ September 2014. Water was delivered through the main channel of the Lachlan River by-passing Lake Brewster to maintain natural water quality. The pattern of delivery is shown in Figure 3, illustrating the relative contribution of Commonwealth water to the flow in the river. Approximately 80% of the spring fresh that occurred in September was produced by Commonwealth water.

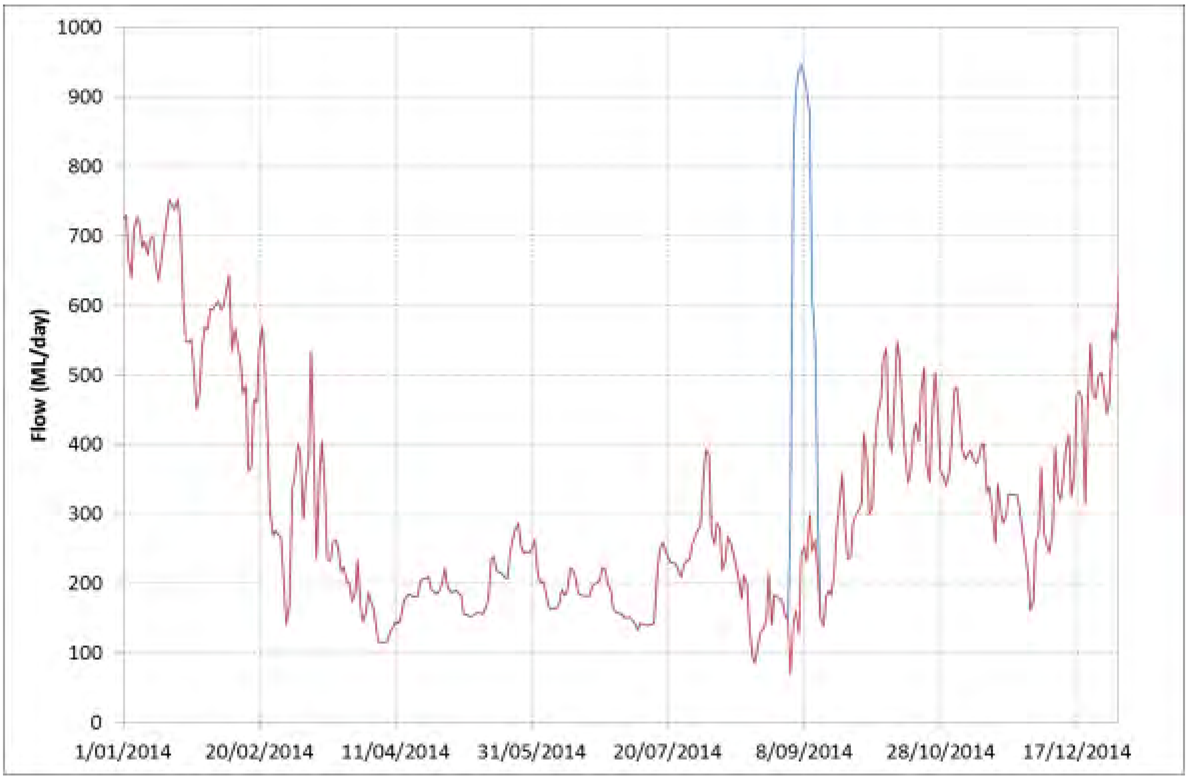


*Figure 3. Flow at Willandra weir illustrating environmental water (blue) delivered to the Lower Lachlan river system during 2014-15. Commonwealth environmental water is shown in blue with normal river flows (including licensed delivery of water) shown in red.*

# 4 Evaluation of watering actions

The 2014-15 watering action targeted the channel of the Lower Lachlan river system to explicitly provide benefits for fish, but implied within this watering action are outcomes for water quality and stream metabolism. Outcomes for vegetation and hydrological connectivity were not specifically targeted but were anticipated as it was an end of system flow which resulted in wetting of the core reed beds in the terminal wetlands.

## 4.1 Evaluation Approach

The LTIM Project has two levels of evaluation:

1) Basin Evaluation which is conducted across seven catchments (Selected Areas) within Murray Darling Basin (MDB) to evaluate the contribution of Commonwealth environmental watering to the objectives of the Murray-Darling Basin Authority's (MDBA) Environmental Watering Plan; and
2) Selected Area evaluation which is conducted to evaluate ecological outcomes of Commonwealth environmental watering at each of the seven Selected Areas.

Basin evaluation is being led by the Monitoring and Evaluation (M&E) Advisors and is designed to address a set of specific evaluation questions (Level 1 and Level 2 questions) which are described in (Gawne *et al.*, 2014). Selected Area evaluation is being led by M&E Providers. While monitoring programs should be designed to be specific to each evaluation scale, to avoid designing two parallel monitoring programs, the indicators used to evaluate ecological outcomes within the Selected Area of the Lower Lachlan river system uses the same indicators as used in the Basin evaluation. Within the Lower Lachlan river system, Basin evaluation needs have been prioritised and define the majority of the monitoring effort.

The indicators required to be monitored to inform Basin Evaluation for the Lower Lachlan river system Selected Area are:

- Ecosystem type.
- Fish (river).
- Fish (larvae).
- Stream metabolism.
- Hydrology (river).
- Vegetation condition and diversity.

Decapods, which are likely to be by-catch from implementing the Fish (river) monitoring, will be included in the Selected Area Evaluation and Turtles may also be similarly included if time and resources permit. The monitoring of waterbird breeding and frog populations and diversity are to be implemented if and when required by the Commonwealth Environmental Water Office.

The Selected Area evaluation will focus on assessing the achievements of Commonwealth environmental watering in relation to expected outcomes specific to the Lachlan river system Selected Area. The evaluation is based on analysis of the monitoring data collected and information/data about the watering action to answer evaluation questions (Level 3 questions, Table 3).

*Table 3. Lower Lachlan river system Selected Area evaluation question and indicators. Questions have been defined as short or long term evaluation questions.*

| Theme | LEVEL 3 EVALUATION QUESTIONS | SHORT- /LONG-TERM | INDICATORS |
|---|---|---|---|
| Ecosystem type (Basin Evaluation only) | What did Commonwealth environmental water contribute to sustainable ecosystem diversity? | Long | Ecosystem type |
| | Were ecosystems to which Commonwealth environmental water was allocated sustained? | Long | |
| | Was water delivered to a representative suite of ecosystem types? | Long | |
| Vegetation | What did Commonwealth environmental water contribute to vegetation community diversity? | Short<br>Long | Vegetation diversity<br>Hydrology (river and wetland) |
| | What did Commonwealth environmental water contribute to vegetation species diversity? | Short<br>Long | |
| | What did Commonwealth environmental water contribute to populations of long-lived organisms? | Long | Tree community and extent<br>Hydrology (river) |
| | What did Commonwealth environmental water contribute to condition of floodplain and riparian trees? | Short | Tree community and extent<br>Hydrology (river) |
| | What did Commonwealth environmental water contribute to vegetation condition and reproduction? | Short | Tree community and extent<br>Hydrology (river) |
| Fish | What did Commonwealth environmental water contribute to fish community resilience and condition? | Long | Fish (species, abundance and size frequency in rivers)<br>Hydrology (river)<br>Water quality (temperature and dissolved oxygen) |
| | What did Commonwealth environmental water contribute to native fish abundance and diversity? | Long | |
| | What did Commonwealth environmental water contribute to native fish populations in the lower Lachlan River catchment? | Long | |
| | What did Commonwealth environmental water contribute to native fish survival? | Short | |
| | What did Commonwealth environmental water contribute to native fish reproduction? | Short | |
| | What did Commonwealth environmental water contribute to native fish abundance? | Short | |
| | What did Commonwealth environmental water contribute to native fish recruitment? | Short | |
| | What did Commonwealth environmental water contribute to maintenance of drought refugia for native fish? | Short | |
| | What did Commonwealth environmental water contribute to native larval fish growth and survival? | Short | |
| | What did Commonwealth environmental water contribute to fish community resilience? | Short | |
| Waterbirds (Option) | What did Commonwealth environmental water contribute to waterbird populations? | Long | Waterbirds – breeding (colonial nesting species)<br>Hydrology (wetlands)<br>Vegetation type and condition |
| | What did Commonwealth environmental water contribute to waterbird chick fledging? | Short | |
| | What did Commonwealth environmental water contribute to waterbird survival? | Short | |
| | What did Commonwealth environmental water contribute to waterbird breeding? | Short | |
| Stream Metabolism | What did Commonwealth environmental water contribute to patterns and rates of primary productivity? | Short<br>Long | Stream metabolism<br>Hydrology (river) |

| Theme | LEVEL 3 EVALUATION QUESTIONS | SHORT- /LONG-TERM | INDICATORS |
|---|---|---|---|
| | What did Commonwealth environmental water contribute to patterns and rates of decomposition? | Short<br>Long | Stream metabolism<br>Hydrology (river) |
| Water Quality | What did Commonwealth environmental water contribute to temperature regimes? | Short<br>Long | Water quality (dissolved oxygen, temperature)<br>Hydrology (river and wetland) |
| | What did Commonwealth environmental water contribute to dissolved oxygen levels? | Short<br>Long | |
| Other Vertebrates (Option) | What did Commonwealth environmental water contribute to other vertebrate populations? | Long | Frogs<br>Turtles (species and abundance)<br>Hydrology (river) |
| | What did Commonwealth environmental water contribute to other vertebrate species diversity? | Long | |
| | What did Commonwealth environmental water contribute to other vertebrate reproduction and recruitment? | Short | |
| | What did Commonwealth environmental water contribute to other vertebrate survival? | Short | |
| | What did Commonwealth environmental water contribute to refuges? | Short<br>Long | |
| Hydrology | What did Commonwealth environmental water contribute to hydrological connectivity? | Short<br>Long | Hydrology (river) |
| | What did Commonwealth environmental water contribute to sediment transport? | Long | |
| | What did Commonwealth environmental water contribute to biotic dispersal? | Long | |

## 4.2 Monitoring Sites

The Lower Lachlan river system Selected Area has been partitioned into five spatially, geomorphologically and hydrologically distinct river channel zones at a broad landscape scale (Table 4 and Figure 4). These zones are relevant to fish and stream metabolism. The inadequacy of regional vegetation mapping means that it is difficult to determine if the zones are also relevant to vegetation and the entire selected area is defined as a single zone for vegetation.

Monitoring of water quality and stream metabolism, as well as the adult and larval fish community is conducted in Zone 1. This zone is most likely to receive Commonwealth environmental water most regularly during the LTIM Project and is most likely to produce a detectable response. Monitoring of vegetation occurs across the Selected Area.

*Table 4. Zones for the Lower Lachlan river system Selected Area relevant to fish and stream metabolism indicators*

| ZONE | LOCATION | CHARACTER |
|---|---|---|
| Zone 1 | Lachlan River channel between Brewster Weir and Booligal | This zone contains relatively high abundances of the required target species of fish (with potentially limited numbers of freshwater catfish). Situated in the upper reaches of the Selected Area, this zone is likely to receive Commonwealth environmental water every year of the LTIM Project. |
| Zone 2 | Lachlan River channel between Booligal and Corrong | Located downstream of Booligal Weir. Similar to Zone 1 in geomorphology. This zone differs hydrologically because of water diversion and extraction above Booligal Weir. |
| Zone 3 | Lachlan River channel between Corrong and its terminus in the Great Cumbung Swamp | This zone starts at the point at which the mid-Lachlan wetland system re-enters (drains into) the main Lachlan channel, providing an increase in riverine productivity, stimulating food webs. The fish assemblages are currently dominated by alien species. |
| Zone 4 | Merrowie Creek | A distributary creek that receives intermittent regulated stock and domestic flows as well as targeted environmental flows at Lake Tarwong and Cuba Dam. No data exist on the fish assemblage present within Merrowie Creek. |
| Zone 5 | Torriganny, Box, Merrimajeel and Muggabah Creek system | The largely ephemeral, effluent streams of the Merrimajeel and Muggabah system north of the Lachlan main channel and Merrowie creek. This complex system is fundamentally different to main channel zones acting more like linear wetlands that are likely to only retain water for limited periods, during and following environmental flow deliveries. |

## 4.3 2014-15 Monitoring activities

The monitoring activities implemented to evaluate the outcomes of Commonwealth environmental watering actions in 2014-15 included the monitoring of stream flows (hydrology), stream metabolism and water quality, adult and larval fish and the condition and diversity of vegetation. The lack of natural triggers to deliver environmental water for waterbirds or more extensive system watering, meant that the watering action implemented did not trigger the need to monitor waterbirds and other vertebrates. The monitoring sites (Figure 4) and timing of monitoring were specific to the indicators being monitored (Table 5).

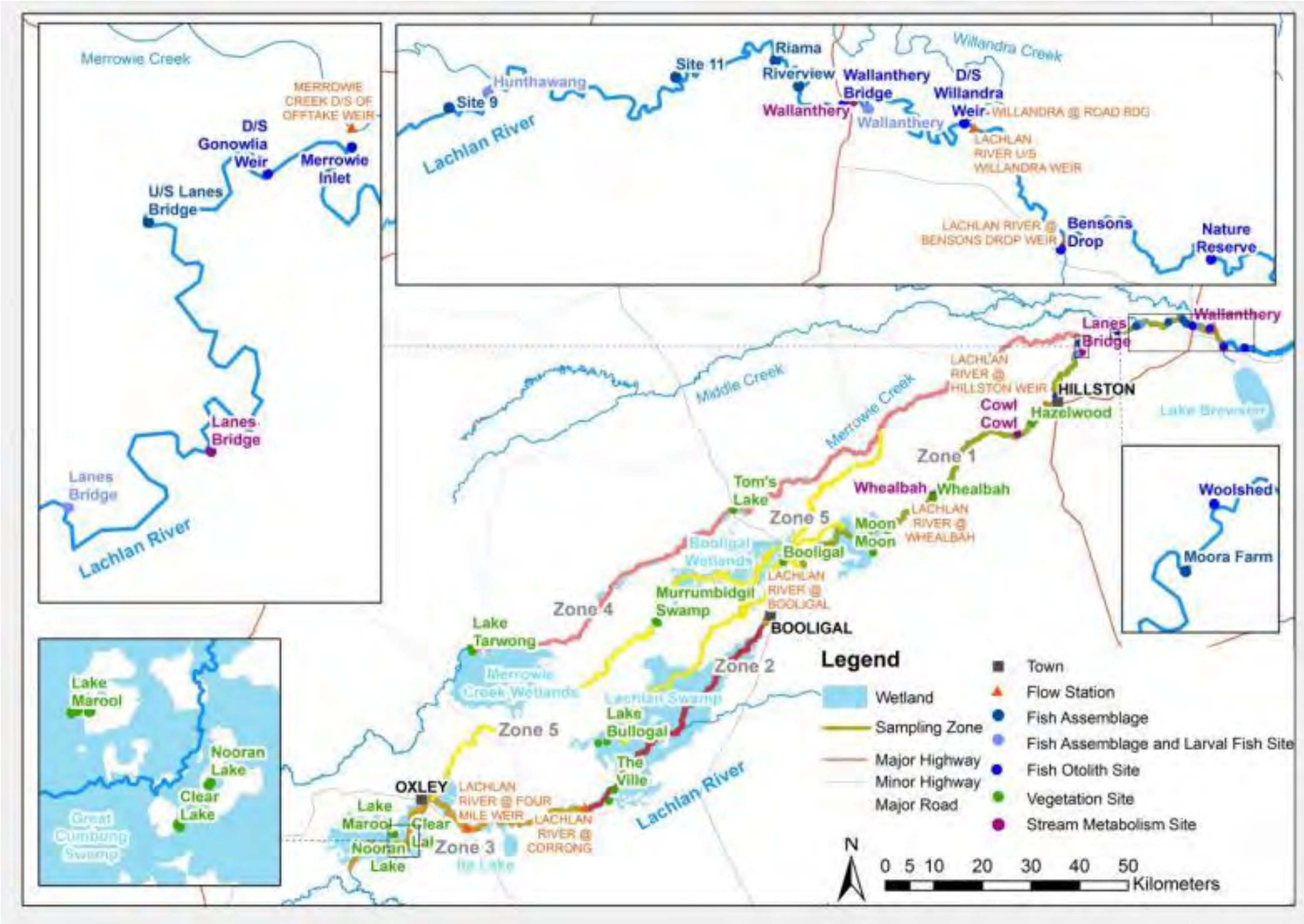


*Figure 4. Map showing the monitoring sites within zones of the Lower Lachlan river system Selected Area.*

*Table 5. Indicators monitored and timing of monitoring activities for sites on the Lower Lachlan river system Selected Area in 2014-15. Provisional Australian National Aquatic Ecosystem classifications (Brooks et al., 2013) have been provided as the Ecosystem Type for each site. These are defined as: Rp 1.4 Permanent lowland streams; Pt1.1.1 Intermittent river red gum floodplain swamp; Pt1.2.1 Intermittent black box floodplain swamp; Lt2.1 Temporary floodplain lakes*

| SITE | ECOSYSTEM TYPE ANAE CLASSIFICATION | HYDROLOGY (RIVER) | STREAM METABOLISM | ADULT FISH | LARVAL FISH | VEGETATION |
|---|---|---|---|---|---|---|
| TIMING | | CONTINUOUS | CONTINUOUS | ANNUAL (MARCH) | FORTNIGHTLY FROM 15/10/14 TO 10/12/14 | NOV/DEC 2014 AND MAY 2015 |
| ***Zone 1*** | | | | | | |
| Wallanthery | Rp 1.4 | water level | ✓ | ✓ | ✓ | |
| Riverview | Rp 1.4 | | | ✓ | | |
| Riama | Rp 1.4 | | | ✓ | | |
| Site 11 | Rp 1.4 | | | ✓ | | |
| Hunthawang | Rp 1.4 | | | ✓ | ✓ | |
| Site 9 | Rp 1.4 | | | ✓ | | |
| Moora Farm | Rp 1.4 | | | ✓ | | |
| U/S Lanes Bridge | Rp 1.4 | flow and water level | | ✓ | | |
| Lanes Bridge | Rp 1.4 | | ✓ | ✓ | ✓ | |
| Hillston | Rp 1.4 | flow and water level | | ✓ | | |
| Cowl Cowl | Rp 1.4 | water level | ✓ | | | |
| Whealbah | Rp 1.4 | flow and water level | ✓ | | | ✓ |
| Moon Moon | Lt2.1 | | | | | ✓ |
| Hazelwood | Pt1.1.1 | | | | | ✓ |
| Whealbah | Pt1.1.1 | | | | | ✓ |

| SITE | ECOSYSTEM TYPE ANAE CLASSIFICATION | HYDROLOGY (RIVER) | STREAM METABOLISM | ADULT FISH | LARVAL FISH | VEGETATION |
|---|---|---|---|---|---|---|
| TIMING | | CONTINUOUS | CONTINUOUS | ANNUAL (MARCH) | FORTNIGHTLY FROM 15/10/14 TO 10/12/14 | NOV/DEC 2014 AND MAY 2015 |
| *Zone 2* | | | | | | |
| Lake Bullogal | Pt1.1.1 | | | | | ✓ |
| The Ville – *non-woody plot* | Rp 1.4 | | | | | ✓ |
| The Ville – *other woody transect* | Pt1.2.1 | | | | | ✓ |
| *Zone 3* | | | | | | |
| Corrong | Rp 1.4 | flow and water level | | | | |
| Clear Lake | Pt1.1.1 | | | | | ✓ |
| Four Mile Weir | Rp 1.4 | flow | | | | |
| Nooran Lake – *non-woody plot* | Pt1.1.1 | | | | | ✓ |
| Nooran Lake – *other woody transect* | Lt2.1 | | | | | ✓ |
| Lake Marrool | Lt2.1 | | | | | ✓ |
| *Zone 4* | | | | | | |
| Lake Tarwong – *non-woody plot* | | | | | | ✓ |
| Lake Tarwong – *other woody transect* | Pt1.1.1<br>Pt1.2.1 | | | | | ✓ |
| Toms Lake | Pt1.2.1 | | | | | ✓ |
| *Zone 5* | | | | | | |
| Booligal | Pt1.2.1 | flow and water level | | | | ✓ |
| Murrumbidgil Swamp | Pt1.1.1 | | | | | ✓ |

## 4.4 Hydrology

Hydrological data inform the analysis and evaluation of outcomes for all ecological indicators. Specific hydrological evaluation questions are not defined.

The 2014-15 environmental watering event was a relatively small fresh (5,821 ML over 10 days, 4-14 September at Willandra Weir) with a peak flow just slightly more than 900 ML/day at Willandra Weir on 7th September (Figure 5). Peak flows reached Whealbah (740 ML/day) on the 12th September and were (naturally) attenuated significantly downstream of Whealbah. A flow of 124 ML/day finally reached Four Mile Weir in the Cumbung Swamp on the 5th October. The delivery of Commonwealth environmental water resulted in the water level rising by up to 1.5 m between Willandra and Booligal with smaller rises in water level evident at Corrong, below Booligal. The fresh resulted in small volumes of water reaching parts of the Cumbung Swamp, predominantly providing water to the main channels and central reed beds of the swamp.

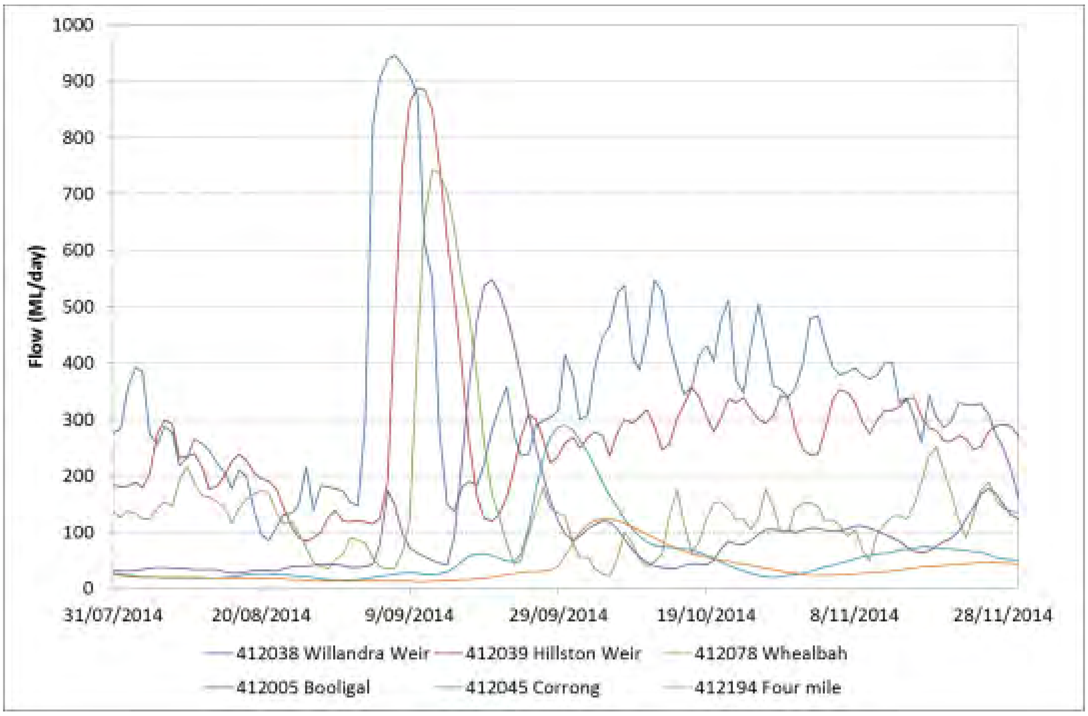


*Figure 5. Passage of the 2014-15 environmental watering event through the Lower Lachlan river system. Data are from http://waterinfo.nsw.gov.au/) for gauging sites within the Selected Area.*

## 4.5 Stream metabolism and water quality

Environmental flow delivery has the potential to affect water quality, through mobilising carbon and nutrients off the flood plain or from upstream, and stream metabolism. Stream metabolism measures the flux of oxygen over a day/night cycle and uses this to estimate: gross primary production (GPP) which is the amount of energy being fixed by photosynthesis; and ecosystem respiration (ER) which is the amount of carbon being processed by consumers, sometimes referred to as decomposition. To assess the contribution of Commonwealth environmental water to water quality and stream metabolism, the following short term (one year) and long term (five year) questions are being tested:

- What did Commonwealth environmental water contribute to patterns and rates of decomposition?
- What did Commonwealth environmental contribute to patterns and rates of primary productivity?

Water quality parameters (temperature, pH, dissolved oxygen, turbidity, conductivity, concentrations of nitrogen and phosphorus) were recorded using a combination of automatic loggers and manual point measures at four riverine sites on the Lower Lachlan river system Selected Area. The variables measured can be used to address the specific evaluation questions around water quality and stream metabolism (Table 3). The responses of water quality and stream metabolism to this single pulse provide some preliminary information on the effects of environmental flows in this system but must be treated with caution. There are numerous confounding factors, including time of year and antecedent conditions, which may be important in determining the presence, and magnitude, of any response. There was no observable effect of environmental watering on the spot measurements of water quality within the target reach (see Section 7.2 for more details).

The delivery of environmental water was associated with a reduction in GPP and ER in the target reach (Figure 6, the dotted line shows the timing of the environmental watering event). Both GPP and ER increased in the weeks following the environmental watering event and peaked in late October when the river returned to relatively low flow conditions. It is likely that the response of GPP and ER is caused by the dilution of phytoplankton and organic matter as well as a reduction in light reaching the photosynthetically active surfaces in the channel. The relatively rapid increase in both GPP and ER after the flow suggests that disruption of biofilms and removal of organic matter are not likely mechanisms underpinning this response. However the flow independent increase in both GPP and ER following the environmental watering event means that data from more flow events will be required to address the effects of environmental flows on these parameters in any definitive way.

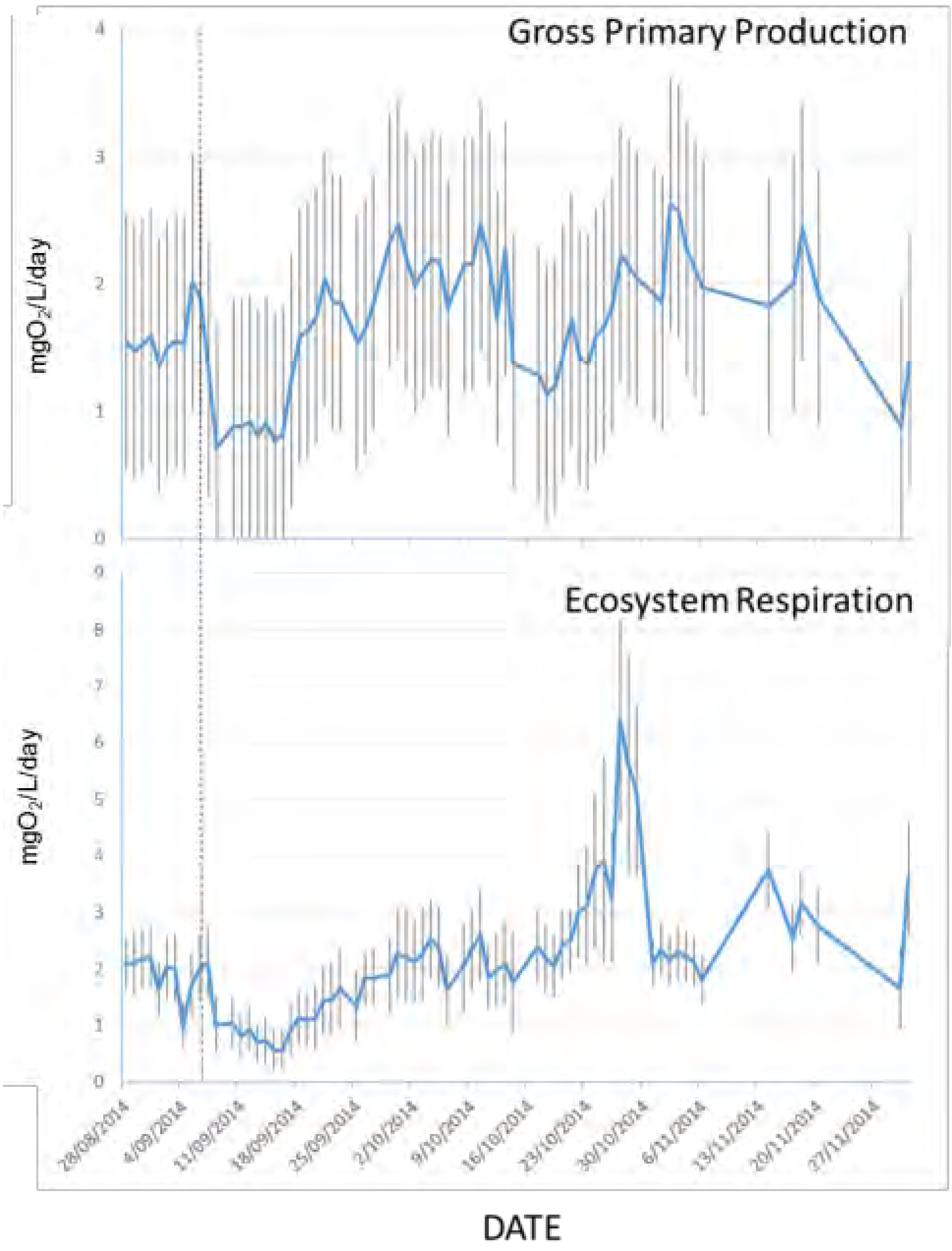


*Figure 6. Gross Primary Production (GPP) and ecosystem respiration (ER) (in mg O2/L/day) during the 2014/15 watering event in the Lower Lachlan river system. The vertical dotted line shows the timing of the environmental watering event. The solid vertical lines are the standard deviations of the fitted estimates for the daily values of GPP and ER.*

## 4.6 Fish

*Figure 7. Examples of large-bodied native fish encountered during sampling in the Lachlan River in 2014-2015. (Clockwise from bottom left) Juvenile Murray cod, freshwater catfish, Murray cod, golden perch, boat-electrofishing launch and a typical sampling site under low flow conditions*

Fish are an integral component of aquatic ecosystems. In Australian dryland rivers, unique ecological communities have adapted to extreme hydrological regimes, and long periods of low flow and drought can be interrupted by extensive flooding. However, the majority of fish communities within these systems have undergone severe declines, largely as a result of altered flow regimes caused by river regulation.

A common goal of many environmental flow regimes is the maintenance and enhancement of the native fish community. This strategy is based on the premise that aspects of the flow regime are linked to key components of the life history of fish, including pre-spawning condition and maturation, movement cues, spawning cues and behaviour, and larval and juvenile survival. Since the strength of recruitment is largely driven by spawning success and growth and survival of young, understanding how the flow regime influences the early life history of fishes is critical to managing fish populations.

The 2014-15 Commonwealth environmental watering action was designed to produce outcomes for native fish by contributing to natural cues for native fish to migrate and spawn as well as contributing to habitat access, fish condition and larval survival. As the event protected tributary inflows, it could be matched to naturally occurring events in the catchment.

### Fish community

To assess the contribution of Commonwealth environmental water to the riverine fish community, the following short term (one year) and long term (five year) questions are being tested:

**Short-term (one-year) questions:**

- What did Commonwealth environmental water contribute to native fish community resilience?

- What did Commonwealth environmental water contribute to native fish survival?

**Long-term (five-year) questions:**

- What did Commonwealth environmental water contribute to native fish populations?
- What did Commonwealth environmental water contribute to native fish diversity?

The fish community was surveyed at 10 riverine sites using boat electrofishing, large and small mesh fyke nets, bait traps and opera house nets. The variables measured can be used to address the specific evaluation questions around native fish community's resilience and survival, fish populations and fish species diversity (Table 3). Monitoring of adult fish in 2014-15 is the first of five years of monitoring and therefore provides a benchmark and description of the fish community in abundance, biomass and community health in the Lower Lachlan river system Selected Area. Data from more than one year of monitoring are required to answer the evaluation questions.

A total of 2,551 fish comprising seven native and three alien species were captured. In order, bony herring, eastern gambusia, common carp, Murray cod and golden perch were the most abundant species, respectively, although Murray cod, common carp, golden perch and bony herring contributed the greatest overall biomass in 2015, respectively. New recruits (juveniles) were detected in two native longer-lived species at multiple sites (bony herring and Murray cod), and three native short-lived species (Australian smelt, carp gudgeon and un-specked hardyhead). No golden perch or freshwater catfish new recruits were captured. New recruits of all alien species were captured (common carp, goldfish and eastern gambusia).

The Overall Condition of the fish community, according to the SRA (Davies *et al.*, 2008; Davies *et al.*, 2012) condition protocol, is rated "Very Poor", with variable scores from three sub-indices: *Nativeness* is rated "Good", *Expectedness* was "Very Poor" and *Recruitment* was "Extremely Poor ". The fish community of the target reach is different from that previously observed across the entire lowland zone of the Lachlan River. The target reach supports a greater proportionate abundance and biomass of native fish whereas the broader region is dominated by alien species; previous data collected across the broader geographic scale rated *Nativeness* for the lowland zone of the Lachlan River as "Very Poor" in 2006 (Davies *et al.*, 2008), "Poor" in 2009 (Davies *et al.*, 2012) and "Very Poor" in 2012 (DPI Fisheries unpublished data).

The size structure of the native fish populations indicates that the conditions in 2014-15 were suitable for spawning and recruitment of some non-flow cued spawners. Six native species predicted to have historically occurred within the area were not detected in this study, and additional remediation activities beyond water delivery (such as stocking or translocation) may be required to restore them to the system, if threatening processes are identified and addressed to support such measures.

### Spawning and larval fish

To assess the contribution of Commonwealth environmental water to native fish spawning and recruitment the following short term and long term questions are being tested:

**Short-term (one year) evaluation questions:**

- What did Commonwealth environmental water contribute to native fish reproduction in the Lower Lachlan river system?
- What did Commonwealth environmental water contribute to native larval fish growth in the Lower Lachlan river system?

***Long-term (five year) evaluation questions:***

- What did Commonwealth environmental water contribute to native fish populations in the Lower Lachlan river system?
- What did Commonwealth environmental water contribute to native fish species diversity in the Lower Lachlan river system?

Larval fish were sampled fortnightly between mid-October and mid-December 2014 using drift nets and light traps set at three sites, Wallanthery, Hunthawang and Lanes Bridge. The timing of sampling aimed to follow the release of Commonwealth environmental water and to coincide with the known spawning windows of six 'representative' target species. Monitoring of larval fish in 2014-15 is the first of five years of monitoring and therefore provides a benchmark and description of the fish community composition and relative abundance in the Lower Lachlan river system Selected Area. Data from more than one year of monitoring are required to answer the evaluation questions. Detection and relative abundance of larval fish for each species will be used to determine native fish reproduction. Larval fish length will be used to assess growth, though without aging, age: length ratios could not be calculated to confirm growth, so this interpretation should be treated with caution. The variables measured can be used to address the specific evaluation questions around native fish reproduction and survival, native fish populations and native fish species diversity (Table 3).

A total of 536 larval fish were captured across the five sampling events of 2014 comprising five native species (Murray cod, flat-headed gudgeon, Australian smelt, freshwater catfish) and two alien fish species (eastern gambusia and common carp).

The results of the first year of monitoring indicate that expected outcomes for the flow release, in terms of providing suitable cues and access to habitat for spawning as well as larval growth and survival, were partially met. Spawning was observed for non-flow dependent species; however, there was no evidence (eggs or larvae) of flow dependent species (golden perch) or bony herring spawning in September-December 2014 (young-of-year of the latter were captured in fish community sampling – see Fish community). Spawning of golden perch was not a specific aim of the 2014-15 flow release and therefore spawning of this species was not expected to occur in conjunction with the flow release.

*Figure 8. Murray cod and Australian smelt larvae in a collection sieve from a light trap set at Hunthawang on the Lower Lachlan river system.*

Murray cod were the most abundant species captured (by an order of magnitude) and were present at each site from sampling event 1 – 4, and were especially abundant during the second sampling event (end of October 2014). The timing of presence of Murray cod larvae found in this study was generally consistent with that previously found in other catchments. A general increase in mean length of larval Murray cod was found across the four sampling events, suggesting that survival and growth was occurring. Without aging, age: length ratios could not be calculated to confirm growth, so this interpretation should be treated with caution (similarly for other species below). The presence of eel-tailed catfish larvae (1 per site) at two sites suggests that conditions were suitable for spawning of this species in the target reach. Although the contribution of Commonwealth environmental water to the spawning at this stage is impossible to quantify, this is a positive result, as the western population of this species has been declared as endangered.

The general increase in mean lengths of flat-headed gudgeon and Australian smelt in the first few sampling events indicate that in channel conditions were suitable for growth and development. A reduction in mean lengths in later sampling events indicates that in channel conditions facilitated multiple spawning events for both species. These results are somewhat expected as flat-headed gudgeon and Australian smelt are capable of spawning multiple times over an extended period.

While not an objective set for the 2014-15 watering action, the outcome was consistent with current understanding of spawning requirements of golden perch. Generally, golden perch are believed to spawn in response to water level increases and water temperatures above 19$^{o}$C and temperatures of greater than 23°C are often quoted as optimal. Considering this, water temperatures during the release of the fish flow in September 2014 (approximately 15°C) are likely to have been too low to promote spawning of this species. If future flows are targeting spawning of golden perch in the Lower Lachlan river system Selected Area, flows should occur from late October onwards and ensure that water temperature is suitable (i.e. above 23°C). This may mean that dam releases are required unless tributary inflows are matched to these requirements.

Our results indicate that the fish flow released in 2014 did not provide suitable conditions for significant spawning of common carp. This is likely because of the timing (water temperatures at the low end of the threshold for common carp) and the peak being within channel meant lack of inundation of wetlands (suspected carp recruitment hotspots). It is acknowledged that there is a risk of the potential to promote a common carp spawning event in response to the release of fish flows in warmer months. Continuing to restrict the flow from inundating wetlands during the warmer months, would most certainly continue to contribute to the low level of spawning response of common carp observed in 2014.

## 4.7 Vegetation

The condition, type and diversity of riparian and wetland vegetation communities are strongly influenced by the frequency and extent of inundation. The 2014-15 Commonwealth environmental watering event was not specifically targeted at vegetation outcomes. The monitoring of vegetation in 2014-15 therefore provides baseline data against which the outcomes of future watering events can be compared. The baseline data when considered against historical data can also help to inform the scale, frequency and timing of future environmental water delivery required to restore wetland vegetation communities. At the time of sampling all sites were dry. The last watering of the sites occurred during the large scale watering action in 2012/13.

The condition and diversity of vegetation in both woodland tree communities and non-tree wetland communities was surveyed at 12 sites during November/December 2014 and in May 2015. The variables measured can be used to address the specific evaluation questions around community diversity, species diversity and vegetation condition (Table 3). Therefore this section includes descriptions of species richness, understorey cover (in combination these will be used in future years to provide measures of diversity), tree condition and recruitment across the monitored sites.

### 4.7.1 Non-tree wetland community

A total of 105 species were identified across the non-tree community sites during the two sampling periods. This number is conservative as it excludes grasses (individual species were not recorded) and also approximately 5% of taxa that could not be identified to species level accurately. The plant community was dominated by chenopods, woody shrubs and subshrubs that are terrestrial species adapted to dry conditions. Grasses (Poaceae spp.), brassicas (Brassicaceae spp.) and mallows (Malvaceae spp.) commonly occurred at most sites. Of the 105 species identified, slightly more than 60% were native.

The vegetation cover of all sites comprised predominantly terrestrial species. There were very few amphibious species (species that are adapted to a range of water levels, from damp to flooded) observed in the surveys, most likely reflecting the fact that it was several years since watering of any of the monitoring sites. This is to be expected as, the region oscillates between dry and wet phases and, historically, the vegetation communities also move between dry and wet communities. The sites surveyed display a reasonably high degree of nativeness with more than 60% understorey species identified being native. This is likely to be an overestimate as the grasses were not identified to species level and grasses would normally be one of the main contributors of non-native species. However, field observations were that few grass species were present at each site, so the overestimate is likely to be small.

### 4.7.2 Woodland Tree Community

A total of 95 species were identified across the tree community plots during the two sampling periods. This number excludes grasses (individual species were not recorded) and an additional approximately 5% of species that were unable to be identified accurately. Like the non-tree community, the understorey of the tree community was dominated by chenopods; terrestrial species adapted to dry conditions. Species of Asteraceae were the next most abundant.  Of the 95 species identified, around 75% were native species with the same caveats noted with regard to nativeness as those above.

Understorey vegetation cover within the non-tree community was generally less than 20% at most sites with the temporary lakes and red gum swamps displaying very low vegetation cover (and a high proportion of bare ground). An increase in vegetation cover occurred at most sites between November/December 2014 and May 2015 most likely linked to seasonal patterns and recent rain within the catchment.

There were changes in the proportion of dead canopy at most sites between the 2014 and 2015 sampling most changes suggesting a slight improvement in canopy health. The reasons for this are yet to be determined. The foliage cover canopy openness similarly improved over the sampling period. Overall the tree stands at all sites surveyed were mostly in Intermediate condition (using the condition metrics of the NSW Office of Environment and Heritage environmental flow monitoring program Bowen, 2013) with a few sites (Murrumbidgil Swamp river red gums and Lake Tarwong black box) in Intermediate/poor condition in terms of percent dead canopy (Table 6)

All sites had some seedlings/saplings present, except for Lake Bullogal where stocking density was high. Observations suggest that grazing pressure was a factor in the number of seedlings and saplings persisting between sampling dates at a number of sites, although this was site specific. This is likely to render questions around the effects of environmental water for vegetation regeneration difficult to answer in the context of the LTIM project.

*Table 6. Tree condition metrics for the woodland vegetation community of the Lower Lachlan river system. The data are grouped according to provisional ANAE classification. BBX = Black box; RRG = River red gums; RC = River Cooba*

| SITE (n=2 unless otherwise noted) | AVERAGE FOLIAGE COVER (M2) | | | | | | AVERAGE % DEAD CANOPY | | AVERAGE % LIVE BASAL AREA | | TREE CONDITION | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | | | 2015 | | | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| | BBX | RC | RRG | BBX | RC | RRG | | | | | | |
| **Pt1.1.1: Intermittent River red gum floodplain swamp** | | | | | | | | | | | | |
| **Clear Lake** | | | 14.1 | | | 19.3 | 18 | 16 | 96 | 95 | I | I |
| **Hazelwood** | | 0.9 | 5.6 | | 1.7 | 7.6 | 31 | 24 | 64 | 64 | I | I |
| **Lake Bullogal** | | | 12.0 | | | 15.5 | 23 | 30 | 81 | 81 | I | I |
| **Lake Tarwong RRG** | | | 25.8 | | | 30.4 | 29 | 22 | 94 | 94 | I | I |
| **Murrumbidgil Swamp (n=4)** | | | 5.2 | | | 7.3 | 50 | 46 | 54 | 55 | I/P | I/P |
| **The Ville RRG** | 5.7 | 0.5 | 7.4 | 8.9 | 0.6 | 8.8 | 21 | 15 | 98 | 98 | I | I |
| **Whealbah** | | 2.6 | 18.0 | | 4.0 | 21.4 | 23 | 11 | 99 | 99 | I | I |

| SITE (n=2 unless otherwise noted) | AVERAGE FOLIAGE COVER (M2) | | | | | | AVERAGE % DEAD CANOPY | | AVERAGE % LIVE BASAL AREA | | TREE CONDITION | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | | | 2015 | | | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| | BBX | RC | RRG | BBX | RC | RRG | | | | | | |
| **Pt1.2.1 Intermittent black box floodplain swamp** | | | | | | | | | | | | |
| **Booligal** | 14.1 | 8.6 | | 14.9 | 8.6 | | 20 | 26 | 85 | 86 | I | I |
| **Lake Tarwong BBX** | 10.9 | | | 12.2 | | | 50 | 48 | 96 | 94 | I/P | I/P |
| **Tom's Lake** | 12.4 | 5.8 | | 16.4 | 8.6 | | 29 | 22 | 99 | 99 | I | I |
| **Lt2.1: Temporary floodplain lakes** | | | | | | | | | | | | |
| **Lake Marrool** | | | 3.9 | | | 4.8 | 23 | 22 | 85 | 84 | I | I |
| **Moon Moon Swamp** | | | 6.3 | | | 7.8 | 29 | 29 | 79 | 80 | I | I |
| **Nooran Lake** | | | 7.8 | | | 10.8 | 29 | 28 | 92 | 92 | I | I |

G= good condition; I = Intermediate Condition, I/p = Intermediate / poor condition

## 4.8 Evaluation of watering actions

There are two components to the Selected Area evaluation of the ecological outcomes of Commonwealth environmental watering in the Lower Lachlan river system in 2014-15. The first is an evaluation of the ecological outcomes in relation to the specific objectives of the watering actions and the second is evaluation of the watering outcomes framed in the context of specific evaluation questions defined in Dyer et al., 2014. Approximately 80% of the fresh in the river during early spring was Commonwealth environmental water and therefore the responses associated with this fresh are attributable to Commonwealth environmental watering.

### 4.8.1 Evaluation of specific objectives

The objectives of the 2014-15 watering actions were to protect the integrity of natural chemical signals from the unregulated tributaries (Boorowa, Belubula and Mandagery) to provide natural cues to native fish communities. The expected ecological outcomes were natural cues for native fish to migrate and spawn and a contribution to habitat access, fish condition, spawning and larval survival. The small in-channel fresh of 5,821 ML delivered over 10 days in spring 2014 was made up of water sourced from the unregulated tributaries. The target reach for the delivery of water was equivalent to Zone 1 which was the focus of monitoring activities Figure 4. The objectives and expected outcomes are unpacked and evaluated using a combination of data collected during monitoring and expert opinion in the following sections.

### Preserve the integrity of the small to medium unregulated flows through the Lachlan river system through spring-summer

The 2014-15 environmental watering action in the Lower Lachlan river delivered water sourced from unregulated tributaries via the main channel over 10 days in spring (September) 2014. The integrity of the flow was preserved with natural attenuation patterns observed in the hydrographs as the flow passed through the system (Figure 5). Natural temperatures were also maintained with no noticeable increase or decrease in temperatures as the flows passed monitoring sites.

### Provide natural cues for native fish to migrate and spawn

The cues for native fish to migrate and spawn include the timing of the flow (water temperatures and day length), changes in water level and flow velocity (including the rates of rise and fall), and the chemical signature of the water.

Golden perch are the main species within the Lower Lachlan river system that spawn in response to flow. They are noted for displaying opportunistic spawning behaviour (Ebner, Scholz & Gawne, 2009), but the literature suggests that they require water temperatures of greater than 19oC (King *et al.*, 2005; Stuart & Jones, 2006) in the southern Murray-Darling Basin and temperatures of 23°C are often quoted as optimal for spawning (Lake, 1967; Roberts, Duivenvoorden & Stuart, 2008). It is also thought that water level changes of 0.5 m would be sufficient to trigger migration prior to spawning. While the environmental watering event resulted in a water level change of up to 1.5 m, we would not have expected water temperatures in the Lower Lachlan river system in early September to be sufficiently warm to provide cues for golden perch to migrate and spawn. Water temperatures in early September were around 14 degrees and golden perch larvae were not detected in the larval fish monitoring. Thus on its own, the environmental watering action would not be expected to provide the cues for flow respondent species to migrate and spawn, but it is noted subsequent tributary inflows were expected that would have provided flows more appropriate to support spawning. These flows did not occur.

Murray cod, flat headed gudgeons and Australian smelt do not depend on flow to migrate and spawn. Murray cod are known to spawn in October/November and increasing water temperatures are considered to be the key driver of spawning time (Humphries, 2005; Koehn & Harrington, 2006). Temperatures are also important for flat headed gudgeons and Australian smelt, with spawning reported once temperatures exceed 15°C (Milton & Arthington, 1985; Llewellyn, 2007). We would have expected these species to have spawned in the river irrespective of the provision of environmental water, but the provision of a small naturally occurring fresh would provide flow variability and changes in hydraulic character that which are known to be beneficial to fish. Larval Murray cod, flat headed gudgeons and Australian smelt were detected in the larval fish monitoring.

Specific monitoring of the ‘chemical cues’ was not undertaken. Measurements of stream metabolism indicated a reduction in both Gross Primary Productivity (GPP) and Ecosystem Respiration (ER) during the environmental watering event. GPP and ER provide an indication of the basal (primary) resources of the local food web. The reduction observed only occurred during the flow event and did not persist once flows receded. We do not know how this fits into the range of responses that would occur in the Lower Lachlan river system, but it is likely that such changes are a natural response to freshes in early September, when water temperatures are low. Further years of monitoring will enable us to develop a better understanding of the responses.

### Contribute to habitat access

The small fresh caused water level changes of up to 1.5 m and were contained wholly within the channel. It is expected that this will have provided a small increase in habitat available to fish in the reach by providing sufficient water depth for fish to move through shallow sections of the river. An increase of up to 1.5 m would not have been sufficiently large to drown out the multitude of small weirs along the channel and as such the access to additional habitat would be limited by the spatial distribution of weirs.

### Contribute to fish condition, spawning and larval survival

We would not expect that a single small event of only 10 days in early spring would contribute to fish condition in any measurable way, nor would it trigger spawning in flow cued species (see above) or contribute to larval survival. It is noted that in planning the event, subsequent flows were expected that would have had a better chance at supporting spawning. For future management under similar climatic circumstances where the spawning of specific flow-cued species is targeted, providing a second flow peak within an ideal temperature range using releases from storage would be needed.

From the perspective of the fish community condition, it is noted that the event did not result in substantial carp spawning and as such there were no adverse effects for the condition of the fish community as a result of the environmental watering action.

## 4.8.2 Evaluation questions

This is the first year of a five year monitoring program established to address specific evaluation questions (Table 3). The watering event was not designed to produce the broad suite of outcomes associated with the evaluation questions and was limited to those relevant to fish condition, spawning and larval survival. Thus, there was not a strong detectable response of the monitored indicators in the Lower Lachlan river system Selected Area to the flow release in spring 2014 (Table 7). However, the data collected in 2014-15 provides a baseline for answering these questions in future years.

*Table 7. Summary of responses to evaluation questions for the Lower Lachlan river system Selected Area.*

| INDICATOR | EVALUATION QUESTION | RESPONSE |
|---|---|---|
| **Water Quality and Stream Metabolism** | What did Commonwealth environmental water contribute to patterns and rates of decomposition? | Reduction in consumption and productivity followed by an increase as flow receded. Likely a combination of dilution of phytoplankton and organic matter and a reduction in light reaching the photosynthetically active surfaces of the channel.<br>Future monitoring will enable a greater understanding of responses |
| | What did Commonwealth environmental contribute to patterns and rates of primary productivity? | |
| **Fish - community** | *Short-term (one year)* | |
| | What did Commonwealth environmental water contribute to native fish community resilience? | Indeterminate - Baseline data established |
| | What did Commonwealth environmental water contribute to native fish survival? | Indeterminate - Baseline data established |
| | *Long-term (five years)* | |
| | What did Commonwealth environmental water contribute to native fish populations? | Indeterminate - Baseline data established |

| INDICATOR | EVALUATION QUESTION | RESPONSE |
|---|---|---|
| | What did Commonwealth environmental water contribute to native fish diversity? | Indeterminate - Baseline data established |
| **Fish - reproduction** | *Short-term (one year)* | |
| | What did Commonwealth environmental water contribute to native fish reproduction in the Lower Lachlan river system? | Spawning of non-flow dependent fish species detected. No spawning of flow dependent species detected.<br>Future monitoring will enable a greater understanding of responses. |
| | What did Commonwealth environmental water contribute to native larval fish growth in the Lower Lachlan river system? | Cautionary results suggest larval growth observed for some native fish species.<br>Future monitoring will enable a greater understanding of responses. |
| | *Long-term (five years)* | |
| | What did Commonwealth environmental water contribute to native fish populations in the Lower Lachlan river system? | Indeterminate - Baseline data established |
| | What did Commonwealth environmental water contribute to native fish species diversity in the Lower Lachlan river system? | Indeterminate - Baseline data established |
| **Vegetation** | *Short-term (one year) and long-term (five years)* | |
| | What did Commonwealth environmental water contribute to vegetation species diversity? | Indeterminate – baseline data established. |
| | What did Commonwealth environmental water contribute to vegetation community diversity? | Indeterminate – baseline data established. |
| | *Short-term (one year)* | |
| | What did Commonwealth environmental water contribute to condition of floodplain and riparian trees? | Indeterminate – baseline data established. |
| | What did Commonwealth environmental water contribution to vegetation condition and reproduction? | Indeterminate – baseline data established. |
| | *Long-term (five years)* | |
| | What did Commonwealth environmental water contribute to populations of long-lived organisms? | Indeterminate – baseline data established. |

# 5 Additional relevant research in the Lower Lachlan river system Selected Area

Emily Belton did an Honours thesis at the University of Canberra, under the supervision of Fiona Dyer and Ben Broadhurst (University of Canberra) and Kim Jenkins (Charles Sturt University). The thesis was entitled "Diet and prey selectivity of larval Murray cod *Maccullochella peelii* (Mitchell 1938) in an upland and lowland river", and was done in conjunction with the larval fish survey.

This study examined the diet and prey selectivity of Murray cod larvae in target reach (Zone 1) of the Lower Lachlan river system (and an upland section of the Murrumbidgee River). Gut content analysis was used to examine diet composition of Murray cod larvae collected using drift nets and light traps. Prey availability was determined by sampling the pelagic (open water) and epibenthic (at the sediment water interface) microinvertebrate community and then comparing these findings to the diet composition of larval Murray cod to calculate prey selectivity. Cyclopoid copepods (a type of small crustacean) were the most important dietary item for larval Murray cod in the Lower Lachlan river system. These species are primarily found in epibenthic habitats.

Microinvertebrates in epibenthic habitat were found to occur in considerably higher densities and have a distinct community composition compared with the pelagic community. Murray cod were found to exhibit selective feeding for large copepods. Results from this study and that of previous research suggest that larval Murray cod are capable of exploiting a large range of prey items. Abundances of suitable prey items were found to be adequate (based on previous aquaria trials) in the Lachlan River despite no large overbank flows in the period leading up to the field sampling. These findings support the premise that low summer flows in the main channel provide suitable conditions for the survival and recruitment of larval Murray cod.

# 6 Adaptive management

The key findings from the 2014-15 monitoring that can be used to inform future management of environmental water in the Lower Lachlan river system were:

- The delivery of 5,821 ML as a small fresh resulted in some water reaching the Great Cumbung Swamp. However, flows were substantially naturally attenuated downstream of Booligal weir and a small fraction of the delivered environmental water reached Corrong and beyond. It is already understood that achieving widespread benefit in the river and wetlands below Booligal requires far greater volumes of water.
- The small fresh delivered as the environmental watering action in the Lower Lachlan river system protected tributary inflows and provided flows that were suitable for a number of native fish species to spawn., but the event was not sufficiently large enough to encourage spawning of flow cued spawning species. For future management where specific species are targeted, a larger volume would be required within an ideal temperature range to encourage spawning of flow cued spawning species. This is likely to require a release from storage unless tributary inflows are matched to the requirements. For example flows targeting spawning of golden perch in the Lower Lachlan river system Selected Area should occur from late October onwards and ensure that water temperature is suitable (i.e. above 23°C) and flow variability and suitable increases in river height are achieved.
- The current monitoring program for fish is focused on Zone 1 and does not assess the interaction between off-channel and in-channel fish community assemblages, and the associated role of water management in the lowland Lachlan catchment. Subsequently, extrapolation of the results of the current study is limited.
- Detecting spawning responses in the Lower Lachlan river system for flow-cued fish may be limited by the timing of the current sampling program (fortnightly sampling). Increased monitoring intensity (sampling weekly at a minimum) may be required to monitor spawning response of any events specifically targeted at golden perch or other flow cued spawning species.
- Any plans to water off-channel habitats for fish must have realistic expectations regarding floodplain species and their return. Future off-channel watering strategies should support long-term watering plans that will enable conservation stocking or translocation, and the subsequent re-establishment of resident populations of off-channel specialists.
- It is acknowledged that there is a risk of the potential to promote a common carp spawning event in response to the release of fish flows in warmer months. Continuing to restrict the flow from inundating wetlands during the warmer months, would most certainly continue to contribute to the low level of spawning response of common carp observed in 2014.
- The project team's capacity to determine growth and survival of larval native fish is limited by only having estimates of age:length ratios for the target species based on limited published studies. Daily aging of at least a subset of species is strongly recommended to be able to calculate age:length ratios (to be able to determine and compare growth and survival between years) and to accurately estimate spawning date. Samples from 2014 have been stored so that they can be used for aging should funds become available to facilitate this.

- Extrapolation of the results from the fish and stream metabolism monitoring is limited. The interactions between in-channel responses and wetland inundation are not being monitored and are likely to play a significant role in stream metabolic processes and fish recruitment.
- The vegetation communities throughout the Lower Lachlan river system are dominated by terrestrial species at the end of the 2014-15 water year. This indicates that the flood-dependent vegetation communities are currently in a dry phase. Future monitoring of watered sites may provide insight into the presence of other flood dependent vegetation species and for the capacity of the vegetation communities to return to a healthy wet phase. This information will contribute to the development of future watering options for wetland vegetation outcomes.
- Grazing presents a significant pressure on the recruitment of trees. This will affect the ability of environmental watering to achieve outcomes for long lived vegetation species in the catchment.

# 7 Appendices: Technical Reports

The following sections provide supplementary information and technical reports associated with the monitoring of each of the indicators from the Lower Lachlan river system LTIM Project.

## 7.1 Hydrology

This appendix provides additional detail associated with the monitoring and evaluation of riverine hydrology.

### 7.1.1 Methods

Mean daily discharge (ML/day) and daily mean 'stage' (water level as m Above Sea Level, ASL) data were obtained from the NSW WaterInfo site (http://waterinfo.nsw.gov.au/) for gauging sites within the Selected Area (Table 8). The selected gauging sites were those relevant to the locations at which monitoring activities were occurring as well as sites that could be used to illustrate the passage of Commonwealth environmental water through the entire river system. The location of the gauging sites is shown in Figure 9.

*Table 8. River monitoring sites and the source of hydrological data for use in evaluation*

| GAUGING STATION | HYDROLOGICAL ATTRIBUTES | RELEVANT SITES & INDICATORS |
|---|---|---|
| **412038 Lachlan River @ Willandra Weir** | Flow<br>Water Level | Benson's Drop: Riverine Fish; Turtles & Decapods<br>Wallanthery: Riverine Fish; Turtles & Decapods; Larval Fish; Stream Metabolism<br>Moora Farm: Riverine Fish; Turtles & Decapods |
| **412196 Lachlan River d/s Gonowlia Weir** | Water Level | Lanes Bridge: Riverine Fish; Turtles & Decapods; Stream Metabolism;<br>Hunthawang: Larval Fish |
| **412039 Lachlan River @ Hillston** | Flow<br>Water Level | Cowl Cowl: Riverine Fish; Stream Metabolism; turtles and Decapods<br>Hazelwood: Vegetation |
| **412078 Lachlan River @ Whealbah** | Flow<br>Water Level | Whealbah: Stream Metabolism; Vegetation |
| **412005 Lachlan River @ Booligal** | Flow<br>Water Level | Illustrates the passage of water |
| **412045 Lachlan River @ Corrong** | Flow<br>Water Level | Illustrates the passage of water |
| **412194 Lachlan River @ Four Mile Weir** | Flow<br>Water Level | Illustrates the passage of water |

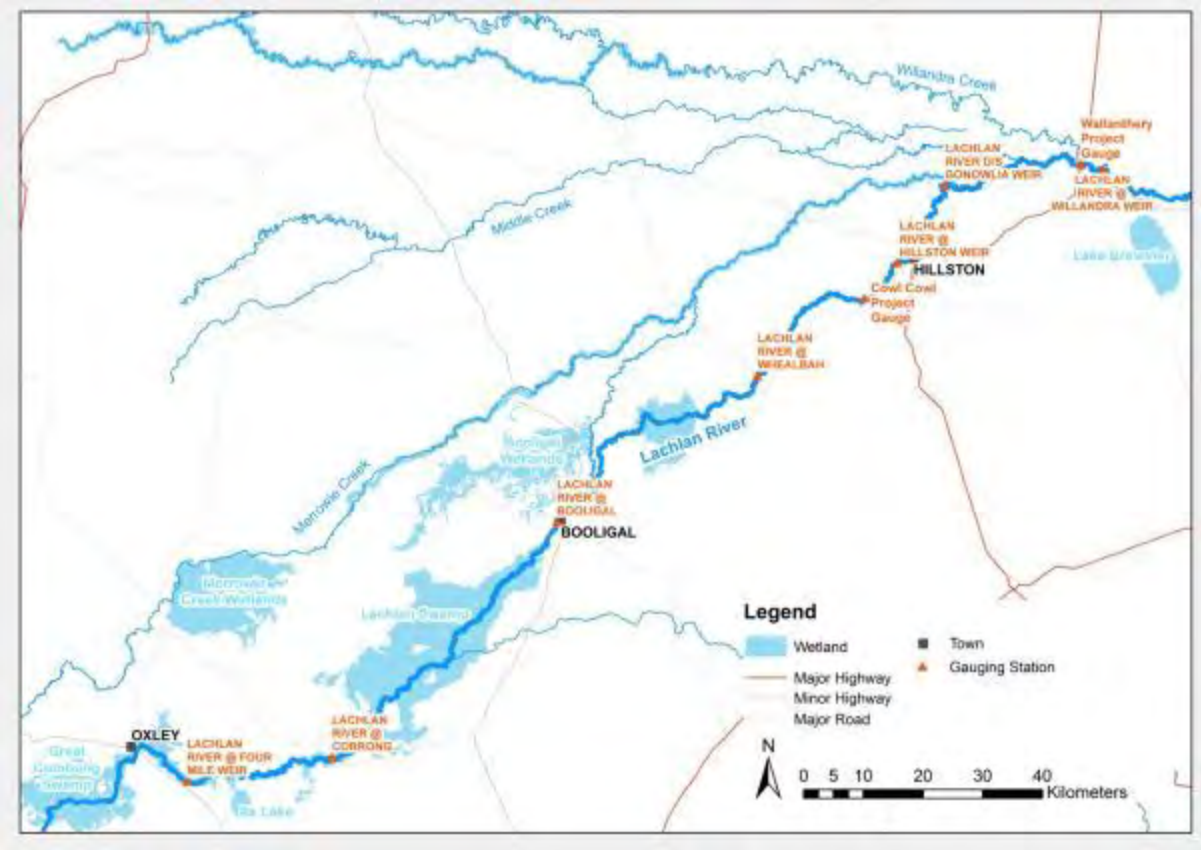


*Figure 9. Map of the Lower Lachlan Rivershowing the region that is the focus for the long term intervention monitoring investment from the Commonwealth Environmental Water Office including the location of the gauging stations.*

It is noted that the survey data for the zero gauge point for some sites on the NSW water info in relation to stage height is either inaccurate or has not been surveyed to an appropriate benchmark e.g. the height (relative to ASL) of the zero gauge at Corrong is lower in the landscape than that of the gauge at Four Mile Weir, yet Corrong is upstream of Four Mile Weir. As such changes in water level relative to a nominal baseline were plotted and the relative stage heights are the most important features of the changes in flow.

In addition to the NSW WaterInfo data, water level recorders were installed at Wallanthery and Cowl Cowl to provide relative changes in water level at these sites.

### 7.1.2 Results

#### Flow

The release began on 4 September 2014, and ended on 14 September 2014. The peak of the environmental water release was just slightly more than 900 ML/day at Willandra Weir on 7 September and peak flow reached Whealbah (740 ML/day) on the 12th September (Figure 10). Peak flows were attenuated significantly downstream of Whealbah and a flow of 124 ML/day finally reached Four Mile Weir in the Cumbung Swamp almost a month later, on the 5th October.

Changes in river level varied with channel dimensions and the influence of weirs along the river. Changes in water level within channel in Zone 1 was in the order of 1.2- 1.5 m (Cowl Cowl, Wallanthery, Lane's Bridge and Whealbah - Figure 11). By the time the water reached Corrong at the end of Zone 2, the water level change was just under 1 m. Rises in water level of 0.3-0.5 m were observed within the weir pools, such as Willandra, Hillston & Booligal in Zone 1 and Four mile weir in Zone 3 (Figure 13).

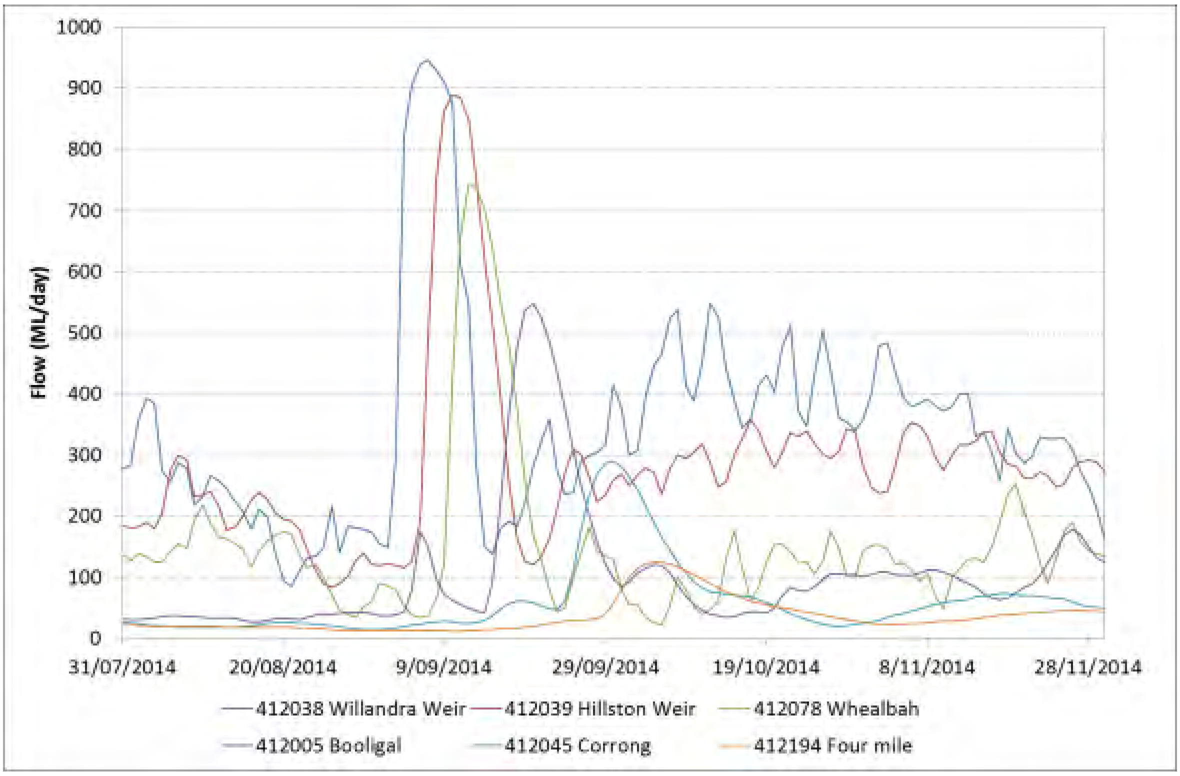


*Figure 10. Passage of the 2014-15 Commonwealth environmental watering release through the Lower Lachlan river system. Data are from [http://waterinfo.nsw.gov.au/](http://waterinfo.nsw.gov.au/)) for gauging sites in the Selected Area.*

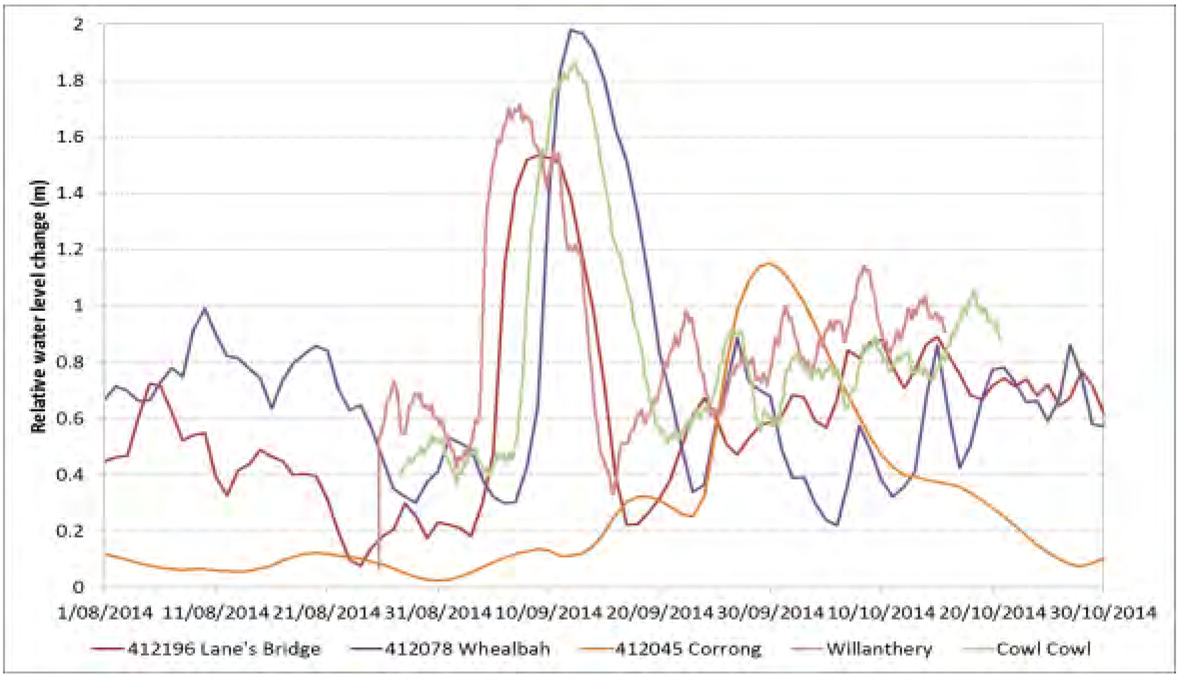


*Figure 11. Relative changes in water level associated with the delivery of Commonwealth environmental water to the Lower Lachlan river system in 2014-15. Data are from [http://waterinfo.nsw.gov.au/](http://waterinfo.nsw.gov.au/)) for Lane's Bridge, Whealbah and Corrong and from project gauges for Wallanthery and Cowl Cowl.*

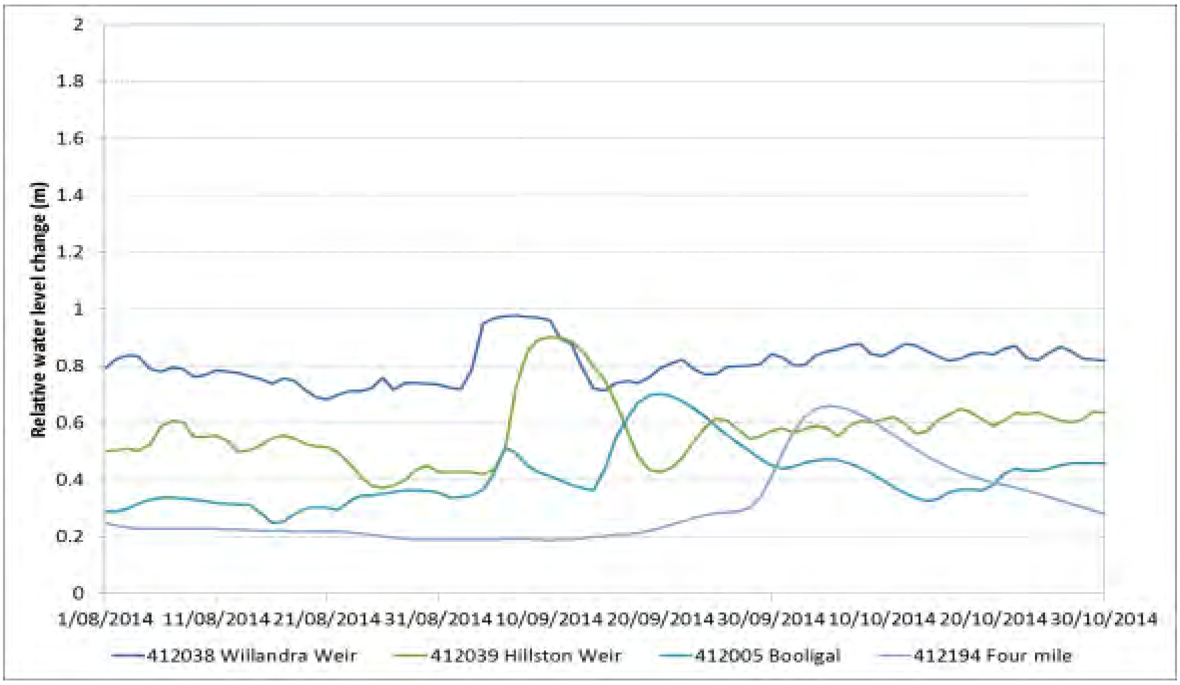


*Figure 12. Relative changes in water level associated with the delivery of Commonwealth environmental water to the Lower Lachlan river system in 2014-15. Data are from http://waterinfo.nsw.gov.au/).*

### 7.1.3 Summary

The environmental release was a relatively small fresh (5,821 ML over 10 days) that was delivered as the only 2014-15 environmental watering event to the Lower Lachlan river system. The water achieved an in-channel rise in water level of up to 1.5 m between Willandra and Booligal with smaller rises in water level evident below Booligal. The fresh resulted in small volumes of water reaching parts of the Cumbung Swamp, predominantly providing water to the main channels and central reed beds of the swamp.

Flows were substantially attenuated downstream of Booligal weir and a small fraction of the delivered environmental water reached Corrong and beyond. The attenuation and losses observed downstream of Booligal are consistent with those expected in this part of the Lower Lachlan river system indicating that the integrity of the unregulated flow was preserved through the system. To provide significant watering to the river and wetlands below Booligal would require greater volumes of water.

## 7.2 Stream Metabolism and Water Quality

### 7.2.1 Introduction

The energetic base of food chains in freshwater systems is provided either by primary production (the energy fixed by photosynthesis occurring in plants and algae) or by breakdown of organic matter which enters the water from terrestrial sources (such as leaves, wood and organic carbon dissolved in the water). Those processes are both influenced by the availability of key nutrients, particularly nitrogen and phosphorus, and a range of physico-chemical variables, particularly water temperature and light. Primary production and organic matter breakdown can be measured through continuous monitoring of changes in the concentration of oxygen in the water (described as measurements of open channel stream metabolism).

Stream metabolism uses measurements of the concentrations of oxygen in the water over a day-night cycle to estimate the amount of carbon being fixed via photosynthesis (gross primary productivity [GPP]), and the amount of carbon being respired due to breakdown of organic material (ecosystem respiration [ER]). In heterotrophic ecosystems, GPP:ER is <1 which means the ecosystem is using more energy than it is creating *in situ*, relying largely on organic inputs from upstream or terrestrial sources. These systems will consume large amounts of oxygen as organic matter decomposes or is fed on by invertebrates (see Figure 13). In autotrophic ecosystems GPP:ER is >1, which means the ecosystem is creating more energy *in situ* than it is using, and is based on local photosynthesis. Highly autotrophic systems with rapid growth of algae (algal 'blooms') will produce large amounts of oxygen during the day. By combining measurements of oxygen concentration during the day and the night with estimates of aeration (the diffusion of oxygen into the water at the water surface) it is possible to determine the dominant energy source for the aquatic food web. Oxygen measurements can also provide measures of stress to aquatic organisms. Where large amounts of organic carbon enter the channel (e.g. 'blackwater' events) or when algal blooms die off, the demand for oxygen can be sufficiently high that there is insufficient oxygen remaining for fish, resulting in fish kills.

Stream metabolism can be influenced by channel characteristics, flow, availability of light, nutrient availability and biological communities. Delivery of a single-pulse environmental fresh has potential for ecosystem-level responses in riverine productivity. Water quality can be influenced by flow, with increases in nutrient concentrations (and potential reductions in pH) associated with water contacting parts of the dry floodplain or river channel (Baldwin & Mitchell, 2000). This increase in nutrient availability can then potentially increase primary production by benthic and water column algae and phytoplankton (Bunn *et al.*, 2006). However environmental flows also increase water depth and turbidity, which can reduce light availability to photosynthetically active parts of the channel, reducing primary production. Physical effects such as dilution of algal cells and increased current velocities leading to scouring of biofilms (Stewardson *et al.*, 2013) may also act to reduce primary productivity. Environmental flows may influence organic matter supply and retention in a river channel, through laterally washing organic material from the floodplain or river margins into the channel, and importing or exporting organic matter longitudinally along the channel (Boulton & Lake, 1992).

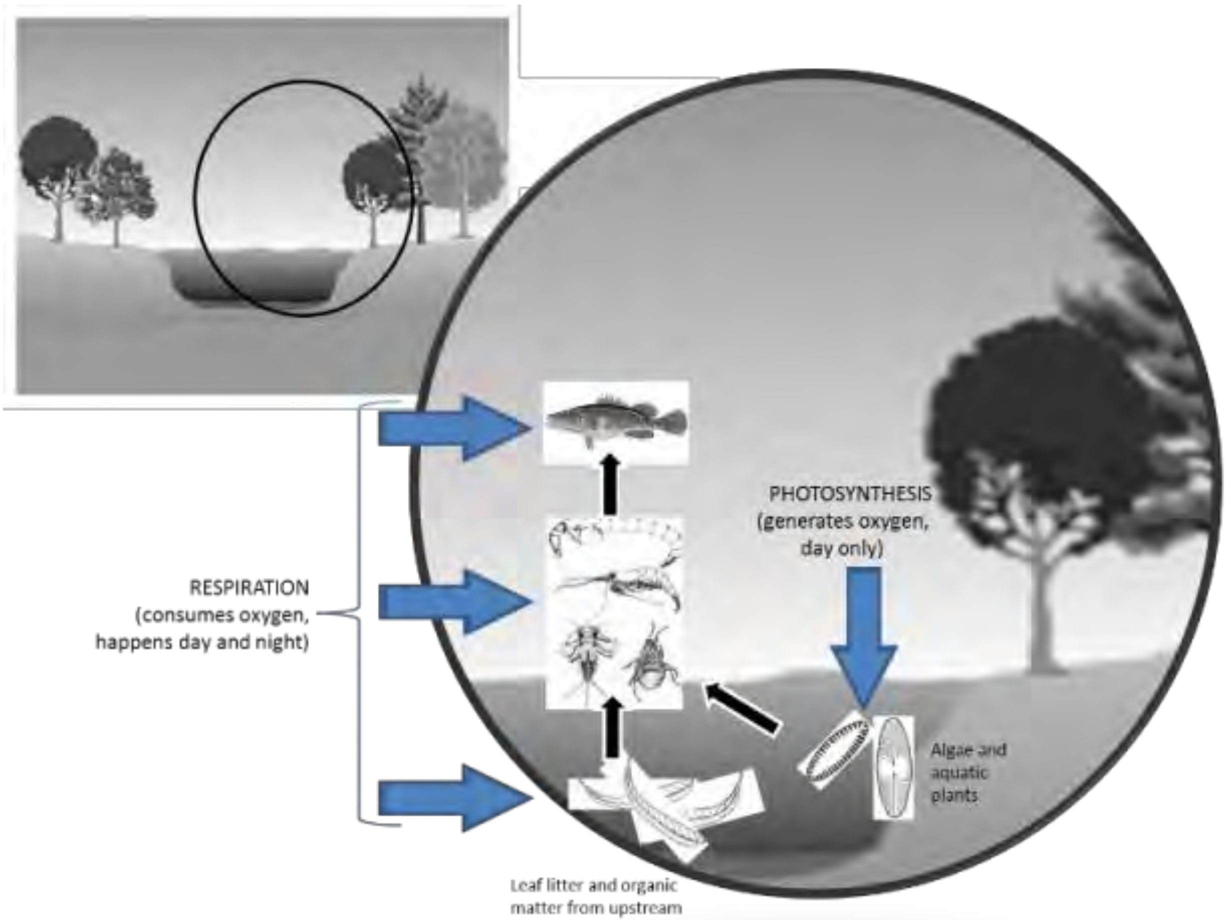


*Figure 13. Conceptual model of oxygen fluxes in a stream channel*

This section of the report addresses the following evaluation questions:

- What did Commonwealth environmental water contribute to patterns and rates of decomposition?
- What did Commonwealth environmental contribute to patterns and rates of primary productivity?

### 7.2.2 Methods

Sampling locations were established at four sites in the target reach; Wallanthery, Whealbah, Cowl Cowl and Lanes Bridge. These sites were sampled from June 2014.

For water quality, duplicate water samples were taken 2m from the water's edge at 1m depth biweekly, before, during and after releases at three locations within each of the four sites. These were placed on ice and returned to University of Canberra for analysis for total nitrogen, nitrate/nitrite, total phosphorus, dissolved reactive phosphorus and ammonia. Conductivity and pH were recorded using a handheld water quality meter. Because of initial issues with access to sites, there is incomplete data prior to and including November 2014 (Table 9).

Stream metabolism was measured applying the standard methods for the LTIM project. An oxygen logger was installed at four of the sites (Wallanthery, Whealbah, Cowl Cowl and Lanes Bridge) in the middle of the water column. Continuous sampling took place from 28 August 2014. Dissolved oxygen

(DO) and water temperature were logged at 10-min intervals using D-Opto dissolved oxygen sensors (Zebra-Tech, Nelson, New Zealand). Before and after placement, the loggers were put in an $O_2$ saturated solution and then together in the stream for 1 hr to account for probe drift, and if required, linear corrections were applied prior to metabolism calculations. Photosynthetic active radiation (PAR) was measured in an adjacent unshaded location at 10-min intervals using photosynthetic irradiance loggers (Odyssey, Christchurch, New Zealand). Barometric pressure was logged with a Silva Atmospheric Data Centre Pro (Silva, Sollentuna, Sweden).

Curve fitting was applied using the BASE model (Grace *et al.*, 2015) to estimate primary production and respiration on a daily basis. Curve fits were examined by eye for the influence of any outliers (Figure 14). Where a single outlier was resulting in poor curve fit, that data point was removed and replaced by the average of the two adjoining data points. After this process estimates derived from curve fits with $R^2 < 0.90$ and/or CV for GPP of > 50% were discarded.

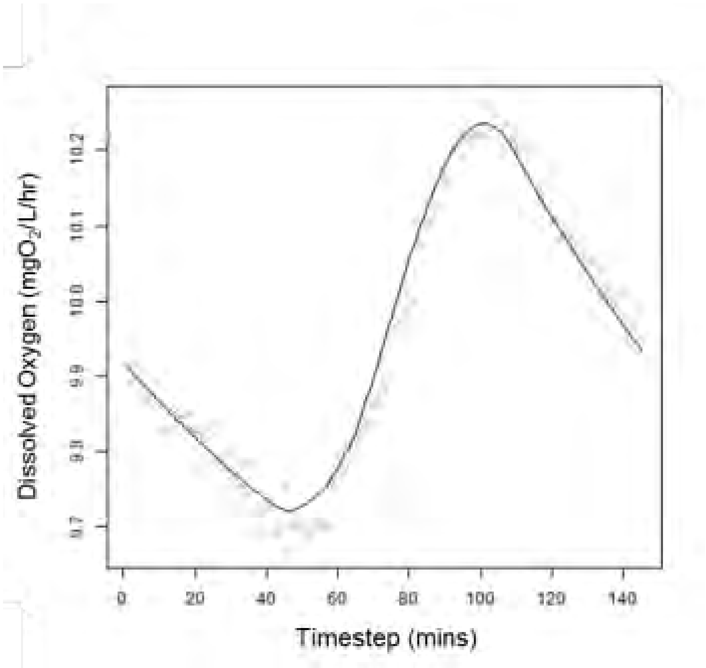


*Figure 14. Example of excellent curve fit to measured dissolved oxygen (DO) generated by the program BASE (data are for 10th September 2014, $R^2$ = 0.98)*

### 7.2.3 Results

A single environmental flow was delivered to the system (peaking on 08 September 2014) (Top panel Figure 15). As a result the potential to infer any effects of environmental flows on the key parameters is limited, as there is no replication. Further, as metabolism monitoring began on 28 August 2014, there is very limited pre data. For this reporting period we have reported on the relationships between flow conditions and water quality and stream metabolism for a single site (Cowl Cowl) over a three month period that includes the environmental flow.

There was no clear effect of the environmental flow delivery on water quality (Table 9 & Table 10) although the data are sparse, and there was no sampling in the period immediately around the environmental flow delivery. Access to sites prior to summer 2014 was very difficult, and as a result data are missing for some sites. There was clear evidence of increasing water temperatures moving into summer (Table 9 & Figure 15). Temperatures associated with the environmental watering event were maintained with no noticeable increase or decrease in temperatures as the flows passed monitoring sites.

*Table 9. Water quality measurements for the four sites over the sampling period: physico-chemical attributes*

| DATE | SITE | TEMPERATURE (deg C) | CONDUCTIVITY (mS/cm) | pH | TURBIDITY (NTU) |
|---|---|---|---|---|---|
| **24/06/2014** | Wallanthery | 12 | 0.47 | 8.2 | 39 |
| | Whealbah | | | | |
| | Cowl Cowl | 11.4 | 0.36 | 7.6 | 70 |
| | Lanes Bridge | 11.8 | 0.44 | 8.1 | 67 |
| **12/11/2014** | Wallanthery | 24.1 | 0.42 | 7.6 | 63 |
| | Whealbah | | | | |
| | Cowl Cowl | 24.4 | 0.51 | 7.3 | 77 |
| | Lanes Bridge | | | | |
| **26/11/2014** | Wallanthery | 24.9 | 0.27 | 8.1 | 75 |
| | Whealbah | 23.7 | 0.29 | 7.8 | 118 |
| | Cowl Cowl | 24.21 | 0.27 | 8.0 | 145 |
| | Lanes Bridge | 24.91 | 0.27 | 8.0 | 125 |
| **10/12/2014** | Wallanthery | 27 | 0.31 | 5.9 | 64 |
| | Whealbah | 26.5 | 0.27 | 7.8 | 147 |
| | Cowl Cowl | 26.5 | 0.28 | 8.1 | 114 |
| | Lanes Bridge | 26.9 | 0.30 | 8.0 | 123 |

*Table 10. Water quality measurements for the four sites over the sampling period: nutrients and chlorophyll A*

| DATE | SITE | TOTAL NITROGEN (mg/L) | NITRATE NITRITE (ug/L) | AMMONIUM (ug/L) | TOTAL PHOSPHORUS (mg/L) | FILTERABLE REACTIVE PHOSPHORUS (ug/L) | DISSOLVED ORGANIC CARBON (ug/L) | CHLOROPHYLL A (ug/L) |
|---|---|---|---|---|---|---|---|---|
| **15/10/2014** | Wallanthry | 0.6 | 0.002 | 0.002 | 0.061 | 0.008 | 8 | 9.472 |
| **16/10/2014** | Cowl Cowl | 0.7 | 0.002 | 0.004 | 0.06 | 0.011 | 8 | 7.4 |
| | Lanes Bridge | 0.56 | 0.003 | 0.003 | 0.044 | 0.008 | 9 | 5.92 |
| | Whealbah | 0.63 | <0.002 | 0.003 | 0.046 | 0.014 | 9 | 8.584 |
| **3/11/2014** | Cowl Cowl | 0.73 | <0.002 | 0.004 | 0.101 | 0.009 | 8 | 10.064 |
| | Lanes Bridge | 0.52 | 0.003 | 0.007 | 0.051 | 0.014 | 8 | 2.368 |
| | Wallanthry | 0.58 | <0.002 | 0.005 | 0.048 | 0.012 | 15 | 6.216 |
| | Whealbah | 0.63 | <0.002 | 0.005 | 0.051 | 0.014 | 8 | 11.84 |
| **13/11/2014** | Cowl Cowl | 0.77 | <0.002 | 0.004 | 0.066 | 0.012 | 9 | 4.144 |
| | Lanes Bridge | 0.69 | <0.002 | 0.004 | 0.059 | 0.013 | 8 | 3.256 |
| | Wallanthry | 0.79 | <0.002 | 0.004 | 0.106 | 0.014 | 9 | 5.624 |
| | Whealbah | 0.65 | <0.002 | 0.004 | 0.055 | 0.014 | 9 | 11.248 |
| **27/11/2014** | Cowl Cowl | 0.79 | 0.02 | 0.008 | 0.086 | 0.016 | 8 | 10.656 |
| | Lanes Bridge | 0.78 | 0.003 | 0.012 | 0.084 | 0.07 | 8 | 8.88 |
| | Wallanthry | 0.72 | <0.002 | 0.006 | 0.072 | 0.013 | 9 | 13.024 |
| | Whealbah | 0.8 | 0.002 | 0.009 | 0.083 | 0.017 | 9 | 8.88 |
| **11/12/2014** | Cowl Cowl | 0.84 | 0.002 | 0.004 | 0.098 | 0.013 | 10 | 12.728 |
| | Lanes Bridge | 0.75 | 0.002 | 0.005 | 0.069 | 0.013 | 10 | 2.96 |
| | Wallanthry | 0.82 | 0.002 | 0.003 | 0.125 | 0.011 | 9 | 12.136 |
| | Whealbah | 0.82 | 0.002 | 0.008 | 0.087 | 0.015 | 9 | 11.544 |
| **25/02/2015** | Cowl Cowl | 0.72 | 0.004 | 0.013 | 0.073 | 0.021 | 8 | 5.328 |
| | Lanes Bridge | 0.64 | 0.005 | 0.009 | 0.06 | 0.017 | 9 | 10.952 |
| **26/02/2015** | Wallanthry | 0.72 | 0.008 | 0.012 | 0.048 | 0.016 | 8 | 4.44 |
| | Whealbah | 0.7 | 0.004 | 0.011 | 0.086 | 0.02 | 9 | 23.088 |

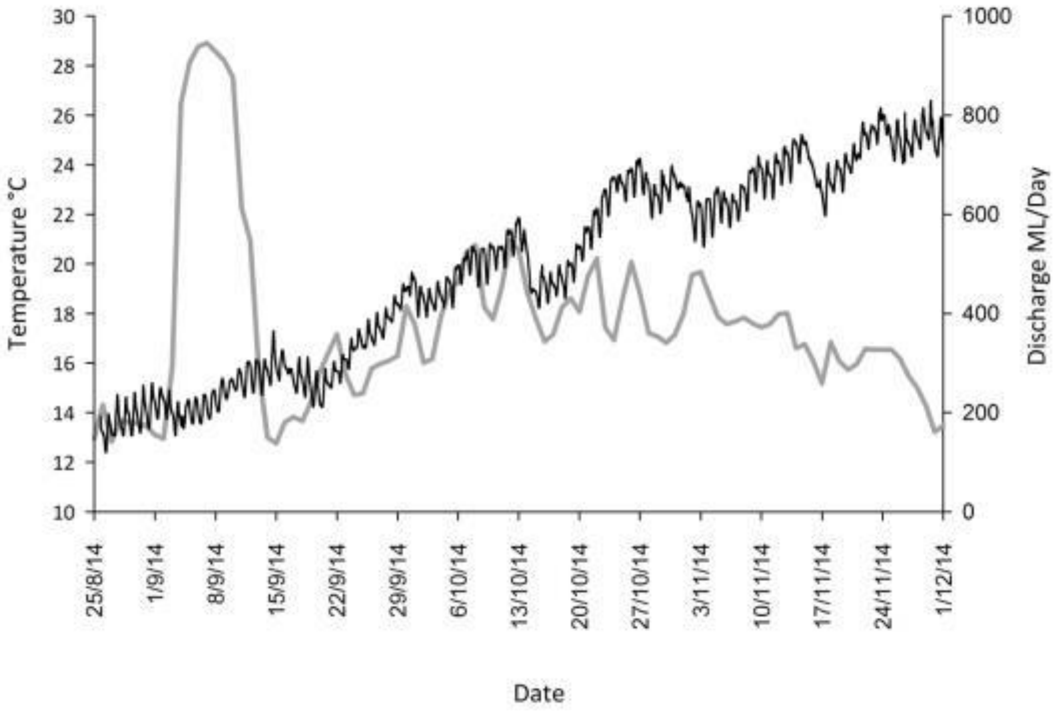


*Figure 15. Water temperature (10minute intervals taken at Wallanthery) and river discharge (taken from gauge upstream of Willandra weir) of the Lower Lachlan river system Selected Area in response to the flow release.*

Stream metabolism data was collected for four sites, but only the results for Cowl Cowl are shown here. Preliminary analysis of the remaining sites suggests that patterns are very similar and that the degree of curve fits across the four sites is broadly similar. For Cowl Cowl, of the 94 daily estimates obtained for GPP and ER over the three month period, 23 were discarded because of poor curve fit, leaving 71 estimates. Determining relationships with flow is difficult because of the single flow event, but it does appear that there was a reduction in both GPP and ER after the flow delivery, and then a slow increase in both parameters (Figure 15 mid and lower panel).

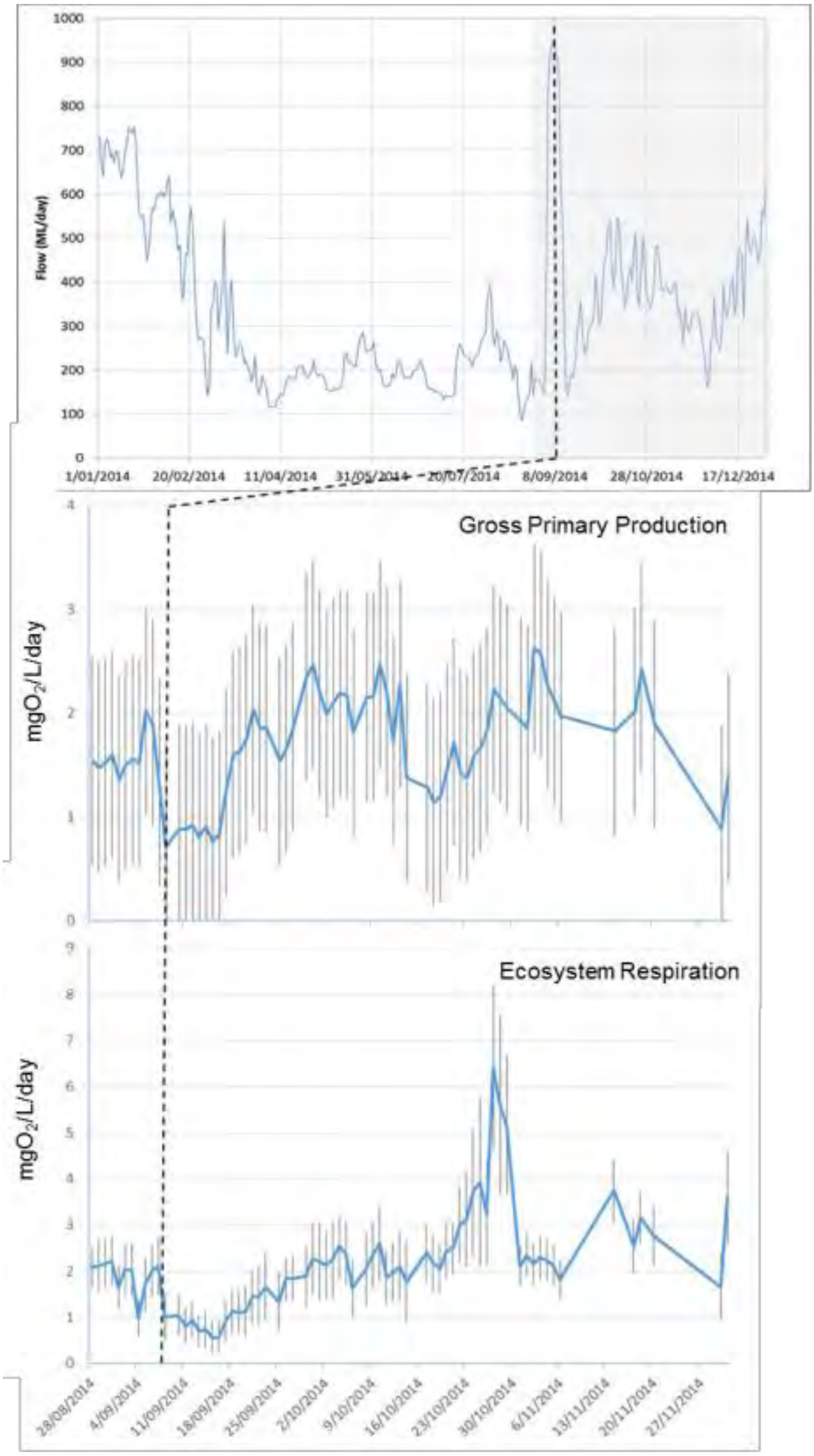


*Figure 16. Flow at Cowl Cowl site (top panel) showing the peak environmental flow (dotted line) in September 2014. Gross primary production (middle panel) and ecosystem respiration (bottom panel) are shown in mg/$O_2$/day with standard deviations around the estimates. Parts of the data series without standard deviation bars indicate dates where GPP and ER estimates could not be made.*

### 7.2.4 Discussion

The period for which data are available currently includes a single environmental flow event in September 2014. Inferring general responses to environmental flows from a single event is unwise, as it is clear from other systems (e.g. Stewardson *et al.*, 2013) that time of year, magnitude of flow and antecedent conditions may all affect the magnitude of the response.

1. Are there alterations in water chemistry (DO, pH, conductivity, macronutrients) associated with environmental flows?

The dataset available (particularly prior to the environmental flow) is currently not adequate to address this question in relation to the fresh delivered in September 2014. In particular there is a lack of data immediately before and after the flow event. As a result no clear conclusions can be drawn on the effects of environmental flows on water chemistry until more data become available in 2015.

2. What is the contribution of environmental flow releases to riverine productivity and respiration?

Rates of GPP and ER in this part of the Lower Lachlan river system were similar to those observed in similar lowland river ecosystems such as the Goulburn R. (Stewardson *et al.*, 2013) and the Edward-Wakool system (Watts *et al.*, 2013). As with those systems there was considerable variability in rates, even in the absence of major flow variability. There was a general trend towards higher values for GPP and ER moving into summer, which is a likely consequence of the observed marked increase in water temperatures.

There was evidence based on the single environmental flow event for a decrease in both GPP and ER after the flow. This is likely to primarily be a consequence of dilution of phytoplankton and organic matter by the higher flows, together with reductions in light reaching the photosynthetically active surfaces in the channel. The relatively rapid increase in both GPP and ER after the flow suggests that disruption of biofilms and removal of organic matter are not likely mechanisms underpinning this response. However the flow independent major increase in both GPP and ER over this period means that data on more flow events will be required to address the effects of environmental flows on these parameters in any definitive way.

It is premature to make management recommendations from these results as they are based on a single flow event. However these results are consistent with those observed in the Short Term Intervention Monitoring (STIM) studies of the Goulburn and Edwards-Wakool systems. Preliminary results suggest that the GPP and ER responses to environmental flows are strongly affected by in-stream temperatures, and that spring environmental flows are likely to have smaller effects on GPP and ER than those in summer. Energetic responses (energy flowing from GPP into the food web and on to target consumers such as fish and birds) are likely to be larger and more rapid when environmental flows are provided in summer.

## 7.3 Fish community

### 7.3.1 Introduction

Fish are an integral component of aquatic ecosystems and have been used as an indicator of aquatic ecosystem health in several large river health monitoring programs in south-east Australia (Davies *et al.*, 2010; Muschal *et al.*, 2010). The advantages of using fish as indicators of aquatic ecosystem condition include; i) fish are relatively long-lived and mobile, so reflect both short and longer-term and local to catchment scale processes, ii) they occupy higher trophic levels within aquatic ecosystems and, in turn, directly impact lower trophic level organisms, iii) they are relatively easily and rapidly collected and can be sampled non-destructively, iv) they are typically present in most waterbodies, and v) biological integrity of fish assemblages can be assessed easily and interpretation of indicators is relatively intuitive (Harris, 1995). Further, as fish have a high public profile, with significant recreational, economic and social values, they foster substantial public interest (MDBC, 2004).

Historically, 14 species of native fish are believed to have occurred in the Lower Lachlan river system (Dean Gilligan, NSW DPI, *Unpublished data*). Recent monitoring indicates that 10 of these species are still present, leaving four species either locally extinct of extremely rare (NSW DPI, *Unpublished data*). These four species include the flat-headed galaxias (*Galaxias rostratus*), southern pygmy perch (*Nannoperca australis*), southern purple spotted gudgeon (*Mogurnda adspersa*) and the Murray-Darling rainbowfish (*Melanotaenia fluviatilis*). Of the 10 extant species, olive perchlet (*Ambassis agassizii*), silver perch (*Bidyanus bidyanus*) and freshwater catfish (*Tandanus tandanus*) are at very low abundance and/or have a very restricted distribution. Only two species; carp-gudgeons (*Hypseleotris* spp.) and bony herring (*Nematalosa erebi*) could be considered widespread and abundant.

Flow plays an important role in the life-cycle of native fishes from larval through to adult life stages. Water may inundate habitat needed for reproduction, triggering a spawning response, create a boost in primary production that improves recruitment success, improve habitat condition through maintaining natural geomorphic processes or stimulate in-stream migration. River channel dependent species require flow triggers to initiate spawning (i.e. golden perch *Macquaria ambigua* and silver perch), and recruitment success may be heavily dependent on nutrient inputs to the river channel following overbank flows. The seasonality of these flow triggers is critically important. Further, sediment transport and scouring during high flow events is essential for the maintenance of deep pools and the input of large wood habitat. Freshes also provide movement triggers and facilitate longitudinal connectivity within the system. Persistence of these species is dependent on the provision of natural spawning triggers and subsequent boosts in primary production to facilitate successful recruitment as well as longitudinal connectivity within the river channel network. For all fish species, access to high quality refugia during drought is critically important for ecosystem resilience, as unlike vegetation, many species of invertebrates, waterbirds and turtles, fish have no mechanisms to cope with the loss of water for even very brief periods of time.

In 2014-15 the CEWH instigated a Long Term Intervention Monitoring (LTIM) Project across the Lower Lachlan river system to quantify changes in ecosystem health in response to Commonwealth environmental water delivery. This included monitoring the fish community.

The objectives of the 2014-15 watering actions were to protect the integrity of natural chemical signals from the unregulated tributaries (Boorowa, Belubula and Mandagery) to provide natural cues to native fish communities. The expected ecological outcomes were natural cues for native fish to migrate and spawn and a contribution to habitat access, fish condition, spawning and larval survival. To assess the contribution of Commonwealth environmental water to the fish community, the relevant short term and long term questions to be evaluated are:

**Short-term (one-year) questions:**

- What did Commonwealth environmental water contribute to native fish community resilience?
- What did Commonwealth environmental water contribute to native fish survival?

**Long-term (five-year) questions:**

- What did Commonwealth environmental water contribute to native fish populations?
- What did Commonwealth environmental water contribute to native fish diversity?

In 2014-15, the  aim of this component of the Lachlan LTIM Project was to benchmark and describe the fish community in terms of its abundance, biomass and community health in the Lower Lachlan river system Selected Area, and so provide a basis for determining changes in relation environmental water releases. The current study reports on the first year of the five-year Long Term Intervention Monitoring Project.

### 7.3.2 Methods

Fish community data was collected from 10 in-channel sites in the Lower Lachlan river system Selected Area, from Wallanthery to Hillston (Figure 17). All sites were randomly selected for this study, or had previously been randomly selected as part of another study (i.e. SRA; Davies et al. 2008, 2012. Sampling was undertaken in March and April 2015, and each site was sampled once using a suite of passive and active gears including boat-electrofishing (*n*=32 operations, each consisting of 90 seconds 'on-time'), unbaited bait traps (*n*=10; median total trap hours soak time 71 hrs, range 31–87 hrs) and small fyke nets (*n*=10; median total trap hours soak time 195 hrs, range 152–210 hrs) (Hale et al. 2014). Additionally, large fyke nets were used at each site to target freshwater catfish (*n*=4; median total trap hours soak time 79 hrs, range 60–84 hrs). Decapods were also surveyed and these were sampled using baited opera house traps (*n*=5; median total trap hours soak time 35 hrs, range 15–42 hrs).

All captures (fish and other non-target taxa) were identified to species level and released onsite, with the exception of small-bodied species which were retained for annual ageing (Hale *et al.*, 2013). Individuals were measured to the nearest mm and weighed to the nearest g. Where large catches of particular species occurred, a sub-sample of individuals was measured and examined for each gear type. The sub-sampling procedure consisted of firstly measuring all individuals in each operation until at least 50 individuals had been measured in total. The remainder of individuals in that operation were also measured, although any individuals of that species from subsequent operations of that gear type were only counted. Fish that escaped capture, but could be positively identified were also counted and recorded as "observed".

Total catch was pooled for all sites and methods, with the exception of calculation of SRA metrics where the first 12 electrofishing shots and bait trap data were used (Davies *et al.*, 2010). Sustainable Rivers Audit (SRA) fish community condition indices (Expectedness, Nativeness, Recruitment) were calculated to quantify overall condition of the fish community assemblage, and to place 2015 in the context of previous sampling. Data were first portioned into recruits and non-recruits. Large-bodied and generally longer lived species (max. age >3 years) were considered recruits when length was less than that of a one-year-old. Small-bodied and generally short-lived species that reach sexual maturity in less than one year were considered recruits when length was less than average length at sexual maturity. Recruitment lengths were derived from published scientific literature or by expert opinion when literature was not available (Table 11). Eight fish metrics were calculated using the methods described by Robinson (2012). These metrics were subsequently aggregated to produce three indicators (Nativeness, Expectedness and Recruitment), and to derive an overall fish community condition index. Metric and indicator aggregation used Expert Rules analysis in the Fuzzy Logic toolbox of MatLab (The Mathworks Inc. USA) (Davies *et al.*, 2010;  Carter, 2012).

*Table 11. Size limits used to distinguish new recruits for each species. Values represent the length at 1 year of age for longer-lived species or the age at sexual maturity for species that reach maturity within 1 year.*

| SPECIES | ESTIMATED SIZE AT 1 YEAR OLD OR AT SEXUAL MATURITY (FORK OR TOTAL LENGTH) |
|---|---|
| ***Native species*** | |
| **Australian smelt** | 40 mm (Pusey, Kennard & Arthington, 2004) |
| **bony herring** | 67 mm (Cadwallader, 1977) |
| **carp gudgeon** | 35 mm (Pusey, Kennard & Arthington, 2004) |
| **freshwater catfish** | 83 mm (Davies, 1977) |
| **golden perch** | 75 mm (Mallen-Cooper, 1996) |
| **Murray cod** | 222 mm (Gavin Butler, Unpublished data) |
| **un-specked hardyhead** | 38 mm (Pusey, Kennard & Arthington, 2004) |
| ***Alien species*** | |
| **common carp** | 155 mm (Vilizzi & Walker, 1999) |
| **eastern gambusia** | 20 mm (McDowall, 1996) |

The Expectedness index is the proportion of native species that are now found within the relevant catchment and altitudinal zone, compared to a historical reference condition (Table 12). The index value is derived from two input metrics; the observed native species richness relative to the expected species richness at each site, and the total native species richness observed within the zone over the total number of species predicted to have existed within the zone historically (Robinson, 2012). The Nativeness index is  the proportion of native compared to alien fishes, and is derived from three input metrics; proportion of total biomass that is native, proportion of total abundance that is native and proportion of total species richness that is native (Robinson, 2012). The Recruitment index represents the recent reproductive activity of the native fish community within each hydrological zone, and is derived from three input metrics; the proportion of native species showing evidence of recruitment anywhere within a zone, the average proportion of sites within a zone at which each species captured was recruiting (corrected for probability of capture based on the number of sites sampled; Table 12), and the average proportion of total abundance of each species that are new recruits (Robinson, 2012). The three indicators are aggregated to generate a weighted overall Fish Condition Index (Carter, 2012). Overall condition is then partitioned into five equal categorical bands to rate the condition of the fish community as “Good” (80–100), “Moderate” (60–79), “Poor” (40–59), “Very Poor” (20–39), or “Extremely Poor” (0–19).

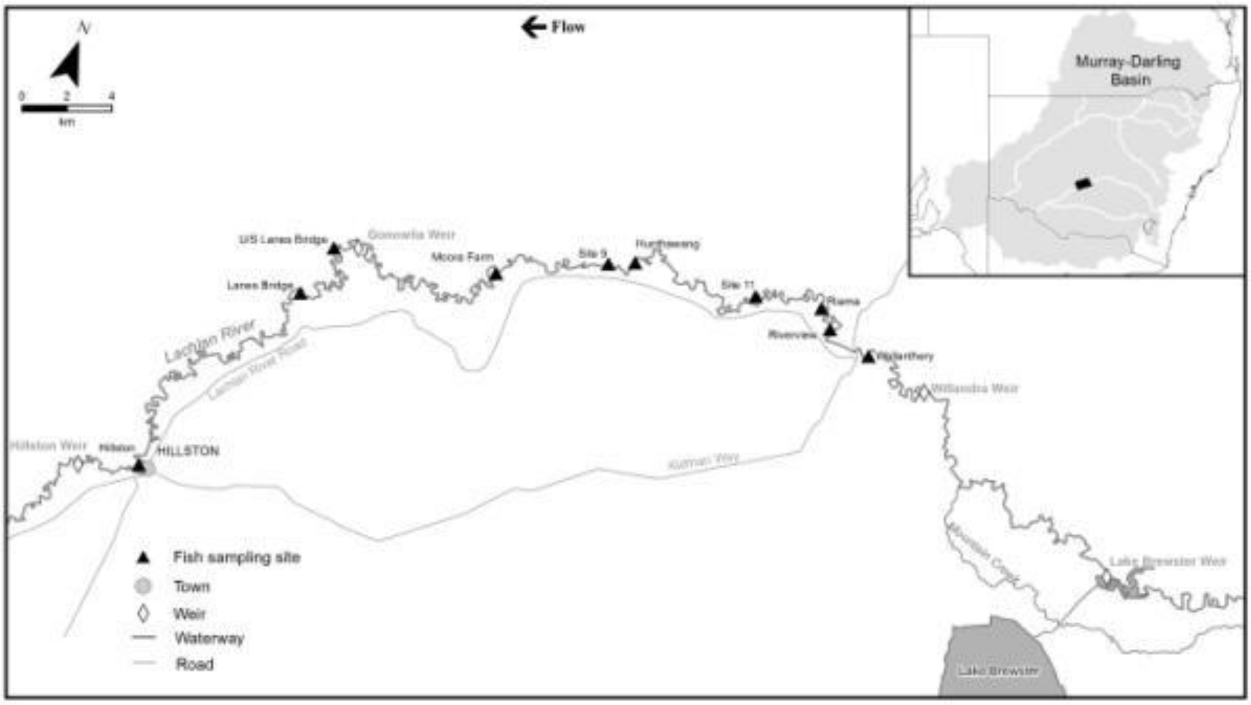


Figure 17. Location of riverine fish sampling sites on the Lachlan River.

### 7.3.3 Results

A total of 2,551 fish comprising seven native and three alien species were captured across 10 in-channel sampling sites in 2015 (Table 12). This included two species listed as threatened: freshwater catfish (endangered population; Fisheries Management Act 1994), and Murray cod (vulnerable; EPBC Act). In order, bony herring, eastern gambusia (*Gambusia holbrooki*), common carp (*Cyprinus carpio*), Murray cod (*Maccullochella peelii*) and golden perch were the most abundant species, respectively (Table 12; Figure 18). In order, Murray cod, common carp, golden perch and bony herring contributed the greatest overall biomass in 2015, respectively (Figure 19).

New recruits (juveniles) were detected in two native longer-lived species at multiple sites (bony herring (at 10 of 10 sites) and Murray cod (8 of 10 sites); Figure 18; Figure 20), and three native short-lived species (Australian smelt (2 of 6 sites), carp gudgeon (8 of 9 sites) and un-specked hardyhead (3 of 4 sites); Figure 18; Figure 20). No golden perch or freshwater catfish new recruits were captured (Figure 18; Figure 20). New recruits of all alien species were captured (common carp (7 of 10 sites), goldfish (*Carassius auratus*) (4 of 4 sites) and eastern gambusia (3 of 10 sites); Figure 18; Figure 20).

Sustainable Rivers Audit indices varied substantially in the target reach. Nativeness rated “Good” (mean ± SE score: 80.3 ± 3.2), Expectedness was “Very Poor” (38.2 ± 2.6) and Recruitment was “Extremely Poor” (18.8; zone metric). The Overall Condition of the fish community is rated “Very Poor” (21.1 ± 1.1).

*Table 12. Total (non-standardised) catch from the Lower Lachlan river system target reach. Sampling was undertaken in autumn 2015 using a combination of five sampling gear types.*

| | SAMPLING METHOD | | | | | |
|---|---|---|---|---|---|---|
| COMMON NAME | BOAT ELECTROFISHING | SMALL FYKE NET | LARGE FYKE NET | BAIT TRAP | OPERA HOUSE TRAP | TOTAL |
| Fish | | | | | | |
| *native species* | | | | | | |
| Australian smelt | 5 | 1 | | | | **6** |
| bony herring | 1555 | 19 | 21 | | 1 | **1596** |
| carp gudgeon complex | 3 | 60 | | 3 | | **66** |
| freshwater catfish | | | 1 | | | **1** |
| golden perch | 150 | 2 | 9 | | | **161** |
| Murray cod | 193 | | | | | **193** |
| un-specked hardyhead | 7 | | | | | **7** |
| *alien species* | | | | | | |
| common carp | 223 | 1 | | | | **224** |
| eastern gambusia | 14 | 271 | | 1 | | **286** |
| goldfish | 11 | | | | | **11** |
| Turtles | | | | | | |
| long-necked turtle | | 1 | 1 | | | **2** |
| Murray River turtle | | | 2 | | | **2** |
| Decapods | | | | | | |
| freshwater prawn | | 2543 | 1 | 282 | 201 | **3027** |
| freshwater shrimp | | 1162 | | 66 | | **1228** |
| freshwater yabby | 1 | 3 | | | | **4** |

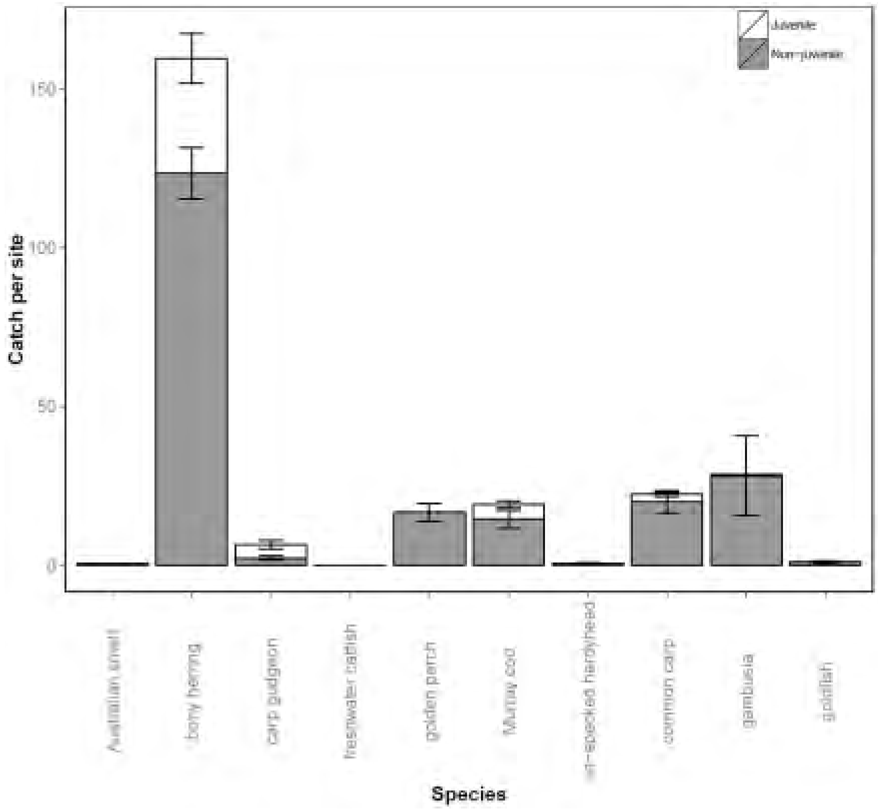


*Figure 18. Catch per site (number of fish; mean ± SE) of each fish species within the Lower Lachlan river system target reach sampled in 2015.*

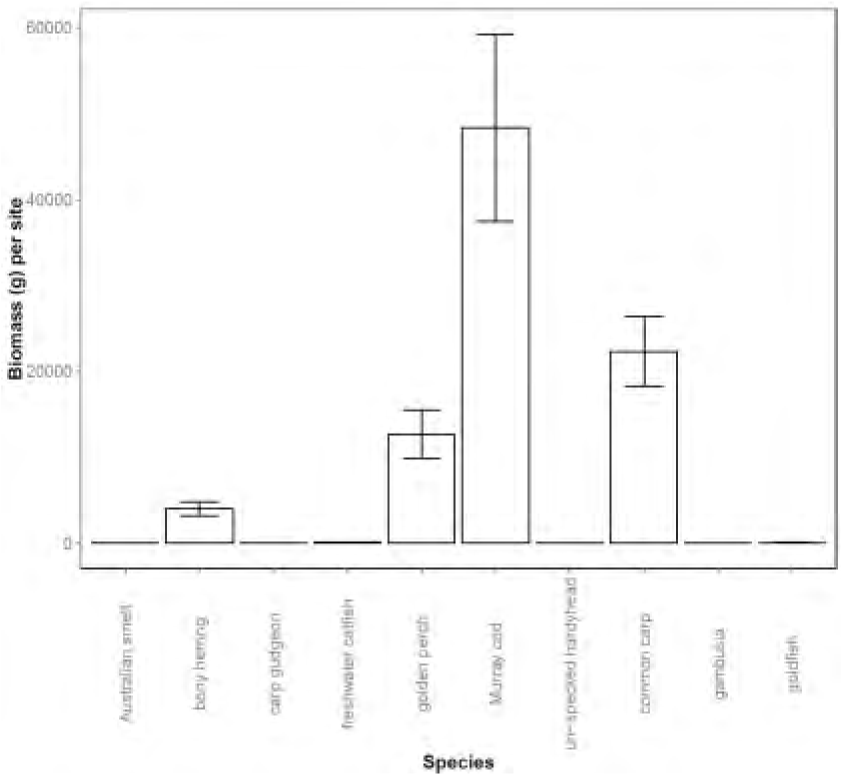


*Figure 19. Biomass per site (g; mean ± SE) of each fish species within the Lower Lachlan river system target reach sampled in 2015.*

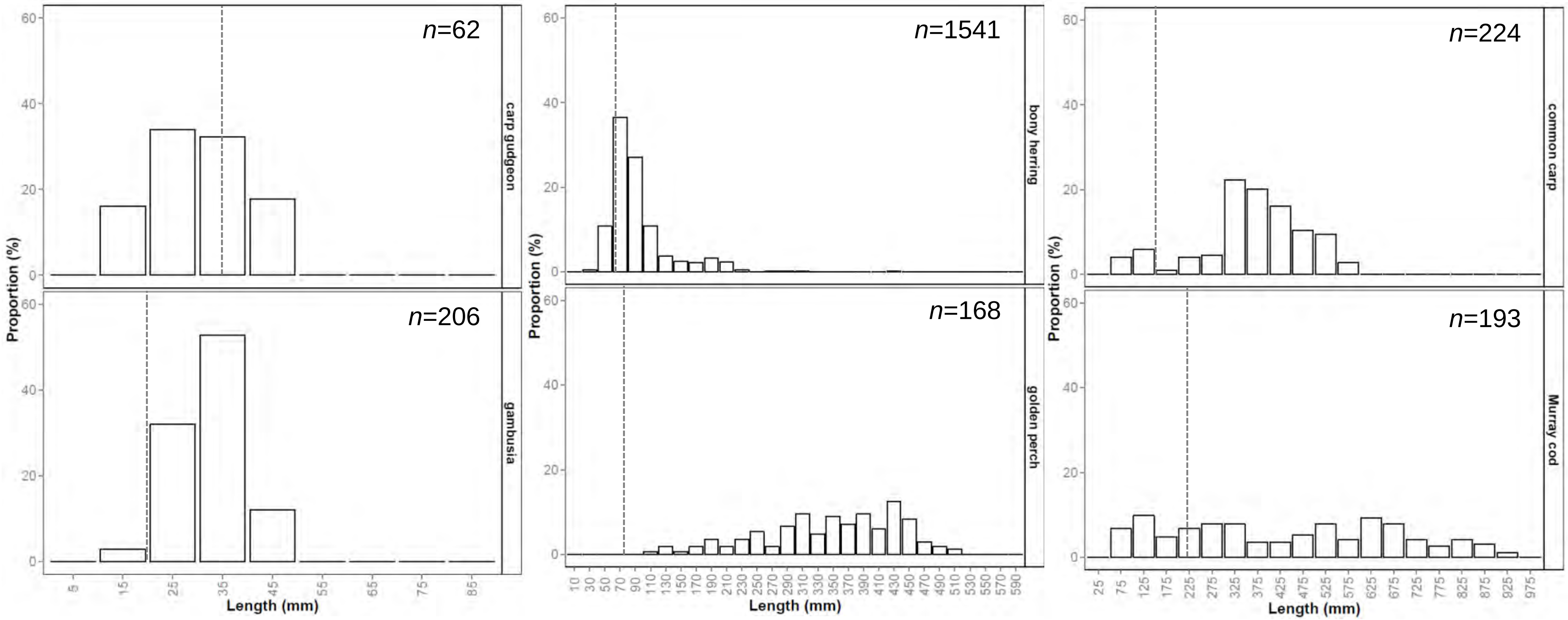


*Figure 20. Proportionate length-frequencies of the six most abundant species captured in the Lachlan River in 2015. The dashed line indicates approximate size limits used to distinguish new recruits for each species (see Table 1).*

### 7.3.4 By-catch

A total of four turtles were captured during fish community monitoring, two long-necked turtles and two Murray River turtles (Table 12). Freshwater shrimp and prawns were the most abundant taxa in small mesh fyke nets and bait traps (Table 12). Only a small number of Yabbies were captured across the 10 monitoring sites (Table 12).

### 7.3.5 Discussion

The current study provides a benchmark with which to compare changes in the fish community assemblage composition across the Lachlan River over the next five years under the LTIM Project. Seven native fish species and three alien species were captured, and Expectedness was "Very Poor". One individual freshwater catfish was captured and additional methods (large fyke nets) targeting this species were required. While freshwater catfish were considered to be historically abundant in the lowland Lachlan Basin, recent records indicate a low abundance (DPI Fisheries, unpublished data). Two native species, Murray-Darling rainbowfish and silver perch, although presumed to have been historically common in lowland sections of the Lachlan Basin are now rarely encountered within the target reach and were not detected in the current study. Flat-headed gudgeon were not encountered in this study, although previous sampling has confirmed their presence at low densities (Wallace and Bindokas 2011, DPI Fisheries, unpublished data). Additionally, four native species (flathead galaxias, olive perchlet, southern purple spotted gudgeon and southern pygmy perch), which were historically present, were not detected. Of these, olive perchlet is the only species to have been recently detected (Wallace and Bindokas 2011, DPI Fisheries, unpublished data). Overall, the species richness identified in the target reach is generally higher than in other parts of the Lachlan River. For example, Gilligan et al. (2010) found that riverine sites between Condobolin and Booligal had the highest native species diversity in the main channel of the entire Lachlan River. The complete absence of some floodplain specialist species within sections of the lowland Lachlan Basin is likely due to localised extinction following long-term disconnection of off-channel habitats.

The Nativeness index, based on metrics for native fish abundance, biomass and species richness was rated "Good" in the target reach. When compared with previous large-scale condition programs in the lowland Lachlan Basin, the target reach currently supports a healthier native fish community. For example, across a broader geographic scale, Nativeness for the lowland zone of the Lachlan River was "Very Poor" in 2006 (Davies *et al.*, 2008), "Poor" in 2009 (Davies *et al.*, 2012) and "Very Poor" in 2012 (DPI Fisheries unpublished data). While these results are not directly transferable to the findings of the current study given the narrower spatial scale of interest here, the data indicate that the fish communities of the broader region are generally unbalanced towards alien species, and that the target reach supports a greater proportionate abundance and biomass of native fish (Gilligan *et al.*, 2010).

Recent recruits of five native and three alien species were captured, and the length-frequency distributions and presence of recruits are consistent with existing knowledge of the life-history requirements of these species. For example, recent Murray cod recruits were captured at 80% of sampling sites. While stocking cannot be ruled out as potentially contributing to this pattern, this result is consistent with the collection of cod larvae, indicating that spawning occurred presumably within the target reach (see section 7.3 Spawning and Larval Fish). Murray cod, and other equilibrium species such as freshwater catfish, generally exhibit consistent spawning responses to broad stimuli such as temperature or day length (King, Humphries & McCasker, 2013). Although spawning itself is not linked directly to flow or fresh, year-class strength is still a function of flow timing and magnitude (Rowland, 1998), and potentially influences the scale of recruitment events. A small number of common carp recent recruits were detected. This species is known to be flexible in the timing of spawning, and location of spawning habitats in southern Murray-Darling Basin rivers (Sivakumaran *et al.*, 2003; Smith & Walker, 2004; Brown *et al.*, 2005), a strategy which contributes to their invasive capacity (Koehn, 2004). However, given that large recruitment events are often associated with spawning in off-channel habitats (e.g. Crook & Gillanders, 2006; Stuart & Jones, 2006) and that little/no off-channel habitat inundation occurred during 2014-15, this result is unsurprising. This is also reflected in the results found in the larval monitoring (see section 7.3 Spawning and Larval Fish). Spawning of golden perch was not detected in the current study (see section 7.3 Spawning and Larval Fish), and the results indicate no recent recruitment. The timing of water delivery during 2014-15 was too early to stimulate a spawning response in this species, which generally occurs when water temperatures exceed 23 $^{o}$C (Harris & Rowland, 1996). However, this species represents an excellent candidate to respond to environmental water delivery in the Lachlan River, given in-channel pulses of water have been observed to elicit spawning and recruitment responses. Further, a reasonable population of adult golden perch in the target reach may result in a detectable response.

### 7.3.6 **Recommendations**

- The small fresh delivered as the environmental watering action in the Lower Lachlan river system provided flows that were suitable for a number of native fish species to spawn, but the event was not sufficiently large enough to trigger spawning of flow cued spawning species known to be present. If future flows target spawning of golden perch in Zone 1 of the Lower Lachlan river system Selected Area, flows should occur from late October onwards and ensure that water temperature is suitable (i.e. above 23°C).
- The current monitoring program for fish is focused on Zone 1 and does not assess the interaction between off-channel and in-channel fish community assemblages, and the associated role of water management in the lowland Lachlan Catchment. Subsequently, extrapolation of the results of the current study is limited.
- Detecting spawning responses in the Lower Lachlan river system for flow-cued fish may be limited by the timing of the current sampling program (fortnightly sampling). Increased monitoring intensity (sampling weekly at a minimum) may be required to monitor spawning response of any events specifically targeted at golden perch or other flow cued spawning species.
- Any plans to water off-channel habitats for fish must have realistic expectations regarding floodplain species and their return. Future off-channel watering strategies should support long-term watering plans that will enable conservation stocking or translocation, and the subsequent re-establishment of resident populations of off-channel specialists.
- It is acknowledged that there is a risk of the potential to promote a common carp spawning event in response to the release of fish flows in warmer months. Continuing to restrict the flow from inundating wetlands during the warmer months, would most certainly continue to contribute to the low level of spawning response of common carp observed in 2014.

- The project team's capacity to determine growth and survival of larval native fish is limited by only having estimates of age:length ratios for the target species based on limited published studies. Daily aging of at least a subset of species is strongly recommended to be able to calculate age:length ratios (to be able to determine and compare growth and survival between years) and to accurately estimate spawning date. Samples from 2014 have been stored so that they can be used for aging should funds become available to facilitate this.
- Extrapolation of the results from the fish and stream metabolism monitoring is limited. The interactions between in-channel responses and wetland inundation are not being monitored and are likely to play a significant role in stream metabolic processes and fish recruitment.

## 7.3.7 Appendices

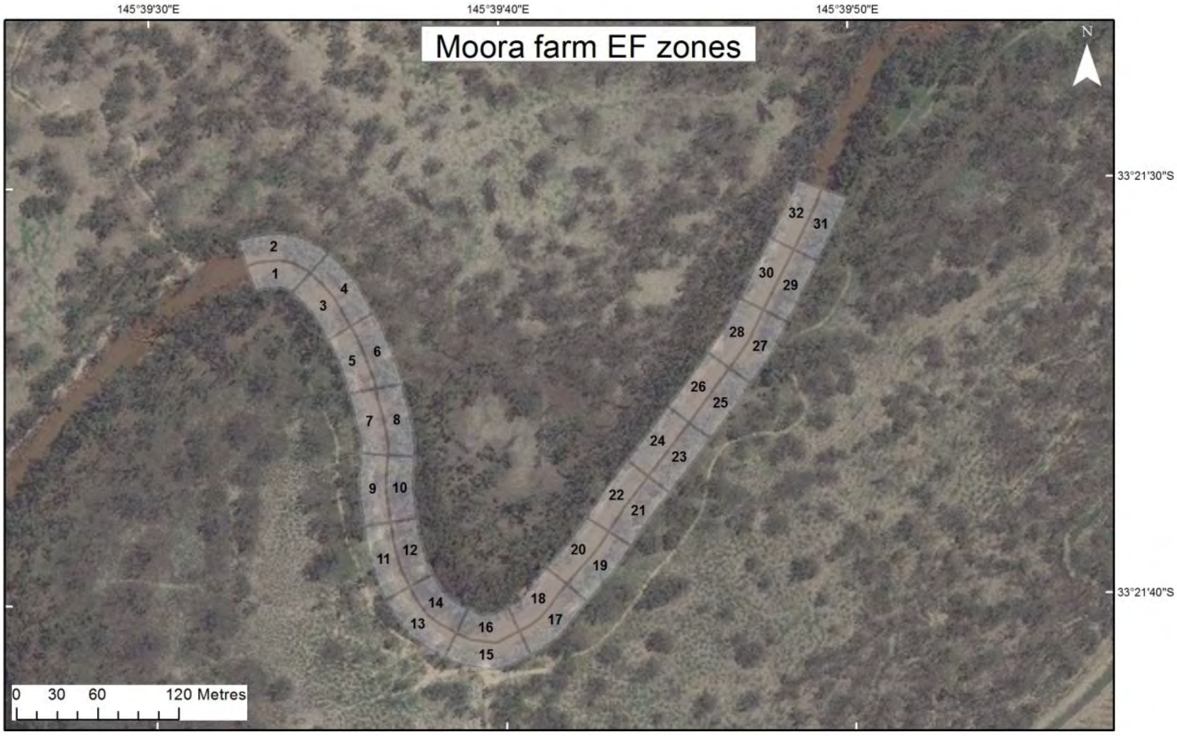


*Figure 21. Example of mapped boat electrofishing units used for Category 1 fish community sampling in the Lachlan River. Each unit was sampled using 90 seconds of 'on-time'.*

*Table 13. Pre-European (PERCH) list of the expected native species present in the lowland Lachlan Basin, their associated rarity and subsequent detection during the LTIM 2015 census. Descriptions of predominance (occurrence) correspond to reference condition categories for the Murray-Darling Basin Sustainable Rivers Audit program and are used to generate fish condition metrics.*

| COMMON NAME | SCIENTIFIC NAME | OCCURRENCE | 2015 LTIM CENSUS |
|---|---|---|---|
| Australian smelt | *Retropinna semoni* | common | Y |
| bony herring | *Nematalosa erebi* | common | Y |
| carp gudgeon | *Hypseleotris spp* | common | Y |
| freshwater catfish | *Tandanus tandanus* | common | Y |
| golden perch | *Macquaria ambigua* | common | Y |
| Murray-Darling rainbowfish | *Melanotaenia fluviatilis* | common | |
| silver perch | *Bidyanus bidyanus* | common | |
| Murray cod | *Maccullochella peelii* | occasional | Y |
| un-specked hardyhead | *Craterocephalus stercusmuscarum fulvus* | occasional | Y |
| flathead galaxias | *Galaxias rostratus* | rare | |
| flat-headed gudgeon | *Philypnodon grandiceps* | rare | |
| olive perchlet | *Ambassis agassizii* | rare | |
| southern purple spotted gudgeon | *Mogurnda adspersa* | rare | |
| southern pygmy perch | *Nannoperca australis* | rare | |

## 7.4 Spawning and Larval Fish

### 7.4.1 Introduction

Environmental flow regimes commonly aim to maintain and enhance native fish community populations (King *et al.*, 2010). The premise being that aspects of the flow regime are linked to key components of the life history of fish, including pre-spawning condition and maturation, movement cues, spawning cues and behaviour, and larval and juvenile survival (Junk, Bayley & Sparks, 1989; Humphries, King & Koehn, 1999; King, Humphries & Lake, 2003; Balcombe *et al.*, 2006). Since the strength of recruitment is largely driven by spawning success, and growth and survival of young, understanding how the flow regime influences the early life history of fishes is critical to managing fish populations (King *et al.*, 2010).

The 2014-15 Commonwealth environmental watering action was designed to protect small to medium sized natural tributary flows in spring-summer from extraction in the mid Lachlan River downstream to Booligal Weir. Thus, flow from the Boorowa River, Belubula River and Mandagery Creek were kept within the river channel providing natural cues to native fish communities. The expected ecological outcomes were:

- Natural cues for native fish to migrate and spawn
- Contribution to habitat access, fish condition, spawning and larval survival

To assess the contribution of Commonwealth environmental water to native fish spawning and recruitment, the relevant short term and long term questions to be evaluated are: .

***Short-term (one year) evaluation questions:***

- What did Commonwealth environmental water contribute to native fish reproduction in the Lower Lachlan river system?
- What did Commonwealth environmental water contribute to native larval fish growth in the Lower Lachlan river system?

***Long-term (five year) evaluation questions:***

- What did Commonwealth environmental water contribute to native fish populations in the Lower Lachlan river system?
- What did Commonwealth environmental water contribute to native fish species diversity in the Lower Lachlan river system?

The larval fish monitoring implemented within the Lower Lachlan river system is directed at Basin scale evaluation and is confined to a single zone within the Lower Lachlan river system Selected Area. There are likely to be strong differences in the fish community and habitats between zones within the Selected Area resulting in the evaluation of outcomes for the Selected Area being confined to the target reach (i.e. Zone 1) (Dyer *et al.*, 2014).

### 7.4.2 Methods

Larval fish were sampled at three sites (Dyer *et al.*, 2014) on the Lower Lachlan river system Selected Area (Wallanthery, Hunthawang and Lanes Bridge see Figure 17). Five sampling events were undertaken between 15/10/14 and the 10/12/14:

- Event 1: 15/10/14
- Event 2: 29/10/12
- Event 3: 12/11/14
- Event 4: 26/11/14
- Event 5: 10/12/14

Sampling followed the release of Commonwealth environmental water and was timed to coincide with the known spawning windows of the six 'representative' target species:

- **Equilibrium:** Murray cod (*Maccullochella peeli*) and freshwater catfish (*Tandanus tandanus*)
- **Periodic:** Golden perch (*Macquaria ambigua*) and bony herring (*Nematalosa erebi*)
- **Opportunistic:** Carp gudgeons (*Hypseleotris spp*) and unspecked hardyhead (*Craterocephalus stercusmuscarum*).

To capture larval fish, three drift nets and 10 light traps were set overnight at each site (for more detail see Dyer *et al.*, 2014). Catches of larval fish for drift nets was standardised as the number of individuals per $m^3$ of water sampled. Set and retrieval times of light traps were recorded so that relative abundance can be expressed as catch-per-unit-effort (CPUE). Analysis of the data in this first year of monitoring is largely descriptive in nature, with further interrogation only possible once multiple years of monitoring have been undertaken.

### 7.4.3 Results

A total of 536 larval fish were captured across the five sampling events of spring-summer 2014 comprising five native species (Murray cod, flat headed gudgeon, Australian smelt, freshwater catfish, and carp gudgeon) and two alien fish species (eastern gambusia and common carp) (

Table 14). Light traps captured twice as many larvae as drift nets across the five sampling events (

Table 14). Larval abundances peaked during the second sampling event (29/10/2014), when 67% of the total catch was captured, though this was largely driven by the abundance of Murray cod (Figure 22). Murray cod were by far the most abundant species recorded with 10-fold abundance of the next most populous species (flat headed gudgeon and Australian smelt) (

Table 14 and Figure 22). Flat headed gudgeon larvae were present during each of the sampling events (Figure 22). Murray cod larvae were the next most frequently encountered species and were present at all except the last sampling event (Figure 22). Common carp (first event), freshwater catfish (fourth event) and eastern gambusia (fifth event) were each only detected during a single sampling event.

*Table 14. Capture summary of larval fish from sampling conducted between mid-October to Mid December 2014 in the Lower Lachlan river system Selected Area.*

| SPECIES | DRIFT NETS | LIGHT TRAPS | TOTAL |
|---|---|---|---|
| **Murray cod** | 157 | 266 | **423** |
| **flat-headed gudgeon** | 3 | 39 | **42** |
| **Australian smelt** | 16 | 24 | **40** |
| **carp gudgeon** | 1 | 10 | **11** |
| **freshwater catfish** | 2 | 0 | **2** |
| **eastern gambusia** | 0 | 16 | **16** |
| **common carp** | 0 | 1 | **1** |
| **TOTAL** | **179** | **357** | **536** |

Larval fish were captured for only three of the six representative target species: two Equilibrium species, Murray Cod, freshwater catfish, and one Opportunistic species, carp gudgeon. Murray cod larvae were captured from all three sites in four of the five sampling events, though sampling event 2 (29 and 30th October 2014) had significantly higher abundances than other sampling events (two-factor ANOVA $df_{4}$, $F_{25.491}$, $P < 0.001$) (Figure 22). The size distribution of Murray cod larvae indicates that there were multiple spawning events at each site. The spawning window for Murray cod in the Lower Lachlan river system Selected Area in 2014 extended from 14th of September to 13th of November 2014 (Figure 23 and Figure 24, section 0

Appendix 1: Estimating fish spawning dates 2014). There were peak dates in the frequency of estimated spawning dates that were consistent between sites, the first from 24/9/14 – 4/10/14 present at Hunthawang and Lanes Bridge and the second commencing 5 days later from 9/10/14 – 24/10/14 (see Figure 24, section 0

Appendix 1: Estimating fish spawning dates 2014). Two freshwater catfish larvae were collected during the fourth sampling event in 2014, each were collected in drift nets at Wallanthery (11.39 mm SL) and Hunthawang (12.96 mm SL).

No Periodic representative species (golden perch or bony herring) were collected during larval sampling in 2015.

Three opportunistic species were collected during larval sampling in 2014, these were carp gudgeons, flat-headed gudgeons and Australian smelt. Flat-headed gudgeon were captured at all three sites and during all five sampling events (Figure 22). The majority (39 / 42) of flat-headed gudgeon were captured in light traps (

Table 14 and Figure 22). Flat-headed gudgeon ranged in length from 7.4 – 17.1 mm (Figure 23) with an estimated age of 24 – 93 days. This corresponds to an estimated spawning window from early August to late October, i.e. possible starting before the delivered fresh, with a peak between early September and early October 2014 when water temperatures were 14 - 19 °C (see Figure 24, section 0

Appendix 1: Estimating fish spawning dates 2014). Mean length of flat-headed gudgeons increased between sampling events 1 and 3 (Figure 23). There was a reduction in the mean size of captured individuals in sampling events four and five.

Australian smelt larvae were detected on the first, second and fourth sampling events (

Table 14 and Figure 22). Australian smelt were captured at each site, and were most common at Hunthawang. Australian smelt captured ranged in size from 7.3 – 19.8 mm (Figure 23) and ranged in estimated age from 3 – 63 days. Length frequency distribution and associated back calculation of estimated spawning dates indicate that Australian smelt spawned from mid-September to mid-November in 2014 with a peak in spawning activity between late-September and late-October 2014, when water temperatures were around 16 – 22 °C (see Figure 24, section 0

Appendix 1: Estimating fish spawning dates 2014). Length of Australian smelt increased between sampling events 1 and 2 (Figure 23). There was an absence of Australian smelt in sampling event three and presence of some of the smallest individuals in sampling event four (Figure 23).

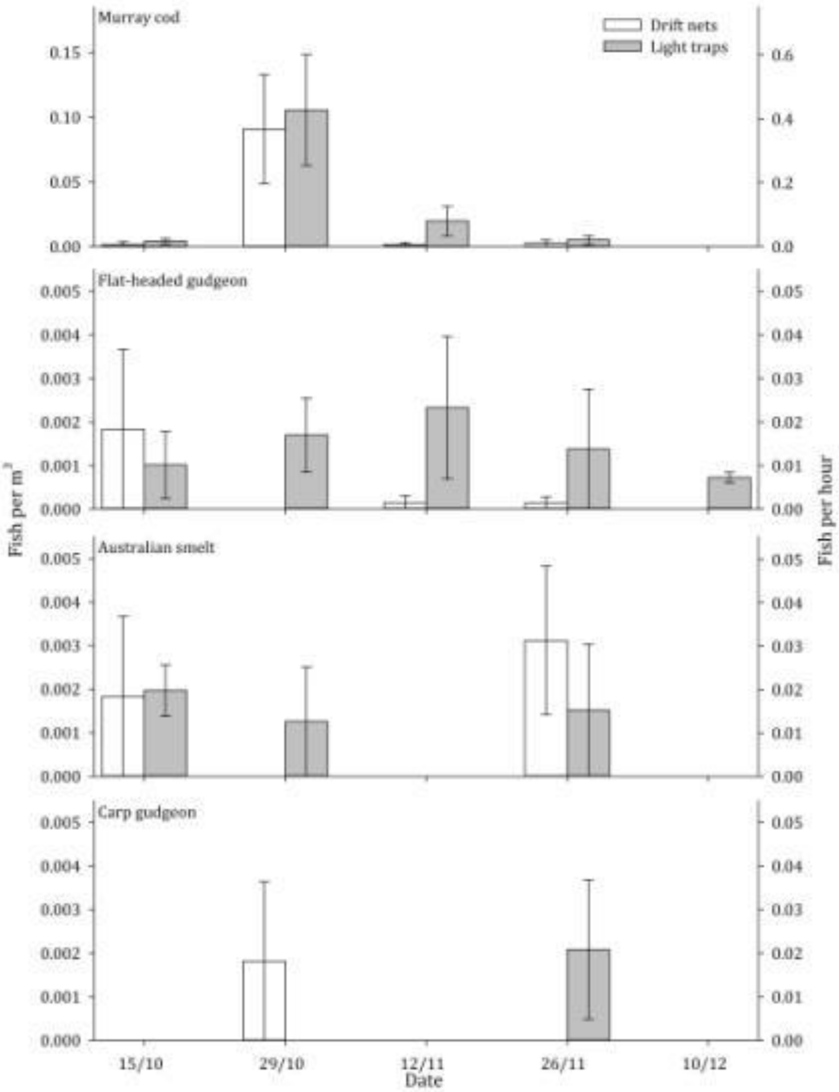


*Figure 22. Mean catch per unit effort (± standard error) of the commonly caught larval native fish for drift nets (left axis, white bars) and light traps (right axis, grey bars) per sampling event from the Lower Lachlan river system Selected Area in spring summer 2014.*

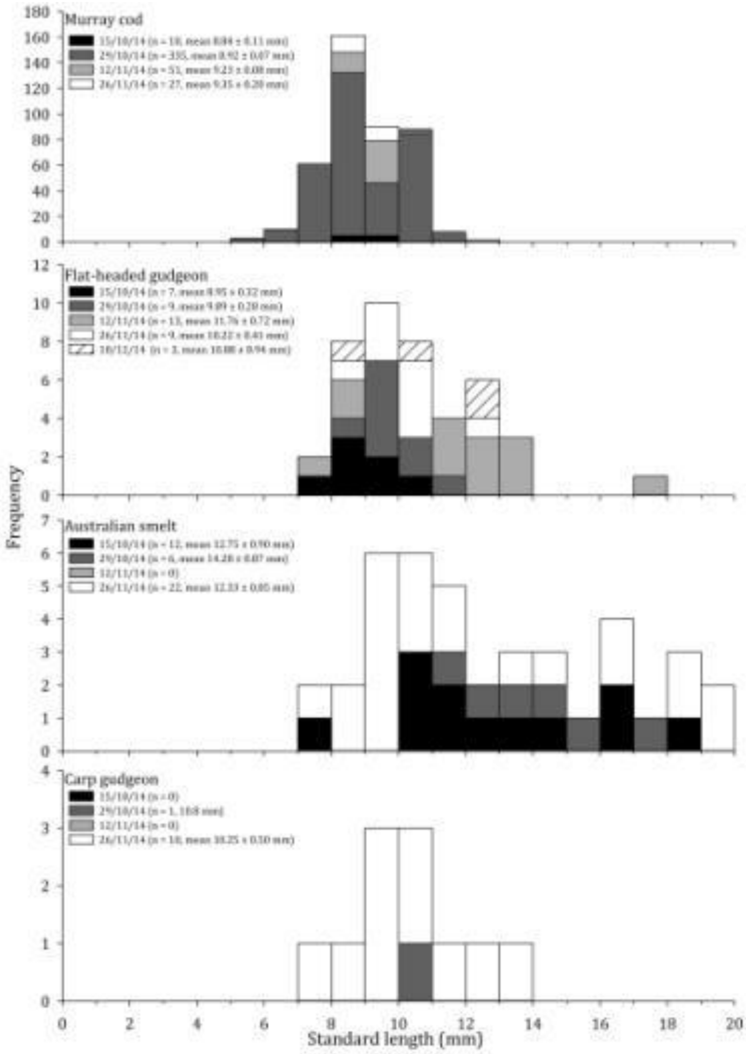


*Figure 23. Length frequency histograms for each sampling event of commonly captured native fish species with site (n = 3) and sampling technique (n = 2) combined.*

A total of 11 carp gudgeon were captured in the 2014 larval fish sampling, most of which were captured from one site (Hunthawang 9 / 11) and during one sampling event (sampling event 4) in light traps (10 / 11) (

Table 14 and Figure 22). One individual was captured in the second sampling event in a drift net (

Table 14 and Figure 22). Carp gudgeon ranged in size from 8.6 – 13.04 mm (Figure 23) and had an estimated age range of 29 – 59 days. Estimated spawning dates in 2014 ranged from mid-September to late October, with a peak around mid-October when water temperatures were 18 – 21 °C (see Figure 24, section 0

Appendix 1: Estimating fish spawning dates 2014).

A total of 17 alien fish larvae were captured in 2014 comprising 16 eastern gambusia and one common carp (

Table 14). All 16 eastern gambusia were captured in light traps from one site (Hunthawang) during sampling event 5. The common carp (6.62 mm SL) was captured in a light trap at the same site (Hunthawang) during sampling event 1.

### 7.4.4 Discussion

The results of the first year of monitoring indicate that expected outcomes for the flow release, in terms of providing suitable cues and access to habitat for spawning as well as larval growth and survival, were partially met. Spawning was observed for non-flow dependent species; however, there was no evidence (eggs or larvae) of flow dependent species (golden perch) or bony herring spawning in September-December 2014 (young-of-year of the latter were captured in fish community sampling – see Fish community). Spawning of golden perch was not a specific aim of the 2014 flow release and therefore spawning of this species was not expected to occur in conjunction with the flow release.

Murray cod dominated the larval counts and were captured at each site from sampling event 1 – 4 in 2014, and were especially abundant during the second sampling event (end of October). In terms of timing, the presence of Murray cod larvae in this part of the Lower Lachlan river system was generally commensurate with other catchments (e.g. Humphries, 2005; King *et al.*, 2005; Koehn & Harrington, 2006). It is likely that this species is responding to factors such as day length and water temperature, rendering their direct spawning activity somewhat independent of large flows (Koehn & Harrington, 2006; Humphries, 2005). The influence of flow on priming adults for spawning, movement and recruitment from larvae to juveniles is not well understood.

The presence of a single freshwater catfish larva at two sites suggests that conditions were suitable for spawning. Although counts were low, this is a positive result, as the western population of this species has been declared as endangered.

The increase in mean lengths of flat-headed gudgeon and Australian smelt in the first few sampling events indicate that in-channel conditions were suitable for growth and development. A reduction in mean lengths in later sampling events indicates that in channel conditions facilitated multiple spawning events for both species. These results are somewhat expected as flat-headed gudgeon and Australian smelt are capable of spawning multiple times over an extended period and are likely to have extended beyond the duration of the sampling events undertaken in 2014 (Humphries *et al.*, 2008; Humphries *et al.*, 2013).

Golden perch spawning was not a specific objective set for the 2014 watering action, and the lack of detection of egg or larvae of this species in 2014 was consistent with current understanding of spawning requirements of golden perch. Golden perch are noted for displaying opportunistic spawning behaviour (Ebner, Scholz & Gawne, 2009), but the literature suggests that they require water temperatures of greater than 19oC (King *et al.*, 2005; Stuart & Jones, 2006) in the southern Murray-Darling Basin and temperatures of 23$^{o}$C are often quoted as optimal for spawning (Lake, 1967; Roberts, Duivenvoorden & Stuart, 2008). It is also thought that water level changes of 0.5 m would be sufficient to trigger migration prior to spawning, though golden perch were also found to have spawned in the Murray River without a rise in water level (King *et al.*, 2005) and in the Murray River without floodplain inundation (Mallen-Cooper & Stuart, 2003; Zampatti & Leigh, 2013) (in channel flow rise in Spring was still present in the later example). Considering this, water temperatures during the release of the fish flow in September 2014 (approximately 15°C) are likely to have been too low to promote spawning of this species. Future flows released to specifically induce spawning of golden perch in the Lower Lachlan river system Selected Area should be released from late October onwards, to ensure that water temperature is suitable (i.e. above 23°C).

Bony Herring were not detected during larval monitoring in 2014, which is somewhat surprising given that recruits were detected at all 10 sites in the fish community monitoring in early 2015 (see chapter 7.3). This species was found to spawn in December and January when water temperatures reached 21-23°C in the lower Murray River (Puckeridge & Walker, 1990). The last sampling event was in early December, which may have preceded the onset of spawning (even though temperatures had reached 25 °C). Certainly the detection of young-of-year in the fish community sampling component of the monitoring program (see chapter 7.3) supports the conclusion that spawning occurred outside the temporal range of the sampling events.

Low numbers of common carp detected during larval fish monitoring indicate that the fish flow released in 2014 did not provide suitable conditions for a significant spawning event for this species. This is likely because of the timing (water temperature right at the lower end of threshold of 15°C (Crivelli, 1981) and lack of inundation of wetlands (suspected carp recruitment hotspots) (Driver *et al.*, 2006; Crook & Gillanders, 2006; MacDonald, Crook & McNeil, 2010). It is acknowledged that there is a risk of the potential to promote a common carp spawning event in response to environmental releases in warmer months. Continuing to restrict the flow from inundating wetlands during the warmer months, would most certainly continue to contribute to the low level of spawning response of common carp observed in 2014.

### 7.4.5 Recommendations

- To encourage reproduction of golden perch, it is recommended that targeted increase in flow (to achieve a river level rise of ~0.5m) be released when temperatures are at least 23°C (late October onwards).
- Increased monitoring intensity is also required to monitor spawning response of golden perch as the current methods are potentially too temporally coarse.
- Daily aging of at least a sub set of species is strongly recommended to be able to calculate age: length ratios (to be able to determine and compare growth and survival between years) and to accurately estimate spawning date. Daily aging was initially excluded from the monitoring program due to budgetary restrictions. Samples from 2014 have been stored so that they can be used for aging.

### 7.4.6 Appendix 1: Estimating fish spawning dates 2014

The most accurate and precise method of estimating larval fish age and hence of deriving spawning date is by direct daily aging using otoliths of larval fish (Anderson, Morison & Ray, 1992; Campana & Thorrold, 2001). Resource constraints meant direct aging was not currently feasible for this project (although larvae captured in 2014 have been stored for potential otolith analysis should funds be available), and this forced the use of less accurate indirect methods of aging and spawning date estimation.

Ages of small bodied species (carp gudgeon, Australian smelt and flat-headed gudgeon) ages were estimated from length-age equations for each species for a site on the Lower Murray floodplain (Lindsay Island), provided in Humphries *et al.* (2008) and matched to capture month. Hatching times for small bodied species were taken from Lintermans (Lintermans, 2007). Murray cod larval age were estimated by multiplying length by 1.372 (a factor to compensate for shrinkage in ethanol) matched against linear length age equation derived from length-age data in Serafini and Humphries (2004) (Age = 6.6302ln-48.104). This age along with estimated incubation period (= 20.67-0.667*[WaterTemp(°C) taken from Ryan *et al.* (2003) – where water temperature was for the five days prior to the estimated spawning date was subtracted from the capture date to provide an estimate of spawning date.

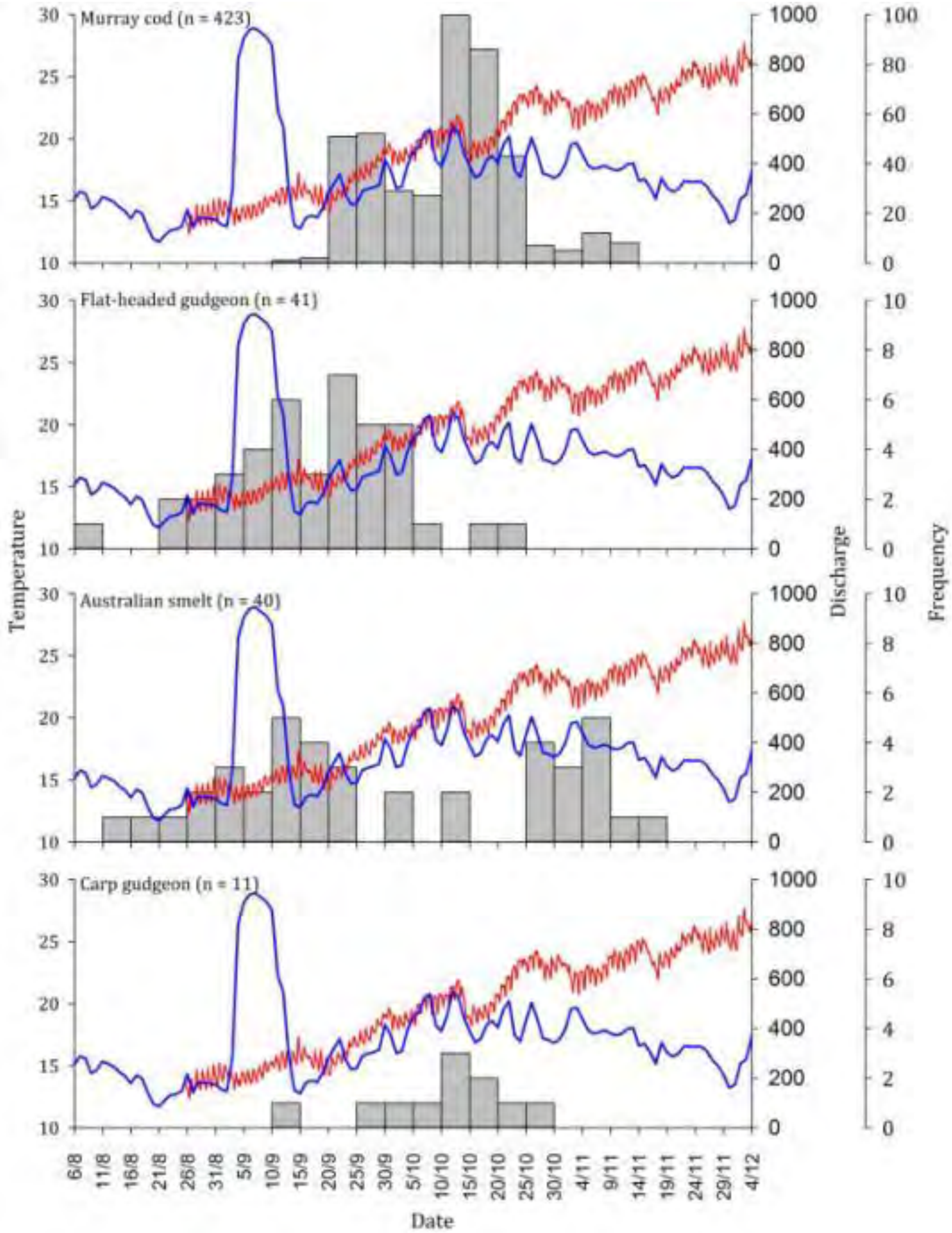


*Figure 24. Estimated spawning date frequency (grey bars) and associated discharge (taken from Lachlan River u/s Willandra Weir: blue line) and temperature (from Wallanthery: red line) for larval native fish species captured in the Lower Lachlan river system Selected Area (all sites and methods combined).*

## 7.5 Vegetation

### 7.5.1 Introduction

The 2014-15 Commonwealth environmental watering action was designed to protect small to medium sized natural tributary in-flows through the mid Lachlan River to Booligal Weir providing natural cues to native fish communities. This watering action did not specifically target vegetation however, they were anticipated as it was an end of system flow which resulted in wetting of the core reed beds of the Cumbung Swamp. The vegetation component of the monitoring activities in 2014-15 characterises the vegetation of the sites and establishes a baseline against which the outcomes of future watering events can be compared. The Selected Area evaluation questions for vegetation (Table 15) have been used to structure the descriptions of vegetation character. As such, this technical report provides a description of the vegetation, the condition of the riparian and floodplain trees as well as the regeneration across the monitored sites in the Lower Lachlan river system.

*Table 15. Lower Lachlan river system Selected Area evaluation questions for vegetation condition and diversity*

| RESPONSE TIMEFRAME | EVALUATION QUESTION |
|---|---|
| Short-term (one-year) and long-term (five year) | What did Commonwealth environmental water contribute to vegetation species diversity?<br>What did Commonwealth environmental water contribute to vegetation community diversity? |
| Long term (five year) | What did Commonwealth environmental water contribute to populations of long-lived organisms? |
| Short term (one-year) | What did Commonwealth environmental water contribute to condition of floodplain and riparian trees?<br>What did Commonwealth environmental water contribution to vegetation condition and reproduction? |

### 7.5.2 Methods

Vegetation surveys were conducted in both non-tree and tree communities during November/December 2014 and in May 2015 (Table 18). Sites were selected to provide a sample from the different vegetation communities distributed across wetlands and riparian zones with different environmental watering probabilities within the constraints of the project budget.

The non-tree community survey was conducted along 100 m transects extending from the fringing woodland into the deeper section of the wetlands and billabongs at each of 10 sites (Table 18) using the methods of Driver et al., (2003) as described in Dyer et al. (2014). Species abundance (as cover) was recorded in 1 $m^2$ quadrats placed at 10 m intervals along the 100 m transects (n=10 per transect). The methods are outlined in greater details in Driver et al. (2003) and Dyer et al. (2014).

Woodland tree communities were surveyed in a minimum of 2 replicate 0.1 ha plots at each of 12 sites (Table 18) using the methods of Bowen (2013) as described in Dyer et al. (2014). An understory floristic survey was undertaken in a nested 0.04 ha plot inside the 0.1 ha plots. In each 0.1 ha plot, measures of stand and tree condition (basal area, canopy openness, canopy extent, live/dead limbs) were recorded as well as tree recruitment (trees less than 10 cm in diameter). In each 0.04 ha plot, the floristic survey recorded species abundance as cover. Additional method details can be found in Bowen (2013) as described in Dyer et al. (2014).

All plants observed were identified to species either during field surveys or from field specimens which were preserved for later identification. The exception was grasses where individual species were not identified.

The water plant functional types (Table 16) of Brock and Casanova (1997) and Casanova (2011) were used to classify all species recorded. Only terrestrially dry (Tdr) and terrestrially damp (Tda) and amphibious species (AmT and AmR classifications) are reported to simplify interpretation. Species were also classified as native/non-native using information provided on PlantNET (http://plantnet.rbgsyd.nsw.gov.au/).

*Table 16. Plant functional group classifications of Brock and Casanova (1997) and Casanova (2011)*

| FUNCTIONAL TYPE | DESCRIPTION |
|---|---|
| **Amphibious responders (AmR)** | Plants which change their growth form in response to flooding and drying cycles. |
| **Amphibious tolerators (AmT)** | Plants which tolerate flooding patterns without changing their growth form. |
| **Terrestrial damp plants (Tda)** | Plants which are terrestrial species but tend to grow close to the water margin on damp soils. |
| **Terrestrial dry plants** | Plants which are terrestrial species which don't normally grow in wetlands but may be encroaching into the area due to prolonged drying. |

For the analysis presented in this report the survey data have been treated in the following way:

- Measures of stand and tree condition at each site were calculated as the average of the plot data from each vegetation community at each site. This means that for sites with more than one vegetation community, there are two measures of stand and tree condition provided (e.g. Lake Tarwong Black Box and Lake Tarwong River red gums). Condition metrics (Table 17) are derived from Bowen (2013), Bowen and Simpson (2010) and Bowen et al (2012) and are adapted from Cunningham et al (2007).
- Species richness was calculated from the combined survey data from the two sampling dates and an average of the data from multiple plots or transects at each site.

*Table 17. Plant condition classification derived from from Bowen (2013), Bowen and Simpson (2010) and Bowen et al (2012) and are adapted from Cunningham et al (2007)*

| CONDITION | DESCRIPTION |
|---|---|
| Good | 0-10% Dead Canopy |
| Intermediate | 11-40% Dead Canopy |
| Intermediate/poor | 41-80% Dead Canopy |
| Poor | > 81% Dead Canopy |

Data from each vegetation community at each site are presented because the communities are likely to have a different watering history and these data represent a baseline for future comparison.

At each site observations relating to landuse and other activities that may confound the interpretation of vegetation response to watering were recorded. The frequency and time since activity were recorded for grazing by livestock, firewood collection, site disturbance. The presence of feral animals was also noted.

### 7.5.3 Results

All sites were dry at both times of sampling. The last watering of most sites occurred during the large scale watering action in 2012/13. The 2012/13 environmental watering aimed to contribute to vegetation recovery in the catchment.

Considerable differences were observed in the number of species recorded on the two sampling dates with more species recorded during May 2015 than November/December 2014. There were also notable seasonal differences in measure of cover and tree health metrics which may be the result of rainfall in the catchment. Such variation is consistent with previous observations of sampling other sites within NSW and is illustrative of the seasonal differences in the plant community.

#### Vegetation diversity

##### NON-TREE COMMUNITY

A total of 105 species were identified across the non-tree community sites during the two sampling periods. This number is conservative as it excludes grasses (individual species were not identified) as well as approximately 5% of species that could not be identified accurately. The plant community was dominated by chenopods (Chenopodiaceae), which are terrestrial species adapted to dry conditions. Grasses (Poaceae spp.), and herbaceous brassicas (Brassicaceae spp.) and mallows (Malvaceae spp.) were common at most sites. Of the 105 species identified, slightly more than 60% were native. It should be noted that the proportion of native species does not include grasses and is therefore likely to be an overestimate as grasses often comprise a significant proportion of non-native species in these systems. Field observations were that only a small number of grasses were present during surveys and as such the overestimate is likely to be small.

The sites with the greatest number of species were two lakes in the Cumbung Swamp (Nooran Lake and Lake Marrool) and Booligal wetlands, with 29-31 species at each (Figure 25). Most sites had between 14 and 20 species occurring at the sites. There was little variation in the proportion of native species across sites (around 60%), with the exception of 'The Ville' where native species comprised 80% of the species recorded (Figure 27). Most of the species observed are classified as terrestrial species (using the definition of Casanova (2011)) and very few amphibious species were observed (Figure 29).

*Table 18. Summary of vegetation monitoring sites in the Lower Lachlan river system. The location of the sites within each Zone has been provided, however we do not consider the vegetation to be clearly separated according to zone. ANAE Classification is interim and is yet to be verified.*

| SITE (CODE) | GEOMORPHIC DESCRIPTION | ANAE CLASSIFICATION | VEGETATION COMMUNITY | TREE COMMUNITY: RIPARIAN PLOTS | NON – TREE COMMUNITY: TRANSECTS |
|---|---|---|---|---|---|
| **ZONE 1** | | | | | |
| **Hazelwood (HW)** | Floodplain Billabong | Pt1.1.1: Intermittent River red gum floodplain swamp | River red gum | 2 | 2 |
| **Whealbah (WB)** | Floodplain Billabong | Pt1.1.1: Intermittent River red gum floodplain swamp | River red gum/lignum | 2 | 2 |
| **Moon Moon (MM)** | Open lake fringed with red gum | Lt2.1: Temporary floodplain lakes<br>Pt1.1.1: Intermittent River red gum floodplain swamp | River red gum | 2 | 2 |
| **ZONE 2** | | | | | |
| **Lake Bullogal (LB)** | Channel mound wetland | Pt1.1.1: Intermittent River red gum floodplain swamp | River red gum | 2 | 2 |
| **The Ville (TV)** | Floodplain Billabong | Pt1.2.1 Intermittent black box floodplain swamp<br>Pt1.1.1: Intermittent River red gum floodplain swamp | Black box/river cooba/lignum<br>River red gum | 4 | 2 |
| **ZONE 3** | | | | | |
| **Clear Lake (CL)** | Lake (with reed beds) fringed with red gum | Pt1.1.1: Intermittent River red gum floodplain swamp | River red gum | 2 | 0 |
| **Nooran Lake (NL)** | Lake (with reed beds) fringed with red gum | Lt2.1: Temporary floodplain lakes | River red gum | 2 | 2 |
| **Lake Marrool (LM)** | Open lake fringed with red gum | Lt2.1: Temporary floodplain lakes | River red gum | 2 | 2 |
| **ZONE 4** | | | | | |
| **Tom's Lake (TL)** | Floodplain distributary channel | Pt1.2.1 Intermittent black box floodplain swamp | Black box/river cooba/lignum | 2 | 0 |
| **Lake Tarwong (LT)** | Floodplain wetland<br>Channel mound wetland | Pt1.2.1 Intermittent black box floodplain swamp/<br>Pt1.1.1: Intermittent River red gum floodplain swamp | Black box/river cooba/lignum<br>River red gum | 4 | 2 |

| SITE (CODE) | GEOMORPHIC DESCRIPTION | ANAE CLASSIFICATION | VEGETATION COMMUNITY | TREE COMMUNITY: RIPARIAN PLOTS | NON – TREE COMMUNITY: TRANSECTS |
|---|---|---|---|---|---|
| **ZONE 5** | | | | | |
| **Booligal (Boo)** | Floodplain distributary channel | Pt1.2.1 Intermittent black box floodplain swamp | Black box/river cooba/lignum | 2 | 2 |
| **Murrumbidgil Swamp (MB)** | Channel mound wetland | Pt1.1.1: Intermittent River red gum floodplain swamp | River red gum | 4 | 4 |

### TREE COMMUNITY

A total of 95 species were identified across the tree community plots during the two sampling periods. This number is conservative as it excludes grasses (individual species were not recorded) as well as approximately 5% of species that were unable to be identified accurately. Like the non-tree plant community, the understory of the tree plant community was dominated by chenopods which are terrestrial species adapted to dry conditions. Species of Asteraceae were the next most speciose family. Of the 95 species identified, around 75% were native species. It should be noted that the proportion of native species does not include grasses and is therefore likely to be an overestimate as grasses often comprise a significant proportion of non-native species in these systems. Field observations were that only a few grass species were present at each site.

Most sites had between 16 and 19 species occurring with only 10 species recorded at Hazelwood Billabong and 9 among the Black Box of Lake Tarwong (Figure 26). The proportion of native species was generally high, with more than 70% of the species recorded being native species (Figure 28). Most of the species recorded are classified as terrestrial species and very few amphibious species were observed (Figure 30).

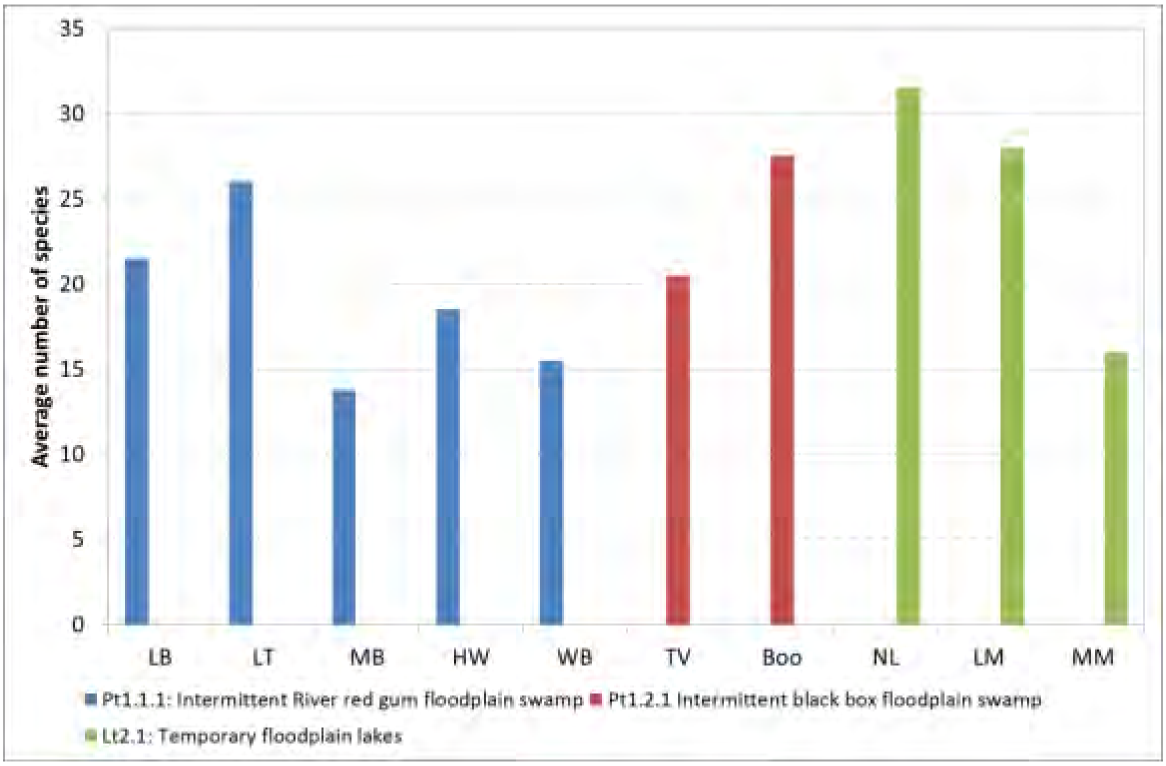


*Figure 25. Average number of groundcover species occurring per site in the non-tree vegetation community. The data are grouped according to provisional ANAE classification. Codes are defined in Table 18.*

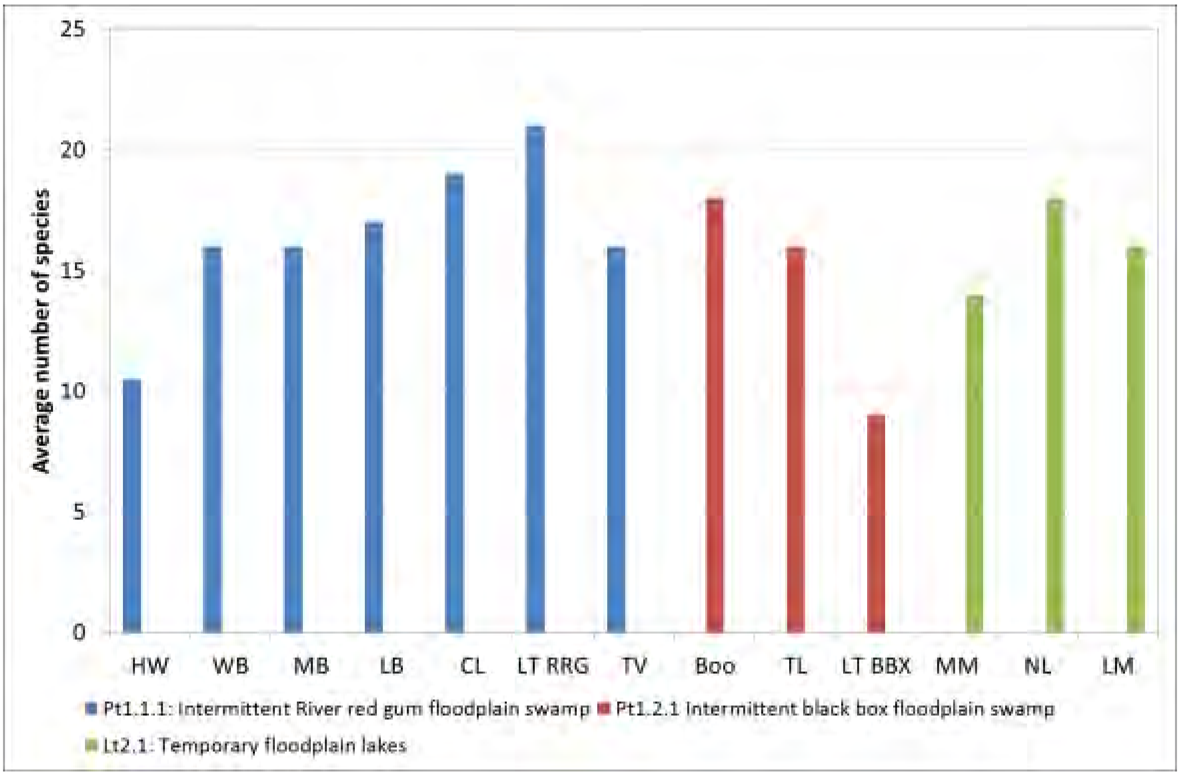


*Figure 26. Average number of groundcover species for each vegetation community at each site occurring in the treed vegetation community. The data are grouped according to provisional ANAE classification. Codes are defined in Table 18.*

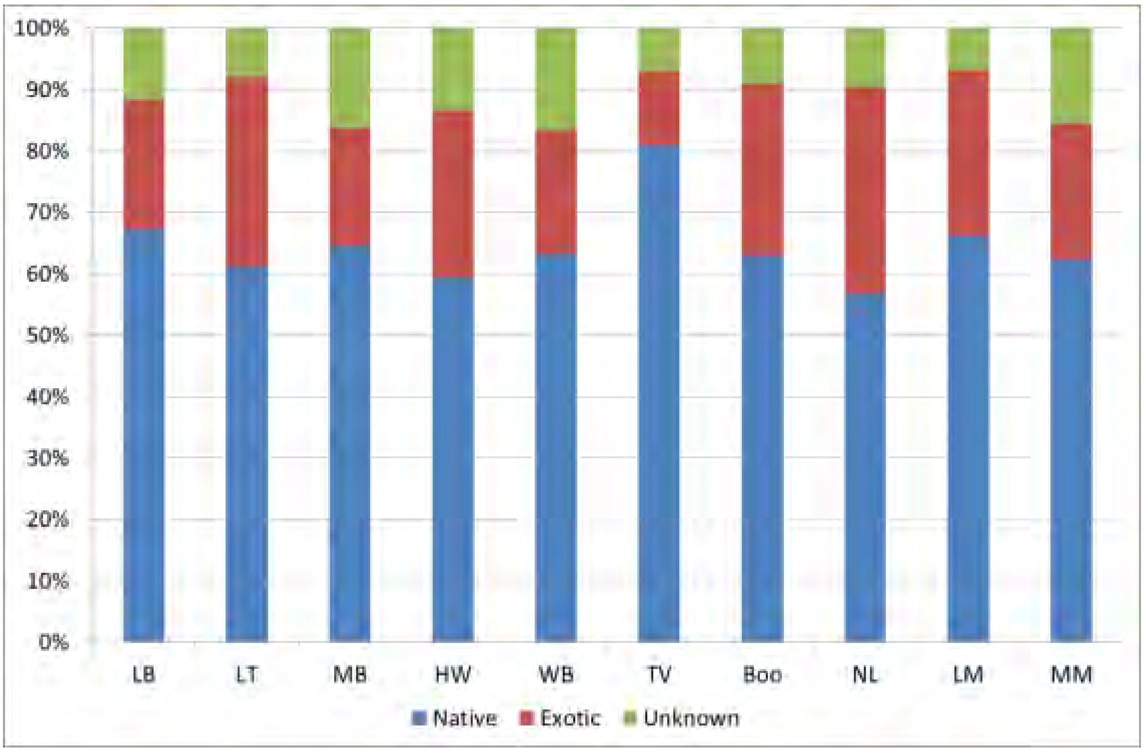


*Figure 27. Average proportion of native and exotic species per site within the non-tree community. Unknown represents species that were unable to be identified to a level suitable for classification. Codes are defined in Table 18.*

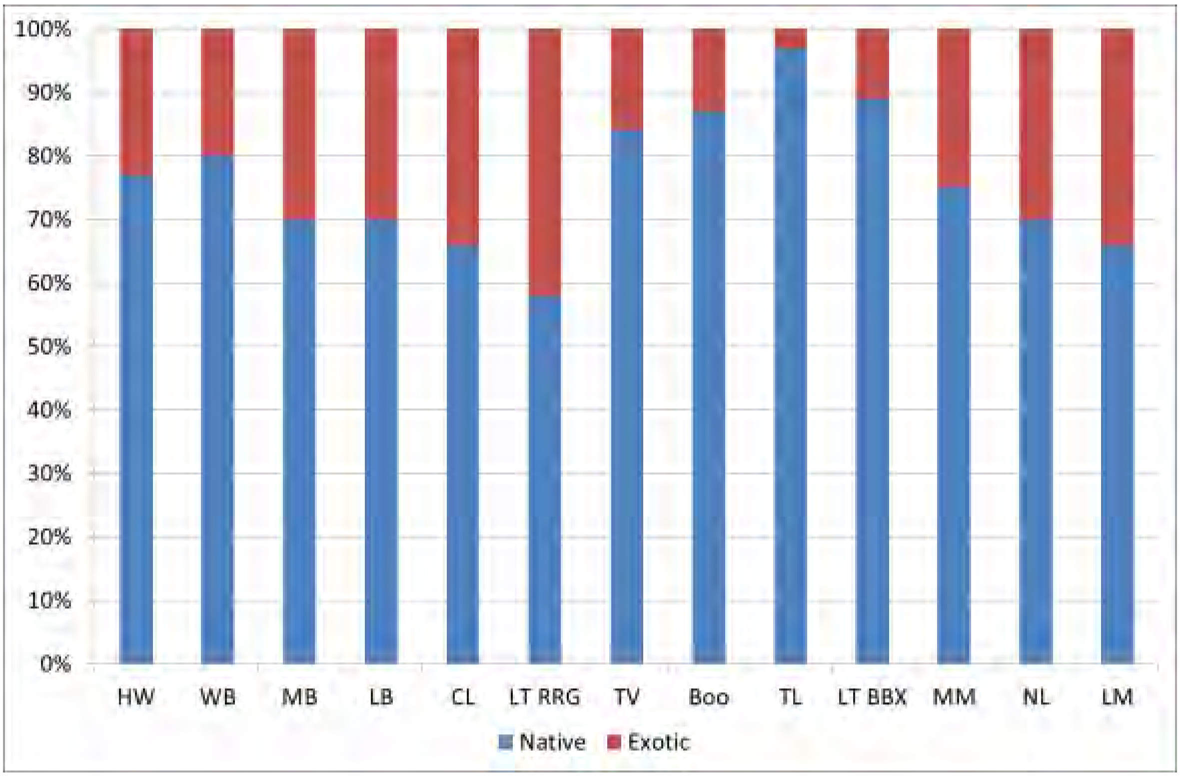


*Figure 28. Average proportion of native and exotic species per vegetation community per site within the tree community. Unknown species removed from the data set prior to classification. Codes are defined in Table 18.*

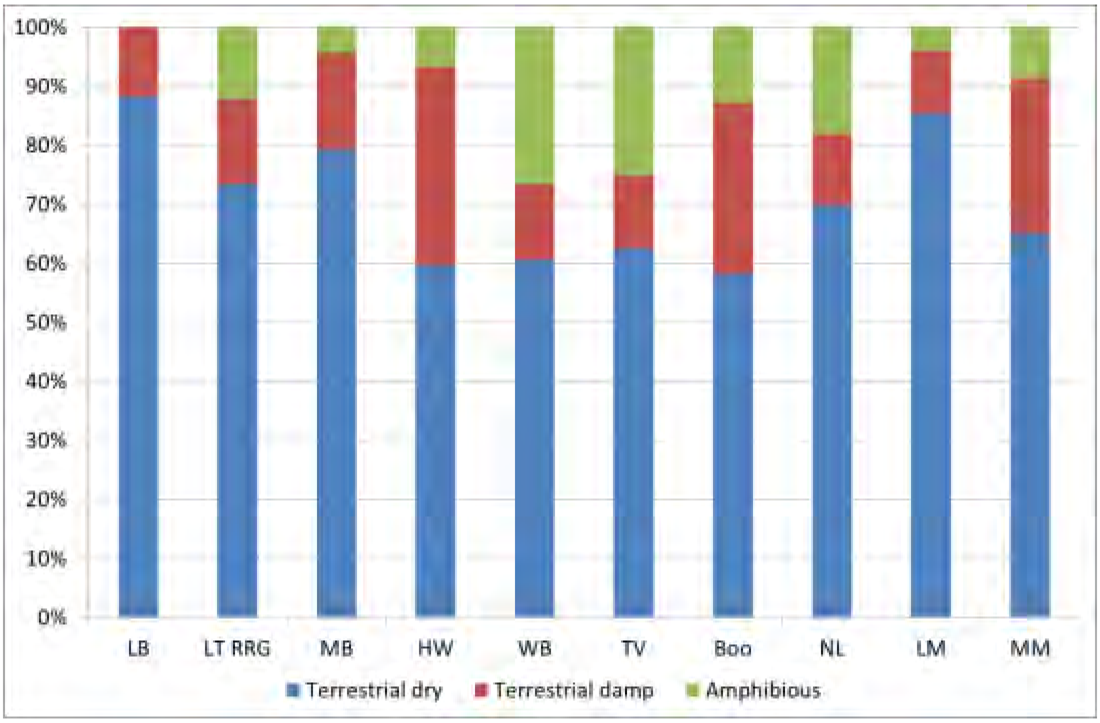


*Figure 29. Average proportion of terrestrial and amphibious species per site within the non-tree community. Codes are defined in Table 18.*

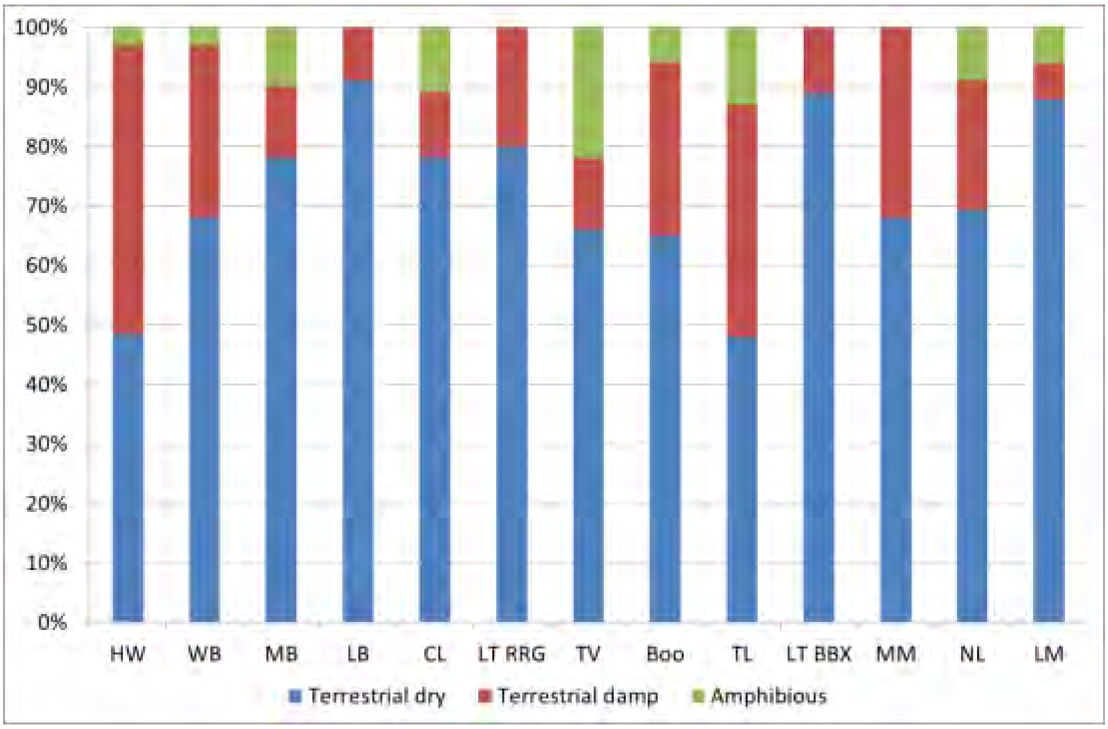


*Figure 30. Average proportion of terrestrial and amphibious species per vegetation community per site within the tree community. Codes are defined in Table 18.*

### Condition of floodplain and riparian trees

Small increases in foliage cover and decreases in the percentage dead canopy cover were observed between the November-December 2014 and May 2015, sampling, illustrating both seasonal and sampling variation between years (Table 19). The percent live basal area was unchanged between the two sampling events.

Seven sites exhibited changes of up to 12% in the percentage of dead canopy (Table 19) with most changes indicating a slight improvement. The reasons for this are yet to be determined but it is likely that differences in field teams between sampling events will have contributed to the differences and a longer period of monitoring is required to determine if the changes are significant. The foliage cover canopy openness similarly improved by up to 20% over the sampling period. Overall the tree stands at all sites surveyed were mostly in Intermediate condition with a few sites (Murrumbidgil Swamp river red gums and Lake Tarwong black box) in Intermediate/poor condition in terms of percent dead canopy (Table 19).

| SITE (n=2 unless otherwise noted) | AVERAGE FOLIAGE COVER (M2) | | | | | | AVERAGE % DEAD CANOPY | | AVERAGE % LIVE BASAL AREA | | TREE CONDITION | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | | | 2015 | | | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| | BBX | RC | RRG | BBX | RC | RRG | | | | | | |
| **Pt1.1.1: Intermittent River red gum floodplain swamp** | | | | | | | | | | | | |
| **Clear Lake** | | | 14.1 | | | 19.3 | 18 | 16 | 96 | 95 | I | I |
| **Hazelwood** | | 0.9 | 5.6 | | 1.7 | 7.6 | 31 | 24 | 64 | 64 | I | I |
| **Lake Bullogal** | | | 12.0 | | | 15.5 | 23 | 30 | 81 | 81 | I | I |
| **Lake Tarwong RRG** | | | 25.8 | | | 30.4 | 29 | 22 | 94 | 94 | I | I |
| **Murrumbidgil Swamp (n=4)** | | | 5.2 | | | 7.3 | 50 | 46 | 54 | 55 | I/P | I/P |
| **The Ville RRG** | 5.7 | 0.5 | 7.4 | 8.9 | 0.6 | 8.8 | 21 | 15 | 98 | 98 | I | I |
| **Whealbah** | | 2.6 | 18.0 | | 4.0 | 21.4 | 23 | 11 | 99 | 99 | I | I |
| **Pt1.2.1 Intermittent black box floodplain swamp** | | | | | | | | | | | | |
| **Booligal** | 14.1 | 8.6 | | 14.9 | 8.6 | | 20 | 26 | 85 | 86 | I | I |
| **Lake Tarwong BBX** | 10.9 | | | 12.2 | | | 50 | 48 | 96 | 94 | I/P | I/P |
| **Tom's Lake** | 12.4 | 5.8 | | 16.4 | 8.6 | | 29 | 22 | 99 | 99 | I | I |
| **Lt2.1: Temporary floodplain lakes** | | | | | | | | | | | | |
| **Lake Marrool** | | | 3.9 | | | 4.8 | 23 | 22 | 85 | 84 | I | I |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Moon Moon Swamp** | | | 6.3 | | | 7.8 | 29 | 29 | 79 | 80 | I | I |
| **Nooran Lake** | | | 7.8 | | | 10.8 | 29 | 28 | 92 | 92 | I | G |

*Table 19. Tree condition metrics for the woodland vegetation community of the Lower Lachlan river system. The data are grouped according to provisional ANAE classification. BBX = Black box; RRG = River red gums; RC = River Cooba*

G= good condition; I = Intermediate Condition, I/p = Intermediate / poor condition

### Regeneration

The numbers of seedlings and saplings present in all plots per site were aggregated to give a combined count per time of sampling, and to facilitate comparison between November-December 2014 and May 2015 (Table 20). All sites had some seedlings or saplings present (Table 20), except for Lake Bullogal where stocking density was high. While field observations suggest that grazing pressure is a major factor in the number of seedlings and saplings persisting at a site, the data suggest that this is site dependent (Table 20).

*Table 20. The average number of seedlings and saplings per site. Data for Booligal Lake Tarwong and Clear Lake not presented as yet unverified.*

| SITE | FLOODPLAIN/WETLAND COMPLEX | LANDUSE | GRAZING INTENSITY | SEEDLINGS AND SAPLINGS | |
|---|---|---|---|---|---|
| ***Red gum community*** | | | | ***2014*** | ***2015*** |
| **Hazelwood Billabong** | Lachlan River Floodplain | Grazing (sheep) | Recent and frequent | 28 | 35 |
| **Whealbah** | Lachlan River Floodplain | Grazing (sheep) | Recent and occasional | >500 | >500 |
| **Moon Moon Swamp** | Booligal Wetlands | Grazing (cattle) | Recent and frequent | 14 | 4 |
| **Nooran Lake** | Cumbung Swamp | Grazing (cattle) | Recent and frequent | 4 | 35 |
| **Lake Marrool** | Cumbung Swamp | Grazing | Recent and occasional | 1 | 2 |
| **Murrumbidgil Swamp** | Booligal Wetlands | Grazing (sheep) | Recent and frequent | 256 | 210 |
| **Lake Bullogal** | Lachlan Swamp | Grazing (sheep – large numbers) | Recent and frequent | 0 | 0 |
| **Lake Tarwong** | Merrowie/Box Creek | Grazing (sheep) | Recent and frequent | n/a | n/a |
| **Clear Lake** | Cumbung Swamp | Grazing (cattle) | Recent and frequent | n/a | n/a |
| ***Black box community*** | | | | | |
| **Booligal wetland** | Booligal Wetlands | Nature conservation | Low | n/a | n/a |
| **Tom's Lake** | Booligal Wetlands | Grazing (cattle) | Recent and frequent | 13 | 1 |
| ***Mixed Red Gum, River Cooba and Black Box*** | | | | | |
| **The Ville** | Lachlan Swamp | Nature conservation | Low | 27 | 50 |

## 7.5.4 Discussion

The monitoring of vegetation in 2014-15 provides baseline data against which the outcomes of future watering events can be compared.

The vegetation communities throughout the Lower Lachlan river system are dominated by terrestrial species at the end of the 2014-15 water year. There were very few amphibious species observed in the surveys, reflecting the fact that it was two years since watering of any of the monitoring sites. Observations and measurement made during the years immediately after the drought (2010-2012) suggested some degree of drought recovery was occurring within wetland vegetation communities, but at least by early 2012 aquatic vegetation was starting to show drought effects again, such as within the Cumbung Swamp, Lake Bullogal and Lake Merrimajeel (Driver, Barbour & Michener, 2011; Driver *et al.*, 2013a; Driver *et al.*, 2013b). These earlier assessments and the recorded dominance of terrestrial species during this survey suggest that the flood-dependent vegetation communities are currently exhibiting a dry phase. Similar trends have been identified in other floodplain wetland complexes in the Murray Darling Basin in the past decade e.g., in the Macquarie Marshes, (Driver & Knight, 2007; Bowen & Simpson, 2010; Thomas *et al.*, 2010; Bino *et al.*, 2015), the Gwydir, (Mawhinney, 2003) and, for the Lachlan (Driver, Barbour & Michener, 2011; Driver *et al.*, 2013a; Driver *et al.*, 2013b).

The sites surveyed display a reasonably high degree of nativeness with more than 60% of the identified understory species recorded being native. While this is likely to be a slight overestimate, it indicates that there is a good range of native species present. Recruitment of trees was observed at most sites, but a notable pressure on the success of recruitment was observed to be grazing of the sites, by both stock and feral species. This is known to mute the desired response to flow within some key wetland species. For example, grazing plots within the mid-Lachlan show that the exclusion of grazing impacts allows for much greater establishment of key fringe wetland plants (typically amphibious species); notably of Lignum (*Duma florulenta*), Warrego Summer Grass, Creeping Knotweed (*Persicaria prostrata*) and river red gum seedlings (Driver *et al.*, 2013b). This will partly render questions around the effects of environmental water for vegetation reproduction difficult to answer in the context of the LTIM project.

There appeared to be a consistent general improvement in vegetation condition between the summer and autumn sampling seasons with the canopy showing less dead material and canopy foliage cover generally improved. These patterns are more likely to be driven by numerous factors, with season and rainfall just before the May sampling trip likely to be strong contributors to this overall pattern. Future analysis with longer term LTIM data is more likely to be able to separate these effects from environmental flow benefits.

### 7.5.5 Adaptive Management Recommendations

- At the end of the 2014-15 water year, the vegetation communities throughout the Lower Lachlan river system are dominated by terrestrial species. This indicates that the flood-dependent vegetation communities are currently in a dry phase. Future monitoring of watered sites may provide insight into the presence of other flood dependent vegetation species and for the capacity of the vegetation communities to return to a healthy wet phase. This information will contribute to the development of future watering options for wetland vegetation outcomes.
- Grazing presents a significant pressure on the recruitment of trees. This will affect the ability of environmental watering to achieve outcomes for long lived vegetation species in the catchment.

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