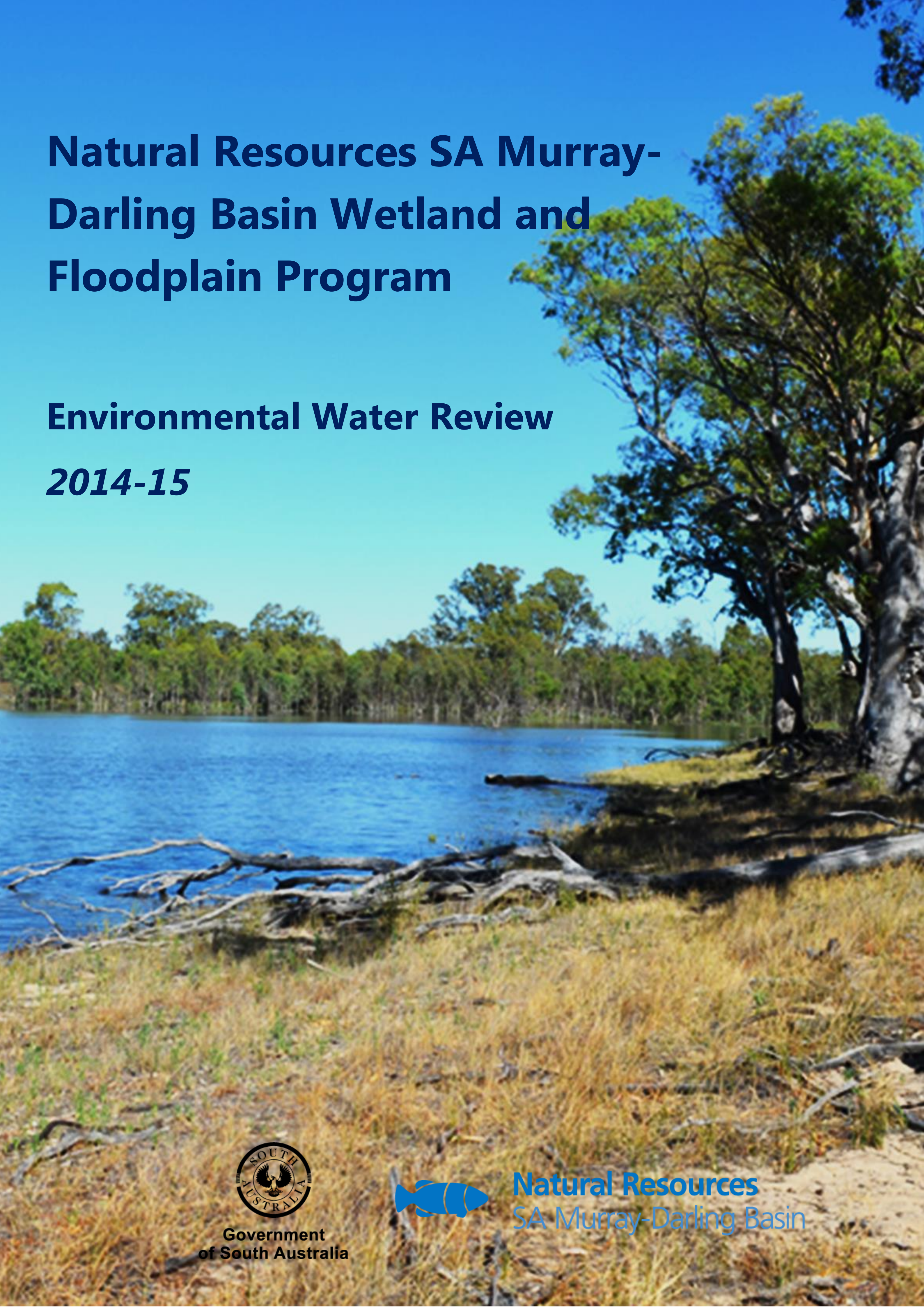
Natural Resources SA Murray-Darling Basin Wetland and Floodplain Program

Environmental Water Review

2014-15



Government of South Australia

Natural Resources
SA Murray-Darling Basin

Government of South Australia
Department of Environment, Water and Natural Resources

Natural Resources
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Cover photo: Markaranka South Wetland, Markaranka Flat Wetland Complex (I. Wegener).

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Executive Summary

The Natural Resources South Australian Murray-Darling Basin (Natural Resources SAMDB) Wetland and Floodplain Team is a key deliverer of environmental water to wetlands and floodplains along the River Murray in South Australia. In 2014/15 a total of 8.397 gigalitres (GL) of water was delivered inundating approximately 811 hectares (ha) across 22 wetland and floodplain sites. Environmental water allocated to these sites were from either the Commonwealth Environmental Water Holder (CEWH), State Environment Reserve or from donation. Most permanent wetlands managed at 'normal' pool levels receive an environmental water allocation via the South Australian River Murray wetland water access entitlement (previously Class 9) known as the Ministers Wetland Water Licence. These are not discussed here.

This report provides a summary of the sites watered, the ecological outcomes achieved and the community engagement undertaken in 2014/15. In addition, this report also provides a review and analysis of the program and environmental watering project for 2014/15, and guides future management and monitoring related to environmental watering activities.

The main ecological outcomes of environmental water delivery for the 2014/15 year were:

- Tree condition improved with an increase in crown extent and density observed at monitored sites.
- Condition of long-lived floodplain vegetation (e.g. lignum (*Duma florulenta*)) was observed improving across watered sites.
- Photopoint monitoring showed vegetation responding to water with tip growth and 'greening'.
- Flowering, seed setting and germination of river red gums (*Eucalyptus camaldulensis*) was observed across watered sites.
- Waterbird species from range of functional groups were observed utilising watered wetlands.
- At least four species of waterbird were recorded breeding across four watered sites, including two species of conservation significance.
- Eight waterbird species of conservation significance were recorded at four watered sites.
- The nationally threatened regent parrot (*Polytelis anthopeplus monarchoides*) was recorded at three watered sites.
- Record numbers of the endangered Murray hardyhead (*Craterocephalus fluviatilis*) were captured at Berri Evaporation Basin and Disher Creek.
- Frog breeding, including that of the nationally threatened southern bell frog (*Litoria raniformis*), was recorded across numerous watered sites.
- Several fish species were captured at pumping sites including two species of conservation significance.

- A range of macroinvertebrates were recorded from pumped sites.
- A number of other terrestrial fauna species (e.g. kangaroos, echidnas and snakes) were recorded utilising watered sites.

In summary, this report clearly demonstrates that the watering program undertaken in 2014/15 resulted in numerous highly beneficial ecological outcomes being achieved across the SAMDB region. It also provides further evidence that environmental water is important for maintaining wetland and floodplain ecosystems and processes in the absence of flood events within the SA Murray-Darling Basin region.

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Acronyms

AHD	Australian Height Datum
CEWH	Commonwealth Environmental Water Holder
DEWNR	Department of Environment, Water and Natural Resources
GL	Gigalitres
ha	Hectares
L	Litre
LAP	Local Action Planning
m	Meter
MDB	Murray-Darling Basin
ML	Megalitre
NGO	Non-government Organisation
SA	South Australia
SAMDB	South Australian Murray-Darling Basin

Part A: Introduction and Background

Part A: Introduction and Background

Natural Resources SAMDB Environmental Watering Program

Each year, the Natural Resources South Australian Murray-Darling Basin (Natural Resources SAMDB) Wetland and Floodplain Team delivers environmental water to wetlands and floodplains across the River Murray region in South Australia. Environmental water is water that is delivered specifically for environmental outcomes. This water has many benefits for the wetlands and floodplains found along the length of the River Murray, such as improving fringing vegetation, supporting frog and waterbird breeding and, providing habitat for threatened fish species. Water is delivered to both permanent and temporary wetlands, as well as targeted floodplain sites across the region.

The Wetland and Floodplain Team has been in existence for over 10 years in various forms. The key roles of the Team are to:

1. Plan and coordinate environmental water and wetland management at a regional scale.
2. Deliver environmental water.
3. Conduct monitoring and analyse ecological data.
4. Undertake community engagement and communications activities.
5. Implement on-ground works.
6. Provide input into the development of policy and State and Federal River Murray projects.

This work is supported by funds from the Federal Government (Commonwealth Environmental Water Office and National Landcare Program) and the State Governments Natural Resources Management Levy, and administered through the South Australian Murray-Darling Basin Natural Resources Management Board.

What is environmental watering?

Environmental water, which is referred to as 'e-water' within this report, is the delivery or use of water to achieve environmental outcomes (DEWNR 2014). These environmental outcomes contribute to the functioning of and, ensure that the ecological value and condition of wetlands and floodplains that lie adjacent the River Murray, as well as the Lower Lakes, Coorong and Murray Mouth, are either maintained, protected and/or restored (DEWNR 2014).

Why do wetlands need water? A current and historical perspective

Freshwater wetland ecosystems have undergone radical change since European settlement of Australia, and in particular have been systematically, excessively and extensively modified and degraded (Patten 2006; Finlayson and Rea 1999; Nielsen and Brock 2009; Davis and Froend 1999). Current estimates suggest more than 90 percent of wetlands located in the Murray-Darling Basin (MDB) have been lost since European settlement (Cramer and Hobbs 2002; Arthington and Pusey 2003). Resulting declines of several iconic and keystone flora and fauna species can be attributed primarily to the necessity to secure reliable water supplies for the human population and agricultural industry, which to a large extent is located within the MDB region (Arthington and Pusey 2003; Jensen 2002).

Throughout Australia, and particularly in the MDB, the ecological integrity of remaining freshwater wetlands is under threat from the combined impacts of over-allocation and extraction of water resources (which includes water extracted for critical human needs), and natural system modification (Patten 2006; Nielsen and Brock 2009; Davis and Froend 1999). The ability of many wetland and floodplain species, both flora and fauna, to persist is highly dependent upon the availability of flows within both the main river channel as well as overbank flood and drought events (Gosselink and Mitsch 2007; Haslam 2003; Bice 2010). When significantly reduced, the productivity of the ecosystem and its ability to support and provide processes and services of importance to the environment and community may be impeded (Bice 2010; Haslam 2003). The freshwater wetlands and adjacent floodplains of the River Murray in South Australia are highly important ecosystems that provide an environment in which many unique flora and fauna species are able to flourish under optimal hydrological conditions (Obst 2005; Mitsch and Gosselink 2007; Haslam 2003; Opperman et al. 2010). Hence, alteration of natural system hydrology is often viewed as the most serious and continuing threat to the ecological health and integrity of freshwater wetland environments throughout the world (Bunn and Arthington 2002; King et al. 2010; Gibson et al. 2005).

The paleolimnological history of the River Murray, shows that the River Murray in South Australia and its floodplains and wetlands, were shaped by numerous large floods in its ancient history (Goode and Harvey 2009). While smaller more frequent flood events were crucial to the maintenance and shaping of floodplain vegetation communities that were spread across them (Goode and Harvey 2009). River regulation has resulted in an alteration to the flooding experienced in the River Murray in South Australia, substantially decreasing the magnitude, duration and frequency of floodplain inundation (Jensen et al. 2007). Small flood events, for example, flows of 30 000 ML/day for a period of 30 days, now occur in approximately five out of 10 years under current conditions, however in comparison would have occurred during almost nine out of 10 years under natural (modelled) conditions (BIGMOD 2011). Larger flood events, such as those of 50 000 ML/day for at least 30 days, under current (modelled) conditions occur approximately four out of 10 years, whereas would have occurred naturally (under modelled scenarios) eight in 10 years (BIGMOD 2011).

Across the SAMDB region, a range of wetland and floodplain types exist that support unique and diverse wetland flora and fauna communities that hold significant local, cultural, social and economic, as well as ecological, values (Nielsen and Brock 2009; Williams 1999a; Postel and Richter 2003). In addition, wetlands provide and support an extensive and wide array of critically important processes and services (Nielsen and Brock 2009; Finlayson and Rea 1999; Baron et al. 2002; Williams 1999b); Dawson et al. 2003). These are identified under four categories (Mitsch and Gosselink 2007; Haslam 2003). They include: 1) provisioning services such as the supply of freshwater and genetic materials; 2) regulating services including the maintenance of the hydrological regime, pollution control and local climate regulation; 3) cultural services for example recreational, tourism, spiritual, scientific and educational services, and; 4) supporting services, for example those services that support biodiversity, soil formation and nutrient cycling (Department of the Environment, Water, Heritage and the Arts 2008; Mitsch and Gosselink 2007; Haslam 2003; Nel et al. 2008; Burkett and Kusler 2000; Mander and Mitsch 2009; Gilbert et al. 2004). Broadly summarised by the Department for Environment and Heritage and Department of Water, Land and Biodiversity Conservation (2003, p. 9), "wetlands are essential to the maintenance of the hydrological, physical and ecological health of the riverine environment and they provide economic, social and cultural benefits to the broader community."

How is environmental water delivered in South Australia?

The basis for the Natural Resources SAMDB Wetland and Floodplain Team's Environmental Watering Program is set out in the Annual Environmental Watering Plan for the SA River Murray (referred to as 'the Annual Plan' in this document) (DEWNR 2014). The Annual Plan aims to ensure that the best environmental outcomes are achieved within the wetlands and along the floodplains that lie adjacent to the River Murray in South Australia, and that these are consistent with requirements that are set out in the Murray-Darling Basin Authority (MDBA) Basin Plan (henceforth referred to as 'the Basin Plan') (DEWNR 2014). The Annual Plan is developed to coordinate and prioritise the delivery of e-water to South Australia, and aims to maximise environmental outcomes from the use of environmental water within the region (DEWNR 2014). In addition, the plan also makes publicly available planned environmental watering activities, meets the requirements of various environmental water holders who provide water to and within South Australia, meets the requirements of the Murray-Darling Basin Plan, and provides input into the SA River Murray Operation Plan 2014-15 (DEWNR 2014).

Each year, e-water proposals are developed using the best available science and ecological data, and are subject to changes as a result of changed river conditions, water availability and adaptive management (DEWNR 2014). Priorities are determined by the scale of environmental benefit, risk of not applying water, environmental risks associated with watering, certainty/likelihood of benefit, and significance of the site (DEWNR 2014). Within the Annual Plan, specific objectives for the 2014/15 water year were used to coordinate the delivery of environmental water and maximise potential outcomes, deliver water to high priority sites (i.e. Lower Lakes, Coorong and Murray Mouth), facilitate the Chowilla Environmental Regulator testing event, and weir pool manipulation trials (DEWNR 2014).

In South Australia, the majority of environmental water delivery is managed through the Department of Environment, Water and Natural Resources (DEWNR). Input is also received from non-government organisations and local stakeholders (e.g. wetland community groups). Within the Natural Resources SAMDB region the planning of environmental water is undertaken in conjunction with wetland community groups, private landholders, traditional owners, industry (e.g. viticulture), Local Action Planning Associations (LAPs) and Landcare groups.

Environmental Water Holders and Sources

The two primary environmental water holders in the Murray-Darling Basin are (DEWNR 2012):

- The Living Murray (TLM) supported by the Murray Darling Basin Authority (MDBA).
- The Commonwealth Environmental Water Holder (CEWH) supported by the CEW Office, within the Commonwealth Department of Environment (DoE).

Other environmental water sources through which environmental benefits to the River Murray in South Australia can be achieved include (DEWNR 2012):

- South Australian Environmental Water Reserve.
- South Australian River Murray wetland water access entitlements (previously Class 9) (known as the Ministers Wetland Water Licence).
- Unregulated flows within the River Murray system.
- Private donations from non-government organisations (NGOs) and irrigators.

The State Environmental Reserve has approximately 6 GL of water for environmental use. In the 2014/15 water year, 100 percent of the water held in the State Reserve was allocated for use (DEWNR 2014).

Water delivered to temporary wetlands, floodplains and specific high priority wetlands (e.g. threatened species sites) through the Natural Resources SAMDB environmental watering program is primarily sourced from the CEWH or the State Environmental Reserve. Donations for small volumes of water have also been made by private irrigators.

Wetlands that access water from the Ministers Wetland Water Licence are those that are permanently connected to the main river channel, some of which are managed through the use of wetland infrastructure to implement wetting and drying phases. The ecological outcomes achieved at the wetlands that access the Minister's Wetland Water License are not discussed within this report.

Long Term Environmental Watering Plan for SA River Murray

The Long Term Environmental Watering Plan (LTWP) for the South Australian River Murray Water Resource Plan (WRP) area is currently in development in accordance with the environmental management framework within the Murray-Darling Basin Plan. The LTWP builds on several years of annual environmental water planning and integrates the information developed through many long-running and successful projects and programs within the region (DEWNR 2015).

A landscape-scale approach was chosen for defining environmental assets, with three priority assets identified within the SARM WRP Area (DEWNR 2015):

1. The Lower Lakes, Coorong and Murray Mouth.
2. The South Australian River Murray Channel.
3. The South Australian River Murray Floodplain.

As part of the development of the LTWP, 16 ecological objectives and 29 nested ecological targets were identified for the Channel Priority Environmental Asset (Wallace 2014) and 22 ecological objectives and 42 nested ecological targets were identified for the Floodplain Priority Environmental Asset (Kilsby 2015). These objectives and targets focus on abiotic processes, water quality, biofilms, vegetation, wetlands, groundwater and fish.

The watering objectives of individual wetlands within the Natural Resources SAMDB environmental watering program correspond to a number of the LTWP objectives and targets in particular those relating to black box, river red gum, river cooba, lignum, frogs, waterbirds (including regent parrots) and fish (DEWNR 2015).

Site Selection

Each year, sites are selected and prioritised for environmental water delivery based on a number of parameters: These include: the volume of water available, resource outlook conditions, requirements (both ecological and flooding frequency history) of the site for water, the ability to build upon waterings conducted in previous years, the risk of not delivering water, support from the community/landholder, logistical capability of water delivery to the site and other resource availability (i.e. staff, project management and funding) to undertake delivery activities.

Environmental Watering 2014/15

In 2014/15 the Natural Resources SAMDB watering program delivered a total of 8.397 GL of water inundating approximately 811 ha at 22 wetland and floodplain sites.

Priority sites identified in 2014/15 for watering included:

1. Two Murray hardyhead sites: Berri Evaporation Basin and Disher Creek
2. Twelve sites within the Valley geomorphic region
3. Seven sites within the Gorge geomorphic region
4. One site between Lock 1 and Wellington
5. One fringing Lower Lakes wetland: Tolderol

Report Overview

This report provides a summary of the sites watered, the ecological outcomes achieved and the community engagement undertaken in 2014/15. The report includes sections on monitoring findings relating to specific parameters across a number of e-watered wetlands:

- surface water quality
- tree condition
- waterbirds
- frogs and tadpoles
- vegetation

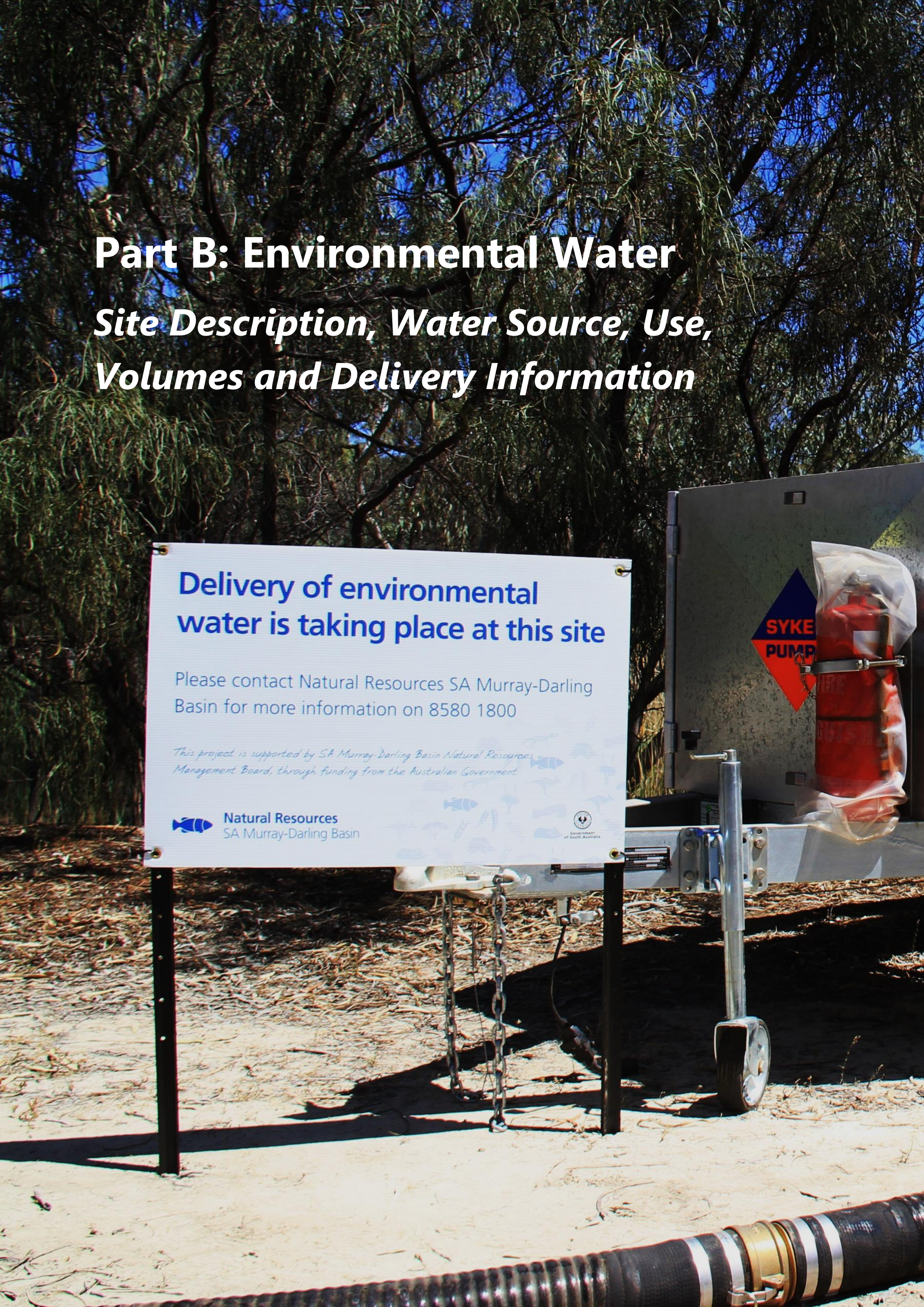
The report also includes sections on findings for the folllowing specific locations / projects:

- Murray hardyhead sites: Berri Evaporation Basin and Disher Creek
- Bookmark Creek
- Gerard Floodplain black box watering trials
- Wiela dripper irrigation trial
- Markaranka Floodplain black box watering trails
- Tolderol Game Reserve
- Sugar Shack Wetland

The communications and community engagement activities undertaken that supported the watering program are also discussed. In addition, this report also provides a review and analysis of the program and environmental watering project and aims to guide future management and monitoring related to environmental watering activities.

Part B: Environmental Water

Site Description, Water Source, Use, Volumes and Delivery Information



Part B: Environmental Water - Site Description and Water Source, Use, Volume and Delivery Information

In 2014/15 the following wetlands received environmental water (Table 1). Table 1 gives a brief physical description of each location receiving environmental water. Locations of the sites receiving environmental water are shown in Appendix A. Environmental water allocated to these sites were from the either the Commonwealth Environmental Water Holder (CEWH), State Reserve or from donation. These are shown in the following tables (Table 2).

Table 1. Physical description of environmental watering site.

Site		Description
Akuna Wetland		Akuna Wetland is a small temporary wetland of moderate to deep depth. It is fringed predominantly by large mature river red gums as well as stands of regenerated gums. At the northern edge, a stand of mature black box fringes the wetland.
Berri Evaporation Basin		A large, shallow wetland basin that receives inflow from surrounding highland irrigation area. High priority site for the conservation of the nationally endangered Murray hardyhead.
Disher Creek		A large, shallow wetland basin that receives inflow from surrounding highland irrigation area. High priority site for the conservation of the nationally endangered Murray hardyhead.
Nikalapko Wetland		Nikalapko Wetland is a large, deep temporary wetland basin. The wetland is fringed by large, mature river red gum trees with an understorey of sedges.
Markaranka Flat Wetland Complex	Markaranka and Markaranka South	Markaranka and Markaranka South wetland basins are situated between the main river channel and Markaranka East Basin. River red gum and river cooba (*Acacia stenophylla*) trees fringe the edge of the large deep wetland basins. Markaranka East is situated between the highland and Markaranka and Markaranka South basins. Dense stands of lignum are found in this basin and it is fringed by river red gums. Surrounding the temporary wetland basins is a relatively intact floodplain dominated by black box trees. Detailed site description is given in Wegener (2011).
	Markaranka East	
	Markaranka Floodplain	
Overland Corner	Main Basin	Comprised of a number of wetland basins and depressions. The Main Basin sheds and is surrounded by river red gums. Upstream of the Main Basin, temporary wetland/depression areas are surrounded by river red gums, river cooba and lignum. The lignum Basins are situated between the main river channel and the Main Basin, with lignum cover and river red gum stand regeneration. A more detailed description can be found in Robertson (2007).
	Lignum Basins	
Piggy Creek		Piggy Creek is situated within the Katarapko National Park. It is comprised of a deep temporary creek with wetland basin. The creek

		is fringed by river red gums and lignum while the wetland basin is dominated by lignum on the bed and fringing the wetland basin.
Whirlpool Corner		Whirlpool Corner Wetland is a small, relatively shallow temporary wetland basin. It is located within the Riverland Ramsar site. The wetland basin is fringed predominantly by river cooba, lignum and black box (*Eucalyptus largiflorens*). More details of the sites physical nature are available in Ecological Associates (2006).
Murtho Park/Wiela Wetland Complex	Wiela wetland	The Murtho Park/Wiela wetland complex is comprised of a mixture of permanent flowing creeks system, permanent lagoons and temporary wetlands basins (Wiela Wetland and Wiela Shedding Basin). Wiela Wetland is comprised of two small-medium sized wetland basins connected by a temporary floodrunner creek. These basins are predominantly surrounded by large mature river red gum trees. Wiela shedding basin is a medium sized wetland basin with significant river red gum regeneration since the 2010/11 flood event. The site is situated within the Riverland Ramsar site and Riverland Biosphere Reserve. More information regarding the site is available in Turner (2007).
	Wiela shedding basin	
Wigley Reach	Western channel	Wigley Reach is comprised of a number of predominantly deep floodrunner channels. These are predominantly fringed by large mature river red gum trees, lignum and river cooba. There are also black box scattered across the floodplain with an understorey of lignum.
	Central channel	
Molo Flat	Eastern and Western basins	Molo Flat is comprised of both floodrunner channels and temporary wetland basins. The floodrunner channels and wetland basins are predominantly fringed by large mature river red gum trees. Large established lignum stands dominate the wetland basin beds, while river cooba are also found at the downstream end of the wetland basins.
	Eastern and Western channels	
Bookmark Creek		Creek anabranch that bypasses Lock 5 at Renmark, it borders the township to the west. Historical use has been as a saline disposal basin, however is no longer used as such. The Creek provides significant and important flowing water habitat in South Australia. Additional site information is detailed in Wegener (2013).
Gerard Floodplain		High conservation and cultural value floodplain located at the downstream end of Katarapko National Park. The floodplain is comprised of lignum basins fringed by mature river red gum and cooba while higher on the elevation gradient, mature black box trees are found with areas of regeneration of these long-lived floodplain species found across the site (Wegener, in prep). Site lies within the Katfish Demonstration Reach Boundary.
Morgan Conservation Park	South Basin	The South Basin is a temporary wetland situated within the Morgan Conservation Park and is therefore regarded to have high conservation value. Large established river red gums fringe the South Basin with dense mature stands of lignum dominating the wetland bed. Additional site information is available in Ireland (2012).

Morgan East		Morgan East temporary wetland is predominately fringed by river red gums trees. In addition black box and river cooba trees are also found around the wetland basin with an understorey of lignum. A detailed site description can be found in Nickolai (2013).
Old Loxton Road		Old Loxton Road temporary wetland lies within the Causeway Wetland Complex. The site is dominated by samphire and saltbush with black box and river cooba fringing the wetland basin. A detailed description of the site is found in Schultz and Harper (2007).
Sugar Shack	Temporary Basin	Sugar Shack wetland complex is comprised of a number of permanent-managed, permanent and, temporary wetlands. The Temporary Basin is dominated by lignum shrubland, fringed with sedges, river red gum and black box.
Templeton Wetland		Templeton wetland is comprised of a number of small intermittent creeks and depressions. Fringing vegetation at this site is comprised of sedges, lignum, river red gum and black box at higher elevations. The site is situated within the Riverland Ramsar site and Riverland Biosphere Reserve (Ecological Associates 2006).
Tolderol		Tolderol Game Reserve is situated on the edge of Lake Alexandrina within the Coorong and Lower Lakes Ramsar region. The site is comprised of a series of regulated artificial bays of varying depths that can be flooded via pumping.
Katarapko Floodplain	Island Creeks	Katarapko Island Creeks and Katarapko Creeks are situated within the Katarapko Floodplain, a floodplain of importance within South Australia. These temporary creeks are deep and fringed by river red gums are prominent in these areas (Katfish Reach Steering Group 2008).
	Creek	

Table 2. Environmental water source, delivered to sites including delivery information, 2014/15.

Commonwealth Environmental Water Holder						
Site		**Water delivery method**	**Location – Lock reach**	**Commence to Flow (~ML/day)**	**Area (ha)***	**Volume delivered (ML)**
Akuna Wetland		Pumping	Lock 2	30 000	6	125.394
Berri Evaporation Basin		Gravity fed	Lock 4	At pool	100	1241
Nikalapko Wetland		Pumping	Lock 1	25 000	46	799.98

Markaranka Wetland Complex	Markaranka and Markaranka South basin	Pumping	Lock 1	30 000	70	1452.47
	Markaranka East	Pumping	Lock 1	65 000	10	799.46
Molo Flat		Pumping	Lock 1	60 000	62	748.355
Overland Corner	Main basin	Pumping	Lock 2	15 – 30 000	93	741
	Lignum basin	Pumping	Lock 2	~60 000	13.4	100.992
Piggy Creek (Katarapko)		Pumping	Lock 4	25 000	33	201.17
Whirlpool Corner		Pumping	Lock 5	15 – 30 000	11	89.999
Wiela Wetland	Temporary basin	Pumping	Lock 5	30 000	7	254.969
Wigley Reach		Pumping	Lock 3	30 000	10	313.962
TOTAL					**461.4**	**6868.751**
State Environment Reserve						
Bookmark Creek		Gravity fed	By-passes Lock 5	At pool	30	420
Gerard Floodplain	Black box watering trial	Gravity fed	Lock 3	20 000 – 350 000	5	0.648
Katarapko Creek		Pumping	Lock 4		4.2	27.329
Katarapko Island Creeks		Pumping	Lock 3		17.76	134.72
Morgan Conservation Park	South basin	Pumping	Lock 1	20 – 30 000	14.2	128.332
Morgan East		Pumping	Lock 1	~20 000	122	193.768
Old Loxton Road		Pumping	Lock 4		3.3	22.324
Overland Corner	Lignum/red gum basins	Pumping	Lock 2	~20 000	93	
Sugar Shack	Temporary basin	Pumping	Wellington – Lock 1		5	41.9
Templeton		Pumping	Lock 5	12 000	9.4	134.097
Tolderol Game Reserve		Pumping	Barrages – Wellington		40	415.717

Wiela	Red gum stands	Pumping	Lock 5	60 000	2	1.008
TOTAL					**345.86**	**1519.843**
Donation						
Markaranka Wetland Complex (Treasury Wine Estates)	Black box watering trial	Irrigation (Vineyard)	Lock 1	>100 000	4	9.4
TOTAL					**4**	**9.4**
TOTAL (ALL)					**811.26**	**8397.994**

* Area does not include zone of influence area from seepage.

In 2014/15 the total volume of water delivered to sites was 8397.994 ML, comprising of 6868.751 ML from the CEWH and 1519.843 ML from the State Reserve (Table 2). In addition, a donation from Treasury Wine Estates of 9.4 ML was also contributed to environmental watering activities in 2014/15. Depending upon the site, purpose of watering and water source, the majority of environmental water was delivered in spring and summer (see Appendix B).

Watering Objectives

In South Australia, the overarching objective for environmental watering is to maximise the environmental outcomes from available water (DEWNR 2014). This overarching objective supports the objectives of the Basin Plan, The Living Murray (TLM) and Commonwealth Environmental Water Office (CEWO), and are largely focused around the protection and restoration of water dependent ecosystems that are resilient to climate change and other risks and threats, and that irreversible loss of key environmental assets is avoided. The ecological objectives and justification for environmental water, are submitted within the state annual environmental watering process and to the CEWH. Specific ecological objectives are developed for sites where water delivery is implemented by the Wetland and Floodplain Program.

Watering objectives are based on site condition assessments, current resource availability, future water resources and climate projections, scientific knowledge and data, with funding availability also a necessary consideration. In addition the frequency of historical water delivery (via unregulated river flows) and the risks of both undertaking and not undertaking the watering are also considered in developing justifications for watering. Ecological objectives for watering undertaken during 2014/15 were largely to:

- Maintain and/or improve the condition of long-lived vegetation such as river red gum, black box, river cooba and lignum, including mature and recently regenerated trees.
- Maintain and/or improve the diversity and abundance of aquatic vegetation.

- Provide and support habitat and breeding opportunities for water-dependent fauna such as waterbirds, frogs and fish.
- Maintain and/or improve conditions and habitat for threatened species such Murray hardyhead, regent parrot and southern bell frog.

The following table shows the ecological objectives for the watering at each site in the 2014/15 water year (Table 3).

Table 3. Objectives for environmental watering sites, 2014/15.

Site	Vegetation – Adult/Mature	Vegetation – Seedlings/Saplings	Vegetation – Aquatic	Vegetation – Other	Waterbirds	Frogs	Fish	Other
Akuna	x	x		x		x		
Berri Evaporation Basin							x – Murray hardyhead	Maintain critical habitat
Bookmark Creek							x	Maintain flowing water habitat
Gerard Floodplain – black box Trial	x – black box			x – understorey				Cultural/spiritual values
Katarapko Creek	x – river red gum							
Katarapko Island Creeks	x –river red gum	x						Bushfire recovery
Markaranka – black box trial	x – black box	x		x – understorey				
Markaranka Flat Wetland Complex (multiple sites)	x		x		x	x		
Molo Flat	x					x		
Morgan Conservation Park (South Basin)	x			x – lignum		x		
Morgan East						x		
Nikalapko Wetland	x					x		
Old Loxton Road				x – lignum		x		Salinity
Overland Corner – lignum basin	x			x – lignum		x		
Overland Corner – main basin	x					x		
Piggy Creek	x	x				x		Flood frequency
Sugar Shack – Temporary Basin					x – cryptic waterbirds	x		Cultural/spiritual values
Templeton Wetland	x	x				x		
Tolderol Game Reserve					x – migratory waders	x		Cultural/spiritual values
Whirlpool Corner	x					x		Flood frequency
Wiela – Dripper Trial		x – river red gum						
Wiela Wetland Basins	x					x		
Wigley Reach	x					x		

Green – Valley Wetlands; Orange – Murray Hardyhead sites; Blue – Gorge Wetlands; Yellow – D/S Lock 1 (Lakes).

Part C: Monitoring and Reporting

Part C: Monitoring and Reporting

To determine if the objectives of environmental watering were met, and to evaluate the ecological outcomes of the delivery of environmental water to sites, monitoring and reporting was undertaken as part of the region's e-water program. It is a requirement of state and federal government agencies to report on water used for environmental watering activities, to ensure that risks are properly monitored, assessed and mitigated; and that future environmental watering projects are able to be improved through adaptive management and building existing knowledge. Monitoring is a key aspect in this process and is important to support decision making for current and future watering activities, establish and manage risks and identify gaps in our knowledge of ecology.

There is also a requirement under the Basin Plan (Matter 9) to report on the use of environmental water. The Natural Resources SAMDB Wetland and Floodplain Program contributes to Matter 9 through the implementation of a monitoring program that assesses ecological outcomes of environmental watering, as well as forming the basis for the prioritisation of environmental water for SA River Murray wetlands in the future. This monitoring also contributes to the scientific knowledge of the environmental water requirements of wetland and floodplain biota across the region and catchment more broadly. The collection of this data feeds into three types of monitoring. That is: operational which is annual; intervention which is over the short to long-term, and; program monitoring which focuses on broad scale monitoring across the SAMDB basin.

Regular updates of water use and ecological outcomes observed at watered sites are provided to relevant stakeholders (namely the CEWO and River Murray Operations Branch, DEWNR) at least fortnightly. The *Water Act* requires the Commonwealth Environmental Water Holder to provide an annual report on the management of Commonwealth Environmental Water (Commonwealth Environmental Water Holder 2013). Within South Australia, DEWNR is responsible for reporting on the delivery of environmental water which align with the states requirements under the Basin Plan (DEWNR 2014).

Site specific monitoring

Monitoring at specific environmental watering locations was carried out prior to watering activities being undertaken, as well as during and after. Early detection of the deterioration of condition is crucial to being able to implement actions that aim to protect, restore and eventually improve condition. Monitoring is an essential component that underpins the prioritisation of sites for environmental water and helps to define realistic targets and objectives for each site. It enables wetland ecologists to make sound and transparent decisions regarding the management of these sites and guides the management of the environmental water delivery.

Monitoring was undertaken at sites to determine ecological outcomes as a result of watering actions. Many incidental observations were also made at sites outside of the 'formal' monitoring by Wetland and Floodplain Program ecologists and have been incorporated into this report where appropriate. All monitoring was undertaken under a DEWNR Scientific Permit, Fisheries (Ministerial) Exemption and in accordance with DEWNR ethics standards. The following table shows parameters monitored at each location 2014/15 (Table 4).

Table 4. Parameters monitored at environmental watering sites 2014/15.

Site	Water level/ volume	Vegetation (Tree condition)	Water-birds	Frogs and tadpoles	Fish	Water quality	Photo-point/ time lapse
Akuna Wetland	x	x		x		x	x
Berri Evaporation Basin	x				x	x	
Bookmark Creek	x	x			x	x	x
Disher Creek	x				x	x	
Gerard Floodplain	x	x					x
Katarapko Creek	x						
Katarapko Island Creeks	x						x
Markaranka – Floodplain	x	x					x
Markaranka Flat Wetland Complex	x	x	x	x		x	x
Molo Flat	x	x		x		x	x
Morgan Conservation Park	x			x		x	x
Morgan East	x			x		x	x
Nikalapko	x		x	x		x	X
Old Loxton Road	x			x		x	x
Overland Corner	x	x	x	x		x	x
Piggy Creek	x	x	x	x		x	X
Sugar Shack	x					x	
Templeton	x			x		x	x
Tolderol	x		x			x	
Whirlpool Corner	x	x		x		x	x
Wiela	x	x		x		x	x
Wiela – Dripper Trial	x	x					x
Wigley Reach	x	x		x		x	x

Note: not all parameters monitored are reported on in this report.

Part D: Surface Water Quality Monitoring

Part D: Surface Water Quality Monitoring

Surface water quality is a critical factor in determining wetland aquatic biota communities and thus is vital in wetland management. Physical and chemical variations can change both over short timeframes (e.g. diurnally) and longer timeframes (e.g. seasonal changes, droughts and floods). Water quality is determined by various factors including the flow of groundwater, the surface topology, geology of the wetland bed and banks and management of the wetland (Tiner 1999; Mitsch and Gosselink 2007; Haslam 2003; Tucker 2003). As such, surface water parameters are different and unique for each wetland, and can vary considerably over time.

Monitoring Methodology

Surface water quality monitoring reported on here was undertaken at 13 wetland locations receiving environmental water via pumping. These are: Akuna Station Wetland, Markaranka Flat Wetland Complex, Morgan Conservation Park (South Basin), Molo Flat Wetland Complex, Morgan East Wetland, Nikalapko Wetland, Overland Corner Wetland, Piggy Creek, Templeton Wetland, Whirlpool Corner Wetland and Wigley Reach Wetland Complex. Monitoring was undertaken between November 2014 and April 2015 at fixed monitoring sites across the locations. Monitoring of surface water was undertaken using a U-52 Horiba. Parameters monitored included electrical conductivity (µS/cm), pH, turbidity (Nephelometric Turbidity Units (NTU)), dissolved oxygen (mg/L) and water temperature (°C). Detailed results from surface water quality monitoring is given in Appendix C.

Surface water electrical conductivity (µS/cm)

Surface water salinity is measured as electrical conductivity (EC) (µS/cm). Surface water EC is expected to reflect the hydrological phases undertaken in the wetland, for example wetting and drying phases. Lower surface water EC levels are likely to be recorded as a result of freshening flows through the wetland complex (either as a result of over bank flows or a specific management action such as opening of structures or pumping) (Jolly et al. 2008a; Jolly et al. 2008b; Baldwin et al. 2005; Nielsen and Brock 2009). Salts are as a result, diluted and/or flushed from the wetland (Tucker et al. 2002). Meanwhile, high surface water EC readings are likely to be observed due to the evapo-concentration of salt within the water column while the wetland is undergoing a drying or low-flow phase (Cramer and Hobbs 2002; Baldwin et al. 2005; Tucker 2003).

Summary of surface water electrical conductivity (µS/cm) monitoring

Surface water EC ranged between 272 and 2040 EC across watered sites (Appendix C). Surface water EC at each monitored site (and wetland location) increased over time on average across the watered sites from initial watering. Upon the initial fill of the wetland, surface water electrical conductivity was measured relatively low, reflecting the relatively low EC of the source water (River Murray). Following initial watering, the surface water electrical conductivity at the monitored sites increased over time. Higher surface water EC was likely recorded as a result of evapoconcentration of salts within the waterbody, as well as the mobilisation of salts from the wetland bed and banks. Lower EC was recorded at some sites due to additional top-up pumping events resulting in the dilution of salts, as well as the relatively low sodic nature of some sites (e.g. Markaranka Flat Wetland Complex) compared with other sites (e.g. Overland Corner Wetland).

Surface water pH

Surface water pH is a measure of the acidity or alkalinity of the water. Typically surface water pH falls between 6 and 9 pH, and levels outside of this range may indicate unusual processes occurring within the wetland (Baldwin et al. 2005). Higher surface water pH may be recorded as a result of abundant aquatic macrophyte growth (Cronk and Fennessy 2001). Aquatic macrophytes remove carbon dioxide (CO_2) from the water column through the process of photosynthesis, which results in elevated surface water pH levels being observed, particularly in summer when photosynthesis rates are generally higher than in winter (Cronk and Fennessy 2001; Berezina 2001; Baldwin et al. 2005). Additionally, surface water pH may be increased through some bacterial processes, such as denitrification or accelerated algal growth (Baldwin et al. 2005). Lower surface water pH may be caused by high organic loads, bacterial processes (such as nitrification) or oxidisation of sulfidic sediments (Baldwin et al. 2005).

Summary of surface water pH (units) monitoring

Surface water pH at sites ranged from a minimum 6.29 to a maximum 10.19 across monitored sites. The minimum pH reading across sites between November 2014 and April 2015 ranged between 6.29 to 7.85, while the maximum pH within this period ranged from 7.42 to 10.19. These readings are within ranges considered to be 'normal' with no readings of concern detected during monitoring.

Surface water turbidity (NTU)

Turbidity is a measure of the cloudiness of water from suspended particles and has an important influence on the level of primary production within the wetland ecosystem (Baldwin et al. 2005; Biolotta and Brazier 2008). Low surface water turbidity can be a result of reduced water circulation through the wetland (Tucker 2003) and given that the watered wetlands were disconnected from the main river channel, is likely to have resulted in relatively clear water conditions being recorded at these sites. Additionally, wetlands with higher salinity levels can have lower turbidity levels as salt causes an increased aggregation of soil particles resulting in clearer water conditions (Tucker 2003). Consolidating wetland bed sediments through drying is also recognised as a factor resulting in lower turbidity readings being recorded upon the re-filling of a wetland (Tucker 2003) although this may be also dependent upon the turbidity levels of water from the water source. As most of the wetlands had been dried prior to receiving environmental water, it is probable that the bed of the wetlands were well consolidated.

Higher turbidity readings may be a result of wind-seiches, especially in shallow wetlands which have a large surface area to volume ratio (Tucker 2003). The bio-turbation activities of common carp (*Cyprinus carpio*), resulting in the resuspension of sediments is also likely to be a cause of increased turbidity levels in surface waters in the River Murray which may have resulted in higher turbidity readings being observed at watered wetlands (Biolotta and Brazier 2008; Tucker 2003). It is also possible that wetland bed sediments may be disturbed through monitoring practices resulting in an increase in turbidity readings (I. Wegener pers. obs. August 2011).

Summary of surface water turbidity (NTU) monitoring

The minimum turbidity recorded across watered sites ranged from 6.3 to 60.3 NTU between November 2014 and April 2015. The maximum across sites ranged from 179 to 800 NTU. The variability in readings simply reflects the differences in sites and conditions at the site at the time of measurement. For example some monitored sites were relatively well sheltered by lignum shrubbery, while other sites were shallow and exposed, resulting in better mixing and suspension of sediments particularly on windy days. In addition, as the wetlands were not connected to the source water supply, the body of water at pumped sites was relatively still, resulting in sediments dropping out of suspension and thus clearer water conditions being recorded.

Surface water dissolved oxygen (mg/L)

Dissolved oxygen (DO) is an important determinant of wetland biota survival (Baldwin et al. 2005; Tucker 2003). DO often shows a cycle where lowest DO is recorded in the early morning and increases during the day as a result of the photosynthetic activities of aquatic plants and algae (Tucker 2003). DO levels typically fall between 7-10 mg/L depending on surface water temperature, with colder water able to contain more DO (Baldwin et al. 2005). The amount of DO water holds is also influenced by atmospheric pressure and the quantity of dissolved particles (e.g. salts). Low DO, that is dissolved oxygen less than 5 mg/L, can cause stress and impede normal functions and functioning in the organisms body, and may lead to the mortality of aquatic organisms (Baldwin et al. 2005; Tucker 2003). As such, persistently low DO levels should be a cause for concern for the management of a wetland complex. Low dissolved oxygen levels may be due to microorganism activity, breaking down organic matter within the wetland, which reduces DO availability (Tucker 2003). High DO levels may occur as a result of wind-assisted mixing as well as generated by photosynthesising algae and submerged plants in the wetland (SKM 2004; Tucker 2003).

Summary of surface water dissolved oxygen (mg/L) monitoring

A range of dissolved oxygen levels were recorded across sites during the monitoring period. The minimum during the monitoring period ranged from 0.32 to 7.76 mg/L while the maximum ranged from 10.74 to 23.95 mg/L. The relatively low readings recorded across sites initially is likely to be as a result of the breakdown of terrestrial vegetation and other organic material upon inundation. The initial breakdown of vegetation on the wetland bed is a natural process and dissolved oxygen levels improve over time as aquatic vegetation develops. While higher readings were taken at the end of the day when oxygenation of the water had occurred throughout the day as a result of photosynthetic processes.

Surface water temperature (°C)

Surface water temperature is largely dependent upon atmospheric temperature and conditions. In winter when cooler atmospheric temperatures are observed, cool water temperatures may be recorded, in summer when warmer atmospheric temperatures are experienced, warmer water temperatures are observed. Water temperature may also be determined by shading provided by overhanging trees.

Summary of surface water temperature (°C) monitoring

Surface water temperature reflected similar trends to atmospheric temperature through the monitoring period November 2014 to April 2015. The minimum temperature recorded across monitored sites throughout the monitoring period ranged from 15.46 to 25.53 °C with higher minimum temperatures recorded in summer months, and decreasing towards autumn. The maximum surface water temperature ranged from 27.96 to 33.51°C, again the higher temperatures recorded during warmer months and lower maximum temperatures during cooler months.

Part E: Tree Condition Monitoring

Part E: Tree Condition Monitoring

Dieback of floodplain trees on the floodplains of the River Murray in South Australia is considered an issue of 'considerable concern' (Jolly et al. 1993). Not only because of the widespread reports of declining condition across the Lower Murray River region that has implications for river and floodplain biodiversity, but because of public concern for the most prominent of floodplain species, the river red gum (*Eucalyptus camaldulensis* var. *camaldulensis*) (Murray-Darling Basin Commission 2003). This species in particular is a distinctive and iconic character of the Murray River and its floodplains and wetlands (Murray-Darling Basin Commission 2003). The cause of this decline has been attributed to natural system modification (river regulation), over-allocation and extraction of water resources and drought combined, and has resulted in widespread declines in the condition and mortality of floodplain trees across the SA Murray-Darling Basin region (Jolly et al. 1993). The drought event commencing in 2001, further exacerbated the impacts of floodplain tree mortality and declining condition and as such, floodplain trees along the River Murray floodplain are generally in poor health condition, with further declines in condition predicted if natural flooding and/or intervention does not occur. Severely reduced rainfall coupled with river regulation dramatically impacted freshwater ecosystems in this region between 2001 and 2010. In addition, lack of regeneration and recruitment of long-lived vegetation has implications for the continued survival of these species (Margules and Partners et al. 1989) and indeed for those species that depend upon them (Murray-Darling Basin Commission 2003). Additionally, floodplains of the South Australian Murray-Darling Basin have undergone extensive ecological character changes since the regulation of the River Murray that places them at further risk through, for example, grazing and modification for other agricultural purposes (Gehrig and Nicol 2010; Jolly et al. 2002).

Although many trees that line the length of the River Murray in South Australia appear to be in good health condition, in other areas of the floodplain, particularly those situated higher on the elevation gradient or further from a source of freshwater, the decline of tree health condition and widespread mortality is prominent (Murray-Darling Basin Commission 2003). The impoundment of water in each weir pool has resulted in the permanent flooding of many areas, and subsequent drowning of trees in others. This is further compounded by the infrequency with which flooding now occurs which has resulted in loss of trees from floodplain areas across the SAMDB (Murray-Darling Basin Commission 2003).

The River Murray floodplain is dominated by two tree species: river red gum and black box (*Eucalyptus largiflorens*) (Murray-Darling Basin Commission 2003). Other long-lived vegetation species such as river cooba (*Acacia stenophylla*) and lignum (*Duma florulenta*) are also present across large areas of the River Murray floodplain in South Australia. Both river red gum and black box are well adapted to an environment that is characterised by frequent drought and flood periods, and are widespread across the inland and arid floodplains of the SAMDB. Howerver they are dependent upon frequent flooding to maintain health condition of trees, as rainfall is generally insufficient to sustain this long-term, and also to recharge and export salts from groundwater and soils (Murray-Darling Basin Commission 2003; Roberts and Marston 2011).

In the last two decades, increasing attention has been focused on the decline in the condition of much of this long-lived vegetation in the South Australian Murray-Darling Basin region and has raised questions in regards to the actual scale and implications of this trend (Murray-Darling Basin Commission 2003). An increasingly common method for maintaining these trees and other vegetation between such flood events has been to deliver water through filling (by pumping) temporary wetland basins and floodplain depressions, and through weir pool manipulation (increasing river water levels) (Gehrig and Nicol 2010).

Tree condition objective

One of the primary aims of environmental watering through the Wetland and Floodplain Program is to improve and/or maintain the condition of floodplain vegetation including floodplain tree species such as river red gum and black box and long-lived vegetation such as lignum. Watering to improve and maintain vegetation condition is important for conserving habitat vital to the survival of wetland fauna and well as maintaining nutrient cycles (e.g. carbon).

Monitoring methodology

Tree condition assessments were conducted on river red gums at three representative wetland sites: Markaranka Flat Wetland Complex, Molo Flat and Wiela. A total of 110 trees (*Markaranka Flat = 47*; *Molo Flat = 36*; *Wiela = 27*) were assessed using The Living Murray (TLM) Tree Health Condition monitoring methodology outlined below (Souter et al. 2010).

'The Living Murray' methodology (Souter, et al. 2010) visually assesses tree condition using a number of parameters. These are:

- *Crown extent* (a percentage score of the assessable (live) crown, including epicormic growth).
- *Crown density* (a percentage score of the amount of light able to penetrate through the crown of live leaves).

Category scales for crown extent and density are as follow Table 5:

Table 5. Category scale for crown extent and density assessment.

Score	Description	Percentage of assessable crown holding leaves (%)
1	None	0
2	Minimal	1 – 10
3	Sparse	11 – 20
4	Sparse – Medium	21 – 40
5	Medium	41 – 60
6	Medium – Major	61 – 80
7	Major	81 – 90
8	Maximum	91 – 100

(From Souter et al. 2010).

Other parameters visually assessed included: epicormic and new tip growth, leaf die-back, mistletoe and reproduction (such as buds, seed pods and flowers). These were assessed using the following scoring index (Table 6). In addition to quantitatively scoring trees, photos were also taken of trees on each monitoring occasion to compare visual changes in crown extent and density over time (e.g. Figure 1).

Table 6. Category scale for epicormic growth, new tip growth, leaf die-back, mistletoe and reproduction.

Score	Description	Definition
0	Absent	Effect is not visible
1	Scarce	Effect is present but not readily visible
2	Common	Effect is clearly visible
3	Abundant	Effect is abundant and dominant

(From Souter et al. 2010).

Figure 1. a) pre-watering photo, b) post watering photo, Wiela Wetland, 2014-15.

Trees were monitored as close as possible to the commencement of watering to minimise the influence of rainfall or other climatic variables. Trees were monitored again six weeks after the commencement of watering to monitor the effect of watering. Dead trees were excluded from data analysis. As visual assessment of tree condition is a subjective method, the same observers monitored sites on both occasions to attempt to reduce differences in observer bias between sampling events.

Data Analysis

Data analysis followed the methodology from Gehrig (2013) and Harper and Shemmield (2012) where the product of the crown extent and crown density category scores was calculated using the following equation, which was used to standardise the resulting scores to between 0 - 1:

Equation 1:

$$\frac{\textit{Crown extent x Crown density}}{0.9025}$$

The tree health condition scores were assigned to a five-class condition score rating (Table 7) based on the product of the above equation (Equation 1) as per Harper and Shemmield (2012).

Table 7: Five-class tree condition index score rating and category equivalent.

Condition score	Condition rating
0 – 0.01	Extremely poor
0.01 – 0.1	Very poor
0.1 – 0.4	Poor
0.4 – 0.7	Good
>0.7	Very good

Markaranka Flat Wetland Complex

The majority of trees monitored prior to the site receiving water were scored as in 'Very poor' (*n=16*) to 'Poor' (*n=26*) condition, with few trees in the 'Good' (*n=4*) and one tree in 'Very good' condition (Figure 2). Six weeks following watering, the majority of trees were recorded to be in 'Good' (*n=32*) condition, with three in 'Very good' condition and twelve in 'Poor' condition.

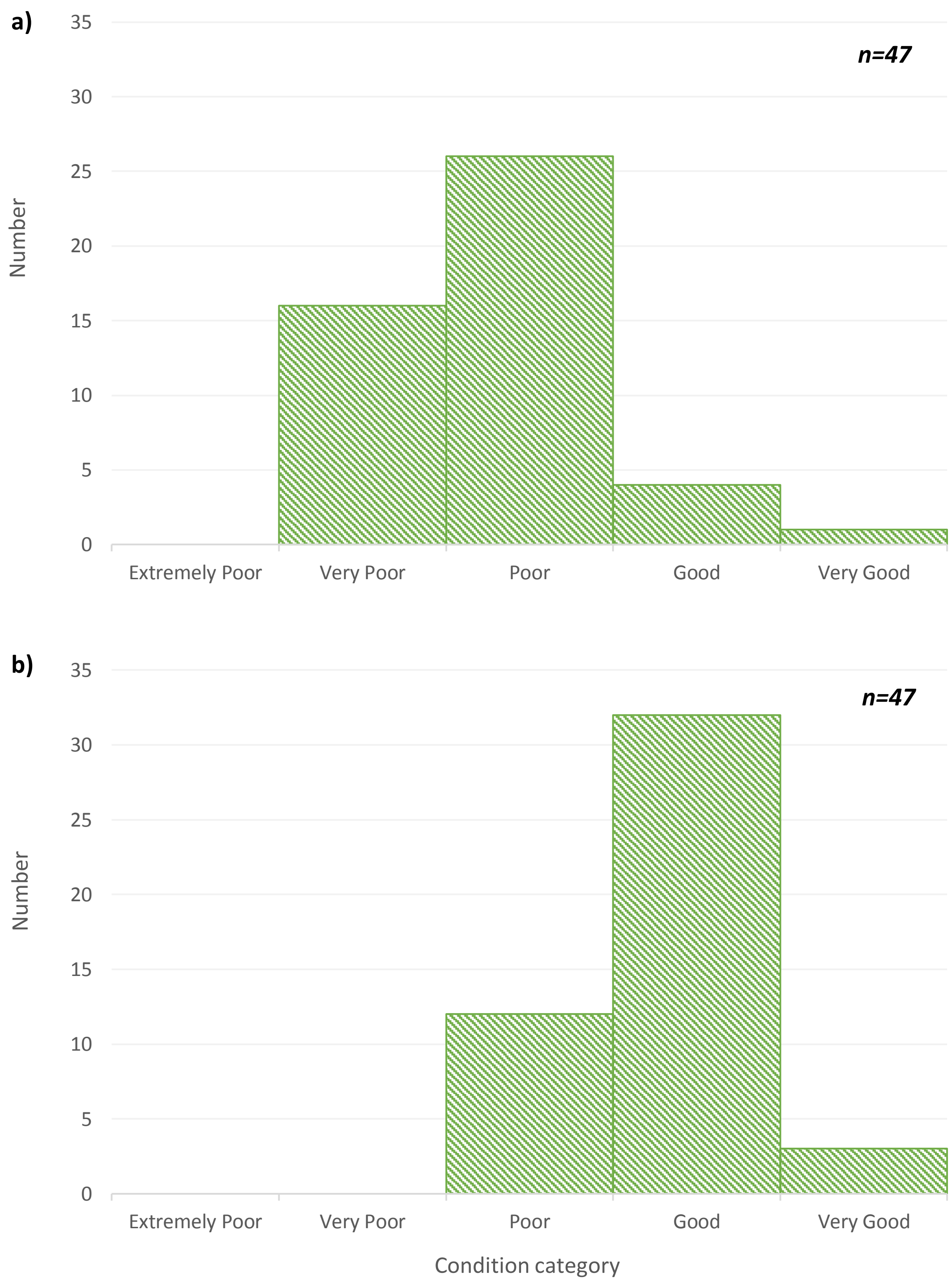


Figure 2. Tree condition before and six weeks following water delivery, Markaranka Flat Wetland Complex, a) November 2014 b) February 2015.

The following figure (Figure 3), shows the observed epicormic and tip growth, leaf dieback and reproduction response of monitored trees at Markaranka Flat Wetland Complex. Prior to watering, many trees (*n=21*) showed no tip growth. The remainder showed mostly 'scarce' tip growth (*n=20*) and few displayed 'common' (*n=6*) growth. Following the commencement of watering, an increase in the number of trees observed with tip growth increased (*total n=45*). An increase in the number of trees exhibiting either 'common' (*n=30*) or 'abundant' (*n=12*) tip growth was also noted.

Prior to watering, the majority of trees at Markaranka showed some signs of dieback (*n=34*) with the remaining trees (*n=13*) not recording any dieback. Following watering, none of the trees (*n=47*) showed any signs of dieback.

There was no clear change in reproduction scores over time with similar numbers recorded showing no sign of reproduction before (n=20) and after watering (n=26). Most other trees were scored as having scarce or common signs of reproduction both before and after watering.

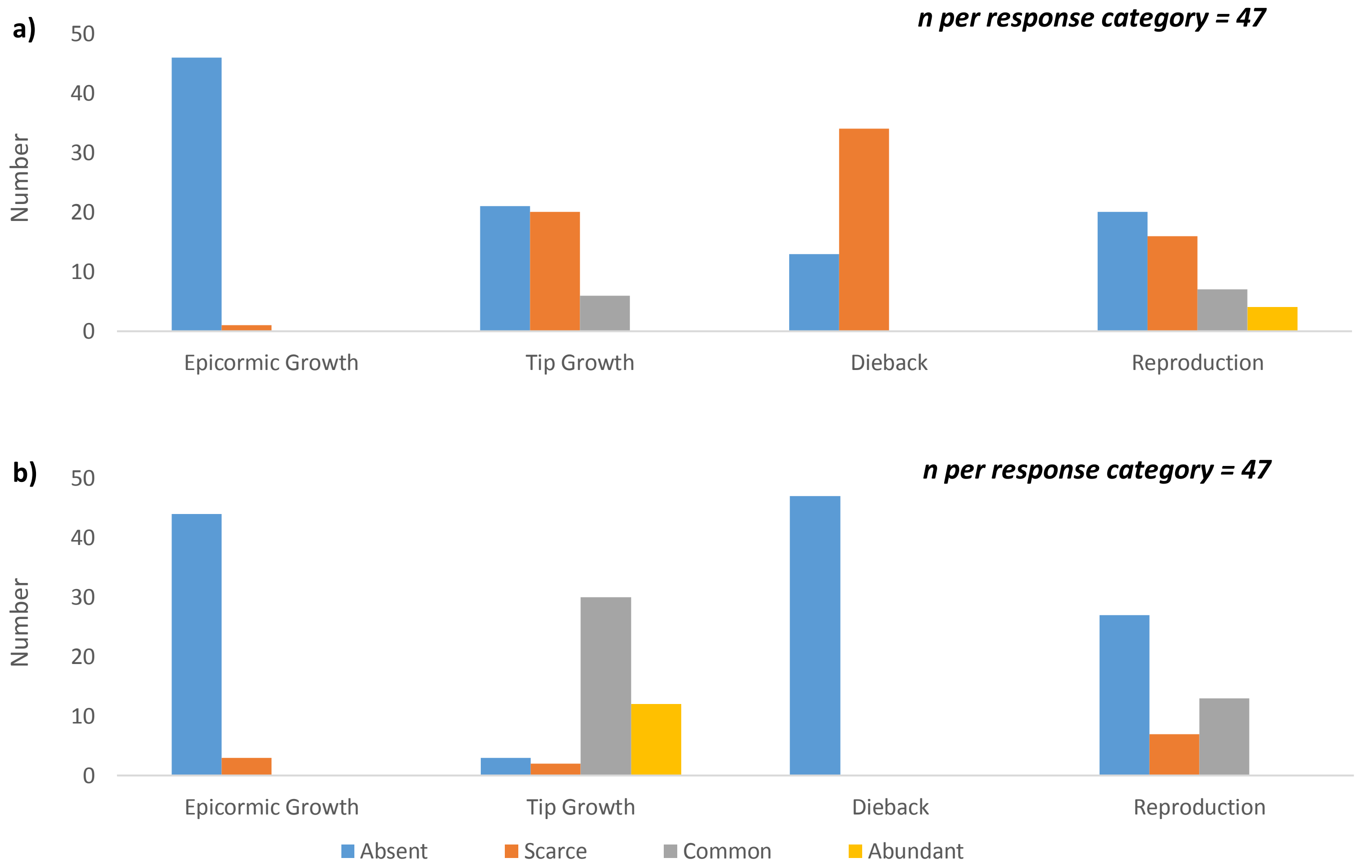


Figure 3. Tree response (epicormic growth, tip growth, dieback and reproduction), Markaranka Flat Wetland Complex, a) November 2014 b) February 2015.

Molo Flat Wetland Complex

Prior to watering, trees at Molo Flat were observed to be mostly in 'Poor' (*n=17*) and 'Good' (*n=15*) condition (Figure 4). After watering however, nearly all trees were classed as 'Good' (*n=25*).

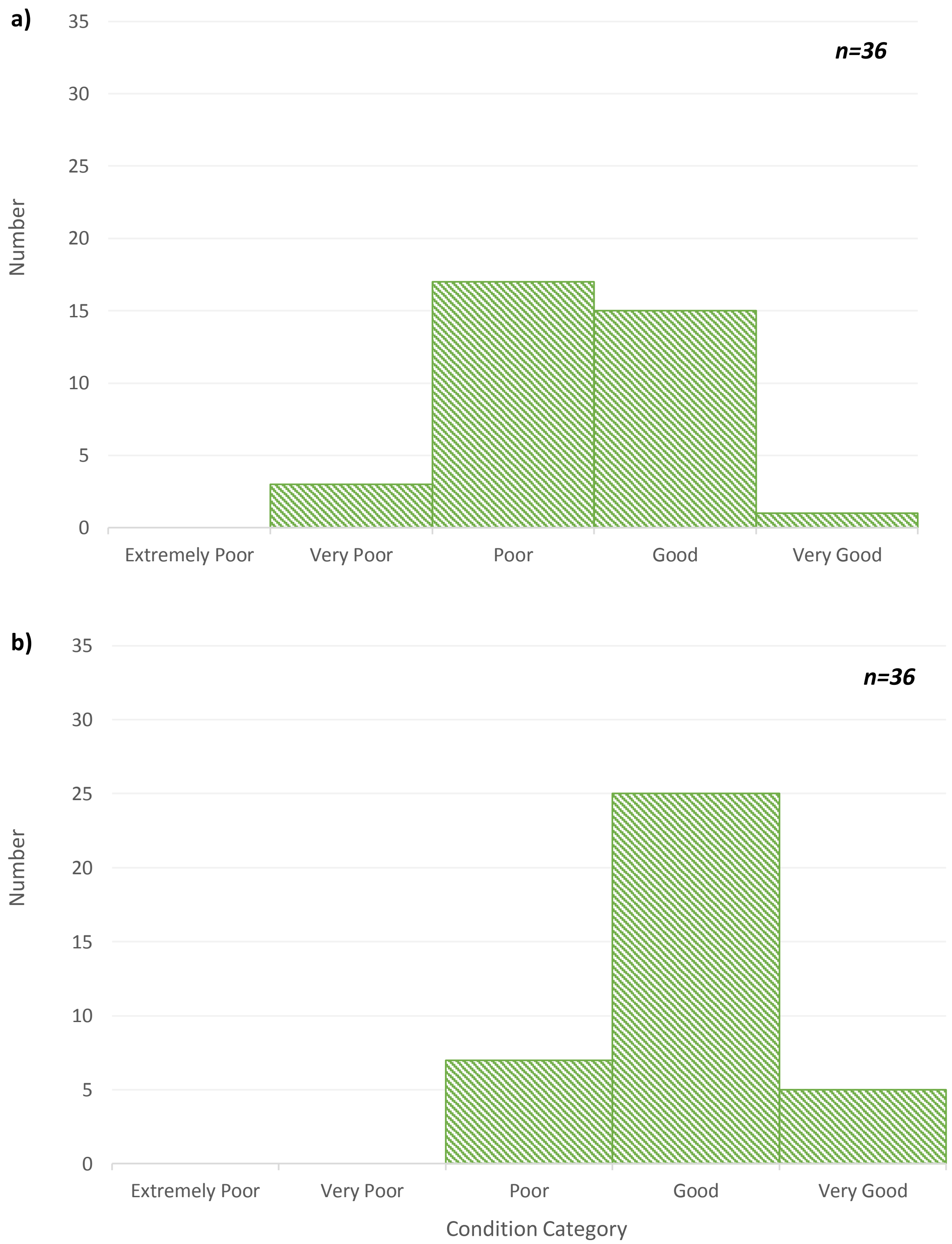


Figure 4. Tree condition before and six weeks following water delivery, Molo Flat Wetland Complex a) November 2014 b) January 2015.

The following figure (Figure 5) shows the observed epicormic and tip growth, leaf dieback and reproduction response of monitored trees at Molo Flat Wetland Complex. Prior to watering, almost half of the trees at Molo Flat had no epicormic growth (*n=17*) while the remaining trees had either 'scarce' (*n=14*) or 'common' (*n=5*) growth. Six weeks after the commencement of watering, all but seven trees showed signs of epicormic growth. Although most showed 'scarce' (*n=26*) signs of epicormic growth, some showed 'common' (n=3) or 'abundant' (*n=1*) epicormic growth.

Prior to watering, tip growth was not observered or recorded as 'scarce'. Only one tree was assessed to have 'common' tip growth prior to watering. Following the commencement of watering, tip growth was observed in all trees (*scarce=25*; *common=10*; *abundant=2*).

The level of dieback observed in trees was similar prior to and six weeks after watering. Dieback was absent in a total of eight of the assessed trees prior to watering and six trees following watering. Prior to watering dieback was observed in 27 trees however this increased to 30 trees after watering. Only one tree was observed with 'common' dieback prior to and following watering.

Following prior to and following watering, the most of the monitored trees exhibited some reproductive response.

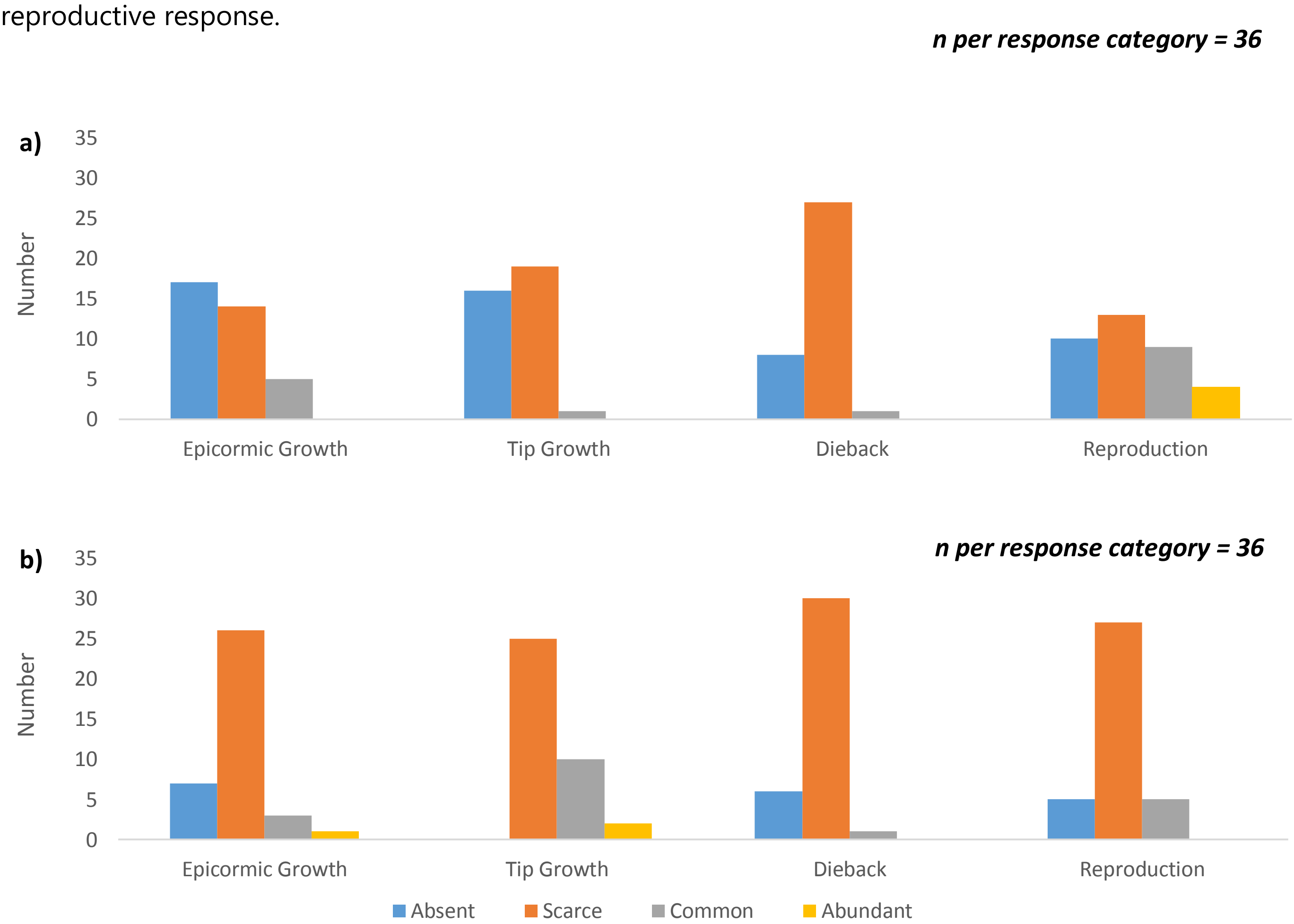


Figure 5. Tree response (epicormic growth, tip growth, dieback and reproduction) Molo Flat Wetland Complex, a) November 2014 b) February 2015.

Wiela Wetland

At Wiela Wetland, the most frequent tree condition class prior to watering was 'poor' (n=15), whereas after watering, more trees were classed in 'good' and 'Very good' condition (n=19) and no trees were classed as 'Very poor' (Figure 6).

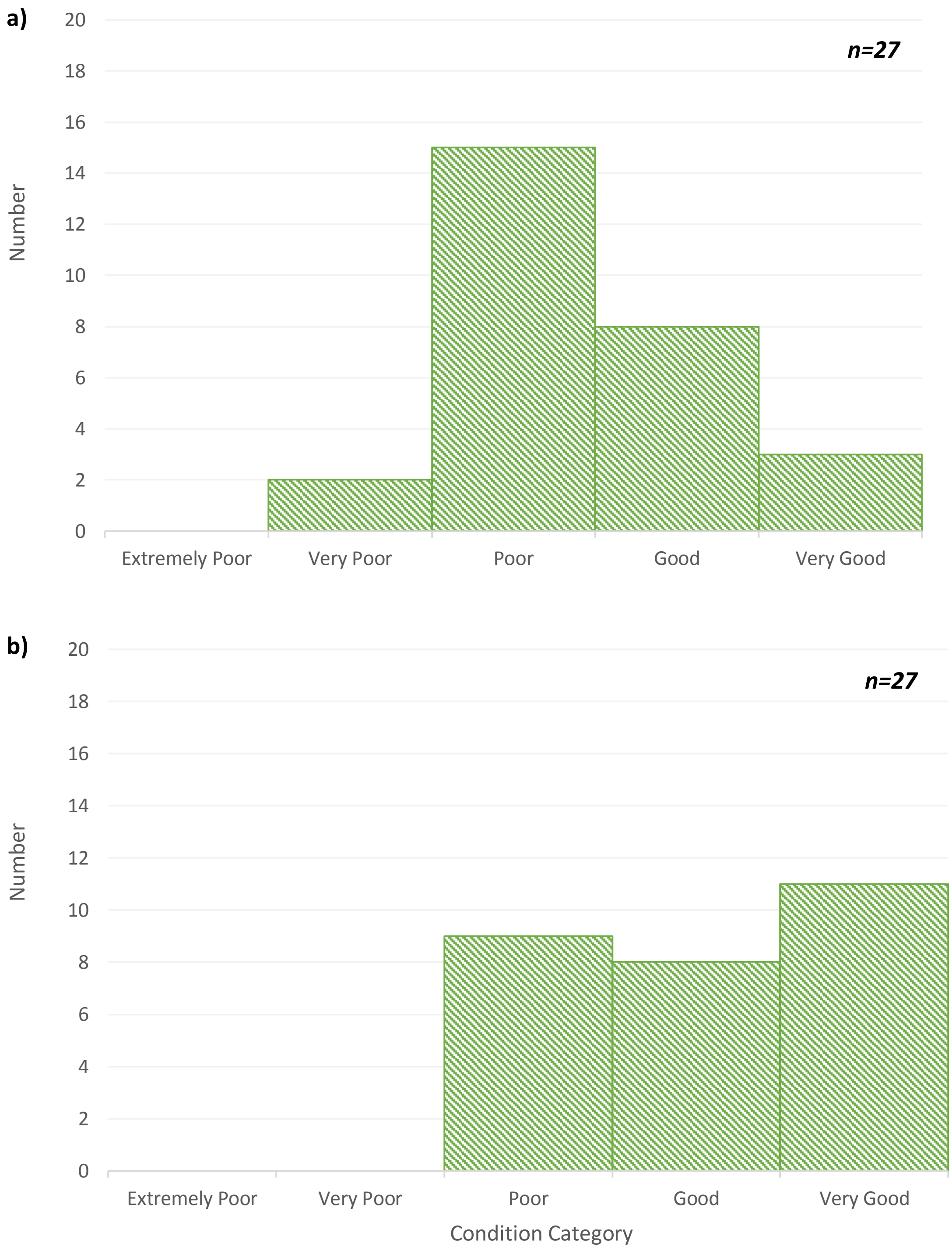


Figure 6. Tree condition before and six weeks following water delivery, Wiela Wetland, a) November 2014 b) January 2015.

The following figure (Figure 7), shows the observed epicormic and tip growth, leaf dieback and reproduction response of monitored trees at Wiela Wetland. Prior to watering commencing at the site, epicormic growth in monitored trees was mostly absent (*n=25*), with 'scarce' epicormic growth observed in only few trees (*n=3*). There was little difference recorded post-watering, with no epicormic growth observed on the majority of trees (*n=19*), although some showed 'scarce' (*n=6*) and 'common' (*n=3*) epicormic growth.

Prior to watering only a few (*n=5*) trees exhibited signs of tip growth while the remaining (*n=23*) showed none, however tip growth was observed in all trees following watering (*scarce=1*; *common=20*; *abundant=7*).

Dieback was recorded in similar levels prior to and post watering. Dieback was not observed in many (*n=20*) trees before watering commenced at the site, although 'scarce' and 'common' dieback was observed in few trees (*scarce=6*; *common=2*). Similarly, dieback was not observed in 25 of the monitored trees and only observed in few (*n=3*) trees following watering.

Scores of the extent of reproduction was similar before and after watering. Prior to watering commencing, reproduction was observed in all trees (*scarce=7*; *common=20*; *abundant=1*). Following watering, reproduction was observed in all but one tree (*scarce=12*; *common=14*; *abundant=1*).

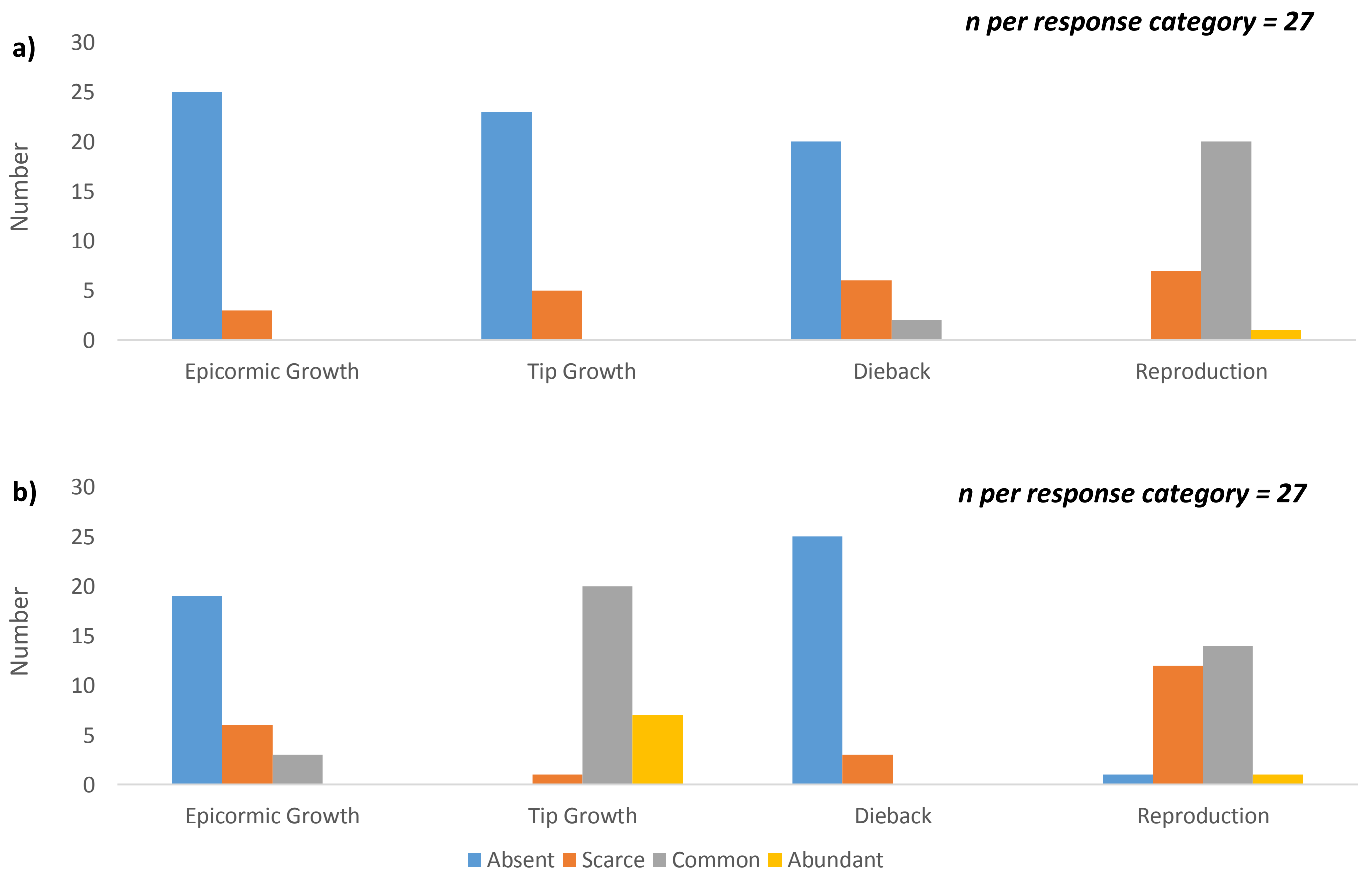


Figure 7. Tree response (epicormic growth, tip growth, dieback and reproduction), Weila Wetland, a) November 2014 b) January 2015.

Overall site tree condition summary

All monitored trees were grouped together to evaluate trends across sites. Overall, across all three wetlands, trees showed a clear positive improvement in condition over time, with a decrease in the number of trees scored in 'Poor' condition and an increase in the number of trees scored as 'Good' or 'Very good' during the six weeks post-inundation surveys (Figure 8).

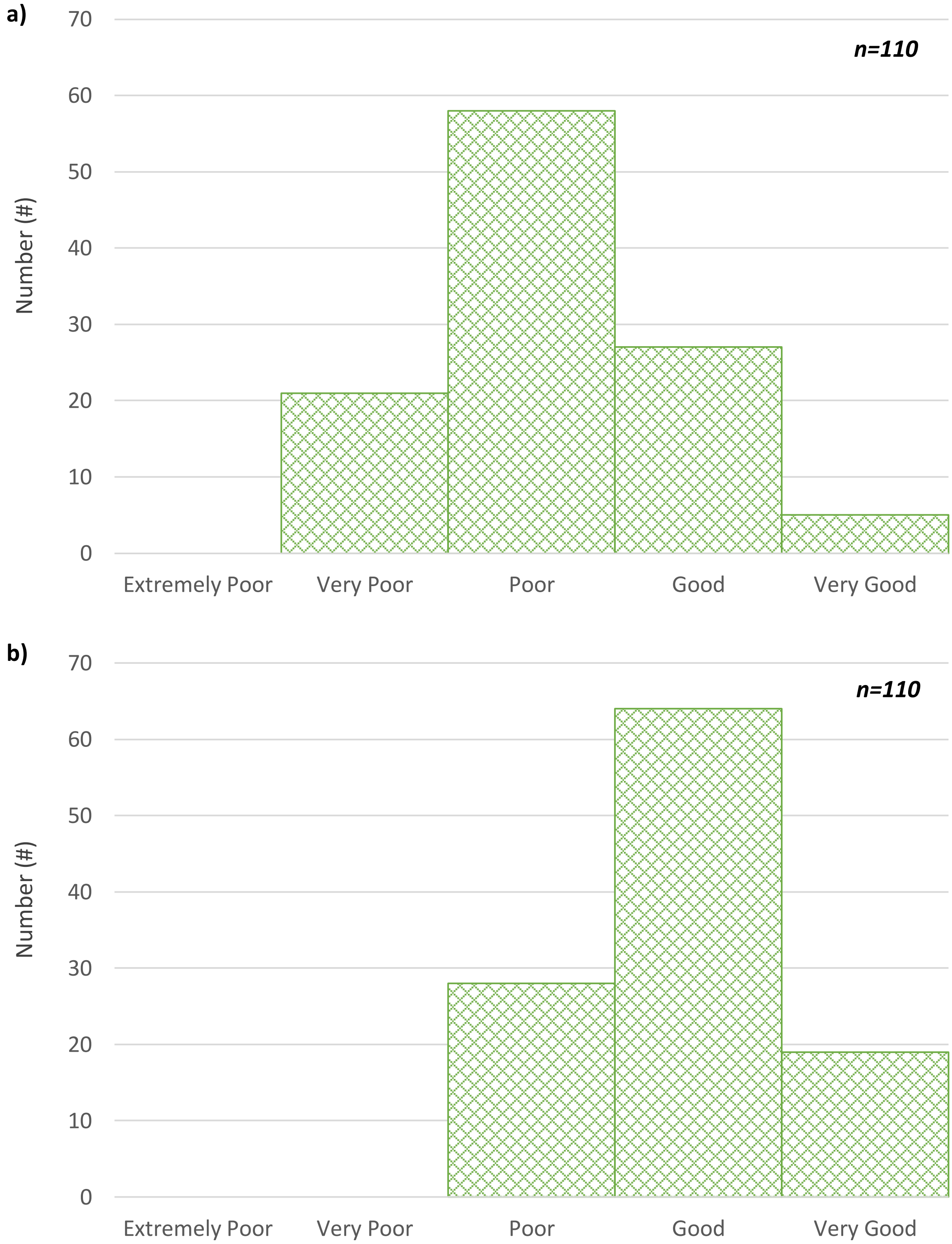


Figure 8. All tree condition before and six weeks following water delivery across all sites, a) November 2014 b) January 2015.

The average tree condition score showed a clear increase following environmental water delivery across all three monitored wetland sites (Figure 9).The greatest change in average condition was observed in tree condition at Markaranka. Initially average tree condition across trees at the site was 'Very poor', however six weeks following watering, average tree index score increased with average tree condition in the 'Good' condition category. Similar trends were observed at Molo Flat and Wiela Wetland as demonstrated below.

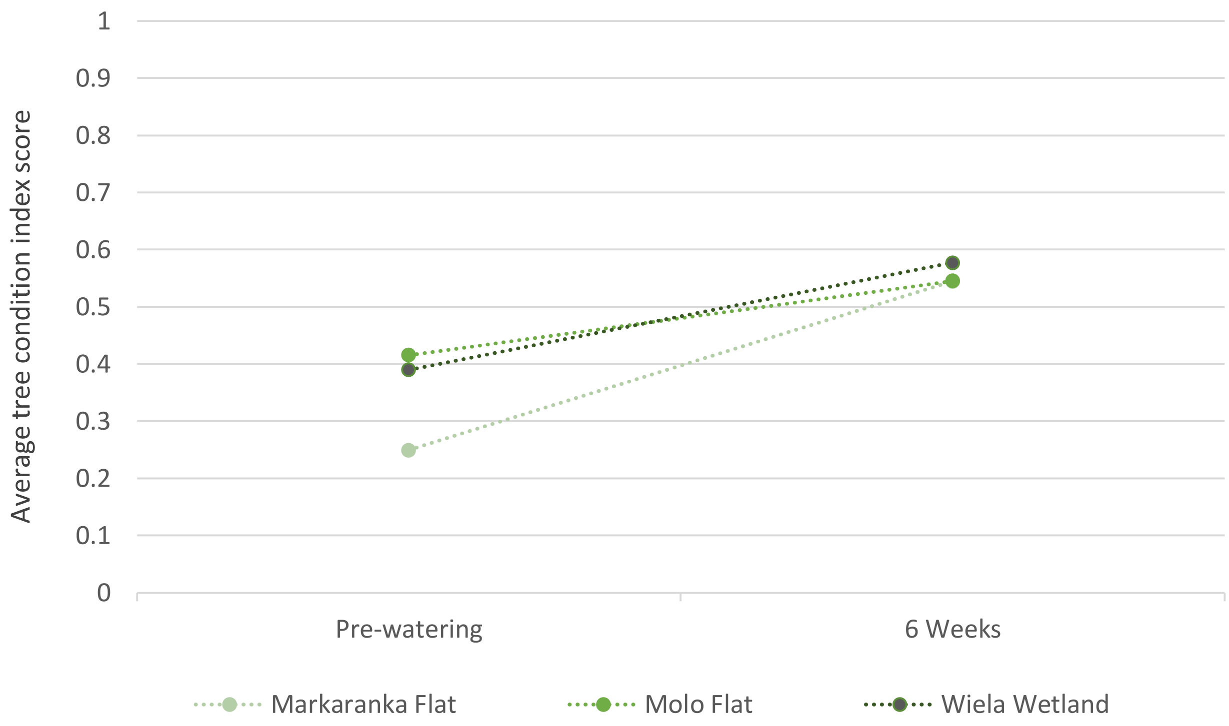
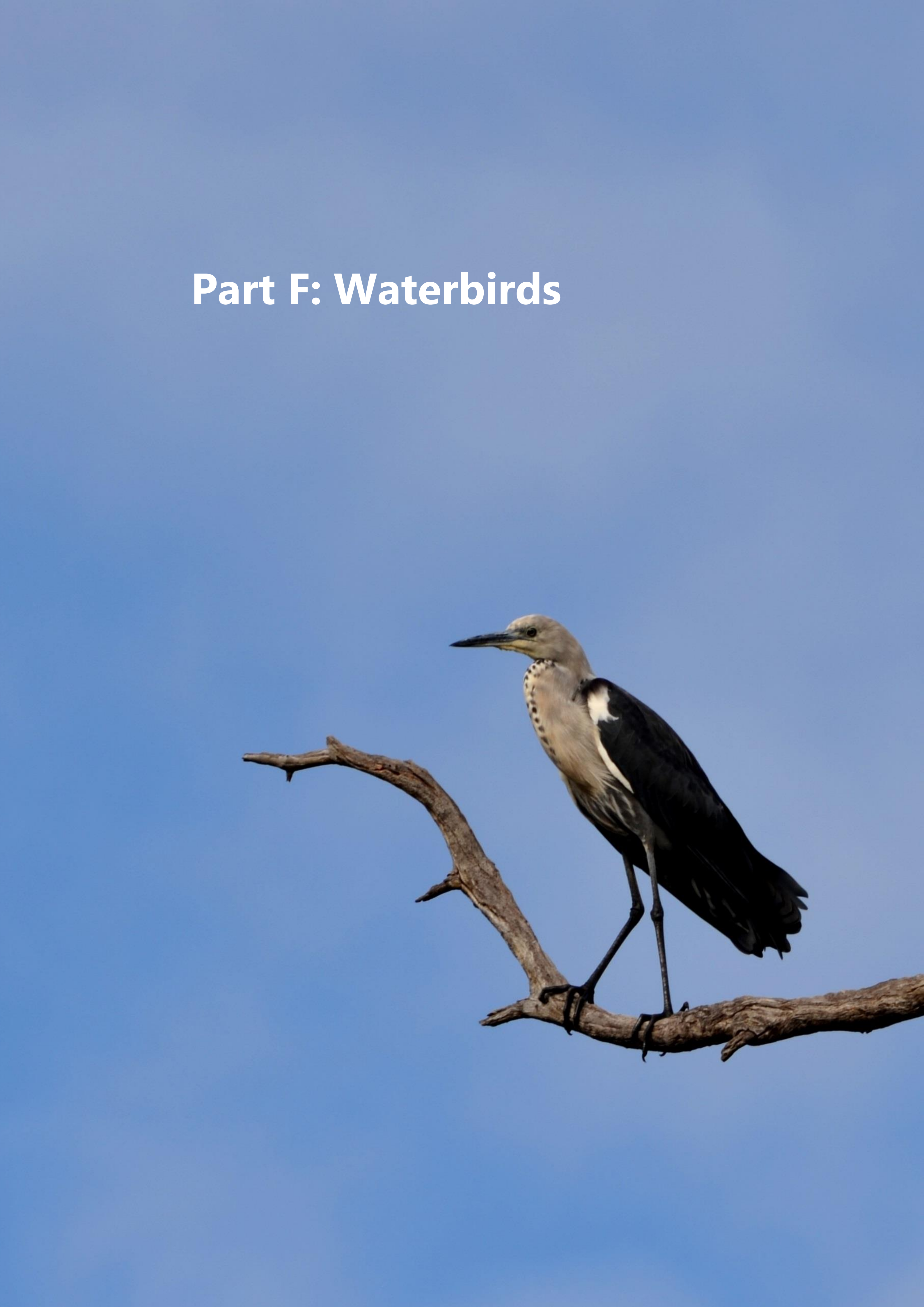


Figure 9. Average tree condition index score across monitored sites (Markaranka Flat Wetland Compex, Molo Flat Wetland Complex and Wiela Wetland), pre-watering and six weeks following watering commencement.

Conclusion

Tree condition monitoring showed that six weeks after watering commenced, tree condition improved across all three monitored sites and was likely due to the delivery of environmental water. Although it should be noted that no control trees were monitored, there was a clear visual improvement in trees at watered sites compared to surrounding sites during this time (pers. Obs. I. Wegener February 2015). Whilst it is unknown what the condition of the trees would have been without watering, it is assumed that, based on the initial condition of trees, previous monitoring trends, known watering requirements of the species, and current and future climate predictions, that if watering intervention had not been undertaken during this time, trees are likely to have declined in condition. This may have, in time, resulted in the mortality and loss of trees from the population in the future.

Part F: Waterbirds



Part F: Waterbirds

Waterbird species are those that are dependent upon surface water for a range of activities that may include feeding (by swimming, wading or diving), or for nesting (Rogers 2011). In this report, waterbirds have been classified according to seven functional groups (Table 8).

Table 8. Waterbird functional groups.

Functional group	Food resource/group	Habitat use	Example species
Dabbling ducks	Generalist	Shallow water, littoral zone	grey teal (*Anas gracilis*), Pacific black duck (*Anas superciliosa*)
Grazing waterfowl	Vegetative material	Shallow water, littoral zone	Australian wood duck (*Chenonetta jubata*), Australian shelduck (*Tadorna tadornoides*)
Piscivores	Fish	Open, deep water	Australasian grebe (*Tachybaptus novaehollandiae*), Australian pelican (*Pelecanus conspicillatus*)
Deep-water foragers		Open, deep water	black swan (*Cygnus atratus*), blue-billed duck (*Oxyura australis*)
Large waders	Macroinvertebrates, fish, amphibians	Littoral zone	yellow-billed spoonbill (*Platalea flavipes*), Australian white ibis (*Threskiornis molucca*)
Small waders	Macroinvertebrates	Littoral zone, wet mud	red-kneed dotterel (*Erythrogonys cinctus*), black-fronted dotterel (*Elseyornis melanops*)
Shoreline foragers	Macroinvertebrates, seeds	Littoral zone, wet mud	masked lapwing (*Vanellus miles*), black-tailed native-hen (*Tribonyx ventralis*)

Adapted from: (Brandis et al. 2009; Rogers 2011)

Loss of wetlands at a global scale has significantly increased the importance of remaining habitat for waterbirds (Taft et al. 2010). Managing remaining habitats to provide alternative or complementary habitat is of particular importance for supporting waterbird communities (Ma et al. 2010; Taft et al. 2010). Across the Murray-Darling Basin, the decline of waterbirds and wetlands is well acknowledged and documented (Kingsford et al. 2014). Much of this decline is attributed to river regulation, namely reductions in flows and overbank flood events, as well as declining habitat availability and condition across floodplains of the Murray-Darling Basin (Kingsford et al. 2014). Consequently, many wetland waterbirds are now considered threatened, rare or endangered across the Murray-Darling Basin region and as such, remaining wetlands across the Murray-Darling Basin provide important habitat for almost 100 species of waterbird (Kingsford et al. 2014).

An important part of protecting and restoring waterbird populations is the provision of connected, resilient and healthy wetlands through delivery of sufficient resources that aim to restore and protect these areas (Kingsford et al. 2014). Long-term recovery of waterbird populations requires a well coordinated and continuing program that aims to protect and restore wetland condition throughout the Basin (Kingsford et al. 2014). River regulation has limited the availability of some habitat types for waterbirds to feed and breed (Kingsford et al. 2014). Additionally, water depth is critical for different species and their ability to access resources (Taft et al. 2010; Ma et al. 2010) and as such, stable river levels within the SA River Murray channel has maintained favourable hydrological conditions for some species but not others. For example, diving birds require deeper water and foraging may be limited by shallow water such as that found in many wetlands across the region can restrict their diving ability (Ma et al. 2010). Within the SA Murray-Darling Basin region piscivores are well suited to the deep water pools of the main river channel and deep permanent wetlands, whereas small waders are relatively constrained to small edge margins of these areas for foraging. This may effect species foraging efficiencies (Ma et al. 2010). As a result, current water management across the SA Murray-Darling Basin region may be inadequate to meet the demands of all but a few functional groups of waterbirds and selected species. Providing complementary habitat, such as shallow water habitat through delivery of environmental water to selected sites, may be of particular importance for the survival of some species in the region. Across a region there may be a range of different habitat types available which exclude some waterbird species and not others, and this highlights the complexities that arise when attempting to manage environmental water for multiple species.

Waterbird breeding is strongly correlated with flood events due to the productivity that these events drive (Kingsford et al. 2014). For example, productivity at the lower levels of the food web (i.e. macrophytes and macroinvertebrates) unsurprisingly, results in large increases in productivity at the higher levels (i.e. fish and frogs) (Kingsford et al. 2014; Rogers 2011). Waterbirds are different to many other aquatic fauna in that they are able to traverse the boundaries of the catchment (Brandis et al. 2009). As such, waterbird population of some species, namely migratory species, may be influenced by factors that occur outside of the Murray-Darling Basin catchment.

Waterbird objective

The aims of environmental watering through the Wetland and Floodplain Program is to provide habitat for both breeding and non-breeding waterbird species. Timing of environmental water delivery is important for example, watering to coincide with biological breeding cues. Where watering does specifically target waterbirds, it may target other objectives, for example maintaining tree or vegetation condition, which may be important to waterbirds generally.

Site selection

Four wetlands within the Riverland region were selected for intensive bird surveying. These sites all received environmental water via pumping (see Part A). Incidental observations of birds were recorded at other sites, however are not reported upon in this report. The four locations sampled were: Markaranka Flat Wetland Complex, Overland Corner (Main Basin), Piggy Creek and Nikalapko Wetland. These locations were surveyed on a monthly basis from December until May, with the exception of Overland Corner which was surveyed from January to May as pumping had not commenced until this time. Descriptions of each site are given in Part B of this report.

Monitoring methodology

Fixed point monitoring sites were conducted at specific sites around each of the monitored wetlands. Monitoring sites were chosen so that all habitat types were included in the survey. The species and abundances of each waterbirds were recorded as well as broad habitat and activity information (e.g. foraging, swimming).

Although regent parrots are not considered waterbirds, due to their dependence upon river red gums for nesting and roosting, and their conservation status as a nationally threatened species, they have been included in the tables below where they were observed, however they are excluded from functional group analysis.

Piggy Creek

A total of 25 waterbird species were recorded at Piggy Creek during the surveying period, with the most abundant species recorded (across all surveys) being grey teal (*Anas gracilis*) (*total n=332*) (Table 9). This species was the most abundant during each survey. Other abundant species observed during all surveys include hardhead (*Aytha australis*) (*total n=33*), Australian wood duck (*Chenonetta jubata*) (*total n=28*), pacific black duck (*Anas superciliosa*) (*total n=48*) and black-fronted dotterel (*Elseyornis melanops*) (*total n=35*). Waterbirds were by far the most abundant during December and January surveys compared with later months.

At Piggy Creek, waterbirds were observed utilising a range of habitat including: on/in water, exposed mud, fringing vegetation and on/near log. Activities which waterbirds were engaged in included: feeding and foraging, swimming, flying, singing or calling and sitting.

Table 9. Waterbird species and abundance at Piggy Creek – Katarapko National Park, December 2014 – May 2015.

	December 2014	January 2015	February 2015	March 2015	April 2015	May 2015	Total abundance
Australasian grebe	3	2					**5**
Australasian shoveler [1]	2						**2**
Australian pelican	4	10		1			**15**
Australian spotted crake	1						**1**
Australian white ibis	2	1				1	**4**
Australian wood duck	10	12	6				**28**
Black-fronted dotterel	2		10	6	4	13	**35**
Black-tailed native hen	8						**8**
Freckled duck [1]	2						**2**
Great cormorant	6						**6**
Great egret		1					**1**
Grey teal	102	88	34	59	14	35	**332**
Hardhead	33						**33**
Hoary-headed grebe	9						**9**
Little pied cormorant	2						**2**
Masked lapwing		4	3			2	**9**
Musk duck [1]		1					**1**
Pacific black duck	9	31	4	2		2	**48**
Pied cormorant		1					**1**
Pink-eared duck	24	1					**25**
Red-kneed dotterel	3				1	5	**9**
Sacred kingfisher [2]	3						**3**
White-faced heron		2		2			**4**
White-necked heron	1						**1**
Yellow-billed spoonbill	6			5	6	1	**18**
Total abundance	**232**	**154**	**57**	**75**	**25**	**59**	**602**

[1] Species of conservation significance [2] Observed breeding at the site

The greatest species diversity (20 species) from a range of functional groups was observed at Piggy Creek in December 2014 (Figure 10). This could be a result of the high productivity of the site following the commencement of watering, combined with warmer temperatures experienced during this time providing abundant food resources for species. This result may also be due to the wide range of habitats, such as deep water to wet mud, available for many species to utilise. Between March and May 2015, lower species diversity was observed at the site, with between four and seven waterbird species recorded during surveys. It is possible that this is a result of the rapid drying of the site within the sampling period. A change in functional group composition was noted as the site dried.

Initially all functional groups were present at the site with piscivore species comprising the greatest proportion of individual species present followed by dabbling ducks (Figure 10). In April and May 2015, large and small waders began to dominate the functional groups (by proportion of species by functional group present) which is indicative of the changing nature of the site (i.e. drying which resulted in greater areas of shallow water habitat becoming available). Between February and May 2015, either three or four functional groups were observed at the site, with only one or two species from these functional groups present. It is possible that given the quick nature in which the site dried, that the resources such as foraging habitat and food resources changed rapidly and excluded many functional groups and particular species within these functional groups from utilising these sites at the time of the survey.

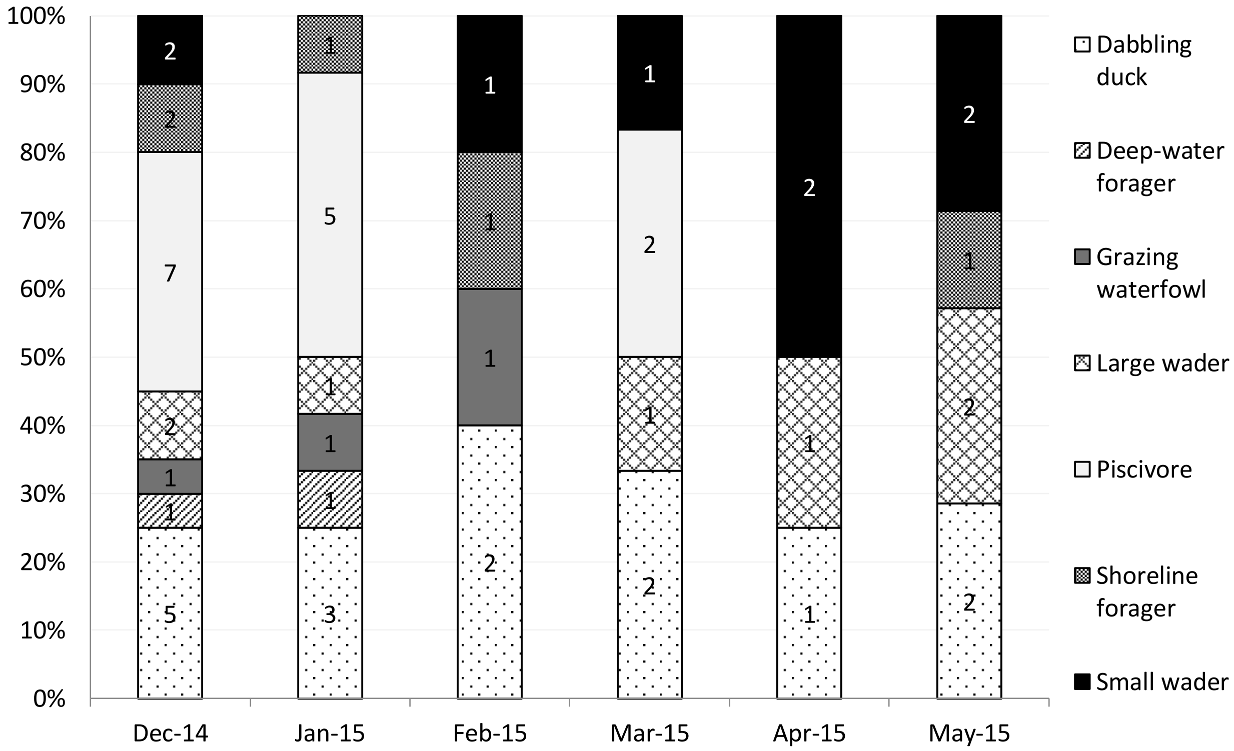


Figure 10. Proportion comprising waterbird functional group species richness, and number per functional group observed at Piggy Creek, December 2014 to May 2015.

Overland Corner

A total of 30 waterbird species were recorded at Overland Corner during the surveying period with the most abundant species recorded (across all survey events) being grey teal (*total n=815*) (Table 10). This species was the most abundant during each survey except in February 2015 when Australian wood duck were the most abundant (*February 2015=126*). Other waterbird species observed in high abundances included Australian wood duck (*total n=205*) black swan (*Cygnus atratus*) (*total n=147*) and Eurasian coot (*Fulica atra*) (*total n=145*).

Waterbirds were observed utilising a range of habitat at Overland Corner including: on/in water, exposed mud, fringing vegetation and on/near logs. Activities which waterbirds were engaged in included: feeding and foraging, swimming, flying, singing or calling and sitting.

Table 10. Bird species and abundance at Overland Corner, January – May 2015.

	January 2015	February 2015	March 2015	April 2015	May 2015	Total abundance
Australasian grebe		2	3	35	20	**60**
Australasian shoveler [1]		17	13	18	22	**70**
Australian pelican				1		**1**
Australian shelduck				2	6	**8**
Australian spotted crake					1	**1**
Australian white ibis	1	2		4	1	**8**
Australian wood duck	2	126	38	17	22	**205**
Black swan	35	27	30	14	41	**147**
Black-fronted dotterel	2		1	1	1	**5**
Black-tailed native hen				6	10	**16**
Blue-billed duck [1]		1				**1**
Caspian tern				3	2	**5**
Eurasian coot	22	16	69	16	22	**145**
Freckled duck [1]					8	**8**
Great cormorant		2				**2**
Great egret			2	1	1	**4**
Grey teal	145	51	204	272	143	**815**
Hardhead	37	4		9	2	**52**
Hoary-headed grebe	3		2	54		**59**
Little pied cormorant	8			1	1	**10**
Masked lapwing		2	1			**3**
Musk duck [1]			1			**1**
Pacific black duck	2	5	10	28	13	**58**
Pied cormorant	1	1	1			**3**
Pink-eared duck	31	2				**33**
Red-kneed dotterel				1	2	**3**
Regent parrot [1]					10	**10**
Straw-necked ibis	13			7		**20**
White-faced heron	4	5	4	2	2	**17**
White-necked heron			2	1		**3**
Yellow-billed spoonbill				3	3	**6**
Total abundance	**306**	**263**	**381**	**496**	**333**	**1779**

[1] Species of conservation significance [2] Observed breeding at the site

The number of species present varied between surveying events, however species richness was generally high and ranged from 14 to 22 species observed on each occasion. Of the seven functional groups, waterbirds from six to seven functional groups were observed during each monitoring event (Figure 11). Six functional groups represented by one to six species in each group were observed between January and March 2015, and seven functional groups represented by between one and eight species in each group were observed during monitoring in April and May 2015. Functional groups present during each monitoring event were dabbling duck, deep-water foragers, grazing waterfowl and piscivores. Species richness from the piscivore functional group generally dominated the waterbirds community present during monitoring events. As with species richness, waterbird abundance was consistently high over the monitoring period ranging from 263 to 496 individuals which may indicate abundant food resources and a range of habitat types available at the site that benefit both a range of species, functional groups and moderately high abundances.

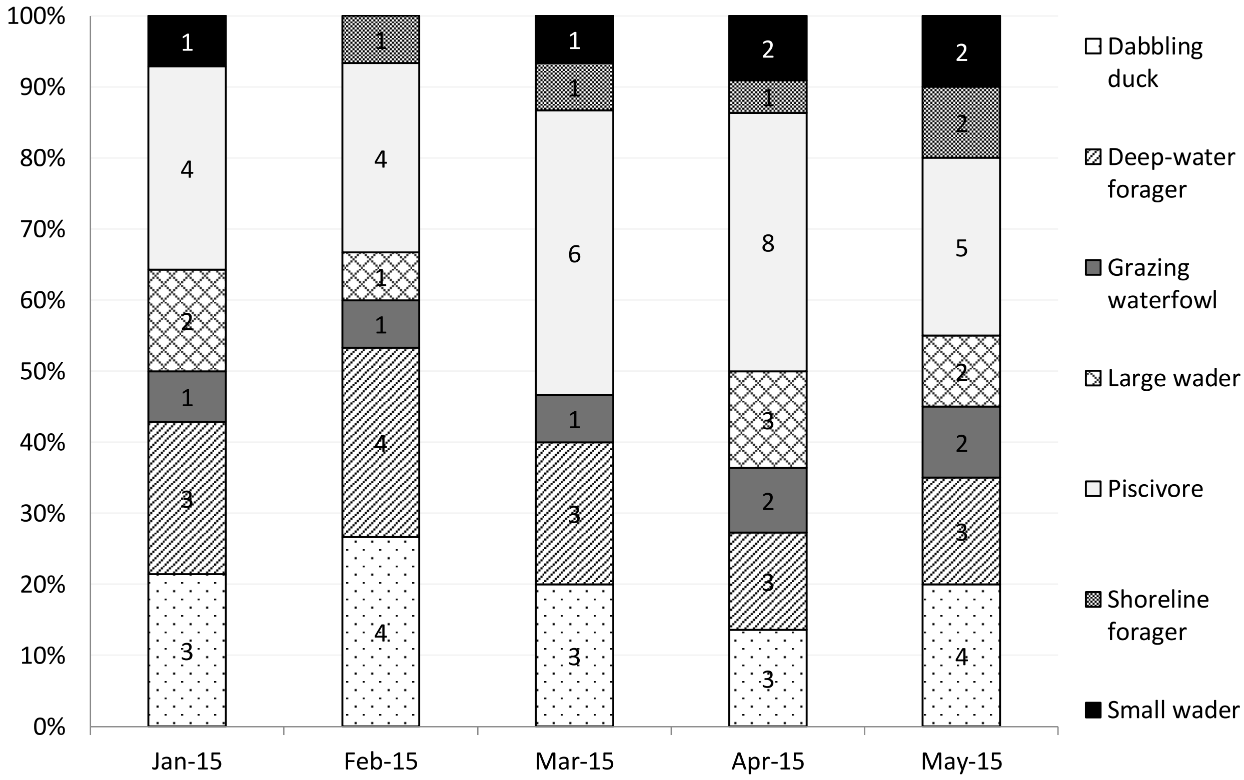


Figure 11. Proportion comprising waterbird functional group species richness, and number per functional group observed, Overland Corner, January to May 2015.

Markaranka Flat Wetland Complex

In total, 30 waterbird species were recorded at Markaranka Flat Wetland Complex during waterbird surveying events. The most abundant species observed on all but two monitoring occasions (December 2014 and May 2015) were grey teal (*total n=920*) followed by pink-eared duck (*Malacorhynchus membranaceus*) (*total n=543*), Eurasian coot (*total n=344*), great cormorant (*Phalacrocorax carbo*) (*total n=283*), hardhead (*total n=248*) and hoary-headed grebe (*Poliocephalus policephalus*) (*total n=164*).

A wide range of habitat was available at Markaranka Flat Wetland Complex during the watering that is likely to have provided a wide range of resources for waterbirds at the site. Waterbirds were observed utilising a range of habitats at the site including: on/in water, exposed mud, fringing vegetation, on/near logs and trees. Activities which waterbirds were engaged in included: feeding and foraging, swimming, flying, singing or calling, and sitting.

Table 11. Bird species and abundance at Markaranka Flat Wetland Complex.

	December 2014	January 2015	February 2015	March 2015	April 2015	May 2015	Total abundance
Australasian darter [1] [2]	1		4	3	6		**14**
Australasian grebe	2	1	1	3	12	24	**43**
Australasian shoveler [1]	4	1			7	8	**16**
Australian pelican			8	6	92	2	**108**
Australian shelduck					6	14	**20**
Australian white ibis		1			3	4	**8**
Australian wood duck [2]	6	14	18	3	16	22	**79**
Black swan	11	3			7	10	**31**
Black-winged stilt					1		**1**
Blue-billed duck [1] [2]		6	2	2		34	**44**
Caspian tern						2	**2**
Chestnut teal					2		**2**
Eurasian coot	49	21	28	77	118	51	**344**
Great cormorant	2	4	3	14	258	2	**283**
Great crested grebe [1]			1				**1**
Great egret				1		1	**2**
Grey teal	46	163	70	124	363	154	**920**
Hardhead	45	15		67	58	63	**248**
Hoary-headed grebe		39	13	14	95	3	**164**
Little black cormorant				6	1		**7**
Little pied cormorant		1				1	**2**
Masked lapwing				2			**2**
Musk duck [1]			1	3	4	7	**15**
Pacific black duck	4	3	3	17	28	5	**60**
Pied cormorant		1		8	9	3	**21**
Pink-eared duck	83	118		3	129	210	**543**
Regent parrot [1]		29	3	2	10	8	**52**
Straw-necked ibis	28	1	1	4			**34**
White-faced heron	1	1	2				**4**
White-necked heron					1		**1**
Yellow-billed spoonbill	1						**1**
Total abundance	**283**	**422**	**158**	**359**	**1226**	**628**	**3076**

[1] Species of conservation significance [2] Observed breeding at the site

The number of individual species present varied between surveying events and ranged between 14 and 21 species observed on each monitoring occasion. Between five and six functional groups were present on each monitoring occasion (Figure 12). Functional groups were represented by one up to eight species. Of the functional groups observed at the site, dabbling duck, deep-water forager, grazing waterfowl, large wader and piscivore functional groups were present during each monitoring event. Shoreline forager and small wader functional groups were only present on one occasion each during monitoring. Piscivores consistently comprised the greatest proportion of species presence during each monitoring event.

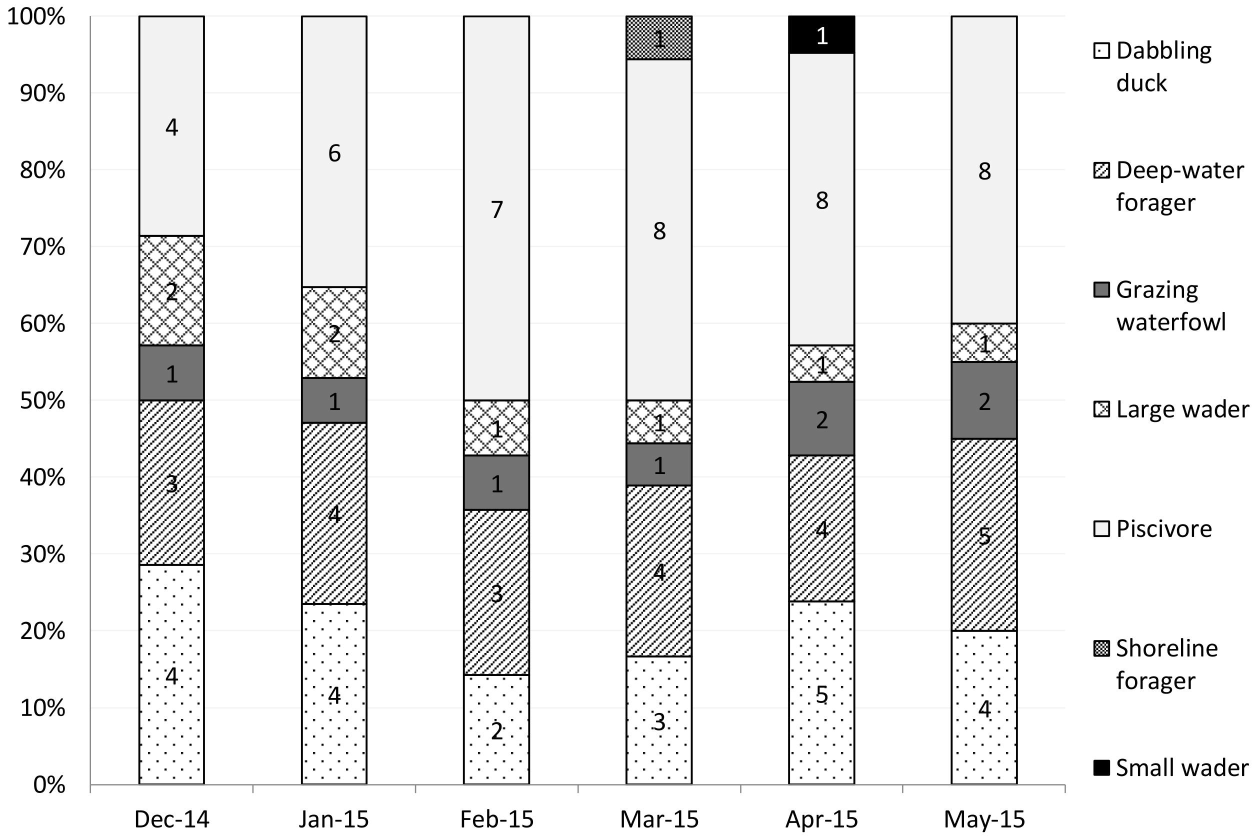


Figure 12. Proportion comprising waterbird functional group species richness, and number per functional group observed, Markaranka Flat Wetland Complex, January to May 2015.

Nikalapko Wetland

In total, 33 waterbird species were recorded at Nikalapko Wetland during all surveying events (Table 12). The most abundant species observed on all monitoring occasions were grey teal (*total n=1385*) followed by Eurasian coot (*total n=305*), hardhead (*total n=304*) and Australian pelican (*total n=204*).

As with the above wetlands, a range of habitat was available at Nikalpako Flat Wetland during the watering. Waterbirds were observed utilising a range of habitat types including: on/in water, exposed mud, fringing vegetation, on/near logs and trees. Activities which waterbirds were engaged in included: feeding and foraging, swimming, flying, singing or calling, and sitting.

Table 12. Waterbird species and abundance observed at Nikalapko Wetland, December 2014 to May 2014.

	December 2014	January 2015	February 2015	March 2015	April 2015	May 2015	Total Abundance
Australasian darter [1]		7	1	3		1	**12**
Australasian grebe	19	2	2			30	**53**
Australasian shoveler [1]				2	1	10	**13**
Australian pelican	13	27	29	107	12	16	**204**
Australian shelduck	6				2	4	**12**
Australian white ibis		5	1	1	2	4	**13**
Australian wood duck	6	8	14		50	17	**95**
Black swan	12	17	12	45	30	4	**120**
Black-fronted dotterel				1		4	**5**
Black-winged stilt	1			10	10	3	**24**
Caspian tern						2	**2**
Chestnut teal		1					**1**
Common greenshank [1]				1			**1**
Eurasian coot	24	70	76	76	46	13	**305**
Glossy ibis [1]			1				**1**
Great cormorant	7	4					**11**
Great crested grebe [1]	4						**4**
Great egret		8		2			**10**
Grey teal	500	156	173	202	238	116	**1385**
Hardhead	48	21	12	38	109	76	**304**
Hoary-headed grebe	3	20	13		31		**67**
Little pied cormorant		4	1				**5**
Masked lapwing	3	2	5				**10**
Musk duck [1]				2		2	**4**
Pacific black duck	6	6	1	14	27	15	**69**
Pied cormorant		4	1				**5**
Pink-eared duck	5	1	24	18	125		**173**
Purple swamphen	1						**1**
Red-kneed dotterel	5				20		**25**
Regent parrot [1]			2				**2**
Silver gull				3			**3**
Straw-necked ibis		2	7	5			**14**
White-faced heron			1		1	2	**4**
Yellow-billed spoonbill	1					10	**11**
Total Abundance	**664**	**365**	**376**	**530**	**704**	**329**	**2968**

[1] Species of conservation significance   [2] Observed breeding at the site

The number of species present varied minimally between surveying events, and ranged between 15 and 19 individual species being observed on each monitoring occasion. Between five and seven (of a total of seven possible functional groups) were present at the site on each monitoring occasion (Figure 13) represented by the presence of one to eight species from each respective group. The greatest functional group diversity was observed in December to February ranging from six to seven functional groups being present. This declined in March to May ranging between five to six functional groups being present and may indicate changes in the availability of different habitat types that occurred between this timeframe. Functional groups present during each monitoring event were dabbling duck, deep-water forager, large water and piscivore. With the exception of April 2015, piscivore species generally comprised the greatest proportion of species present by functional group during the monitoring period. Waterbird abundance varied between 329 individuals in May and 704 individuals in April, however there was no clear pattern in changes over time.

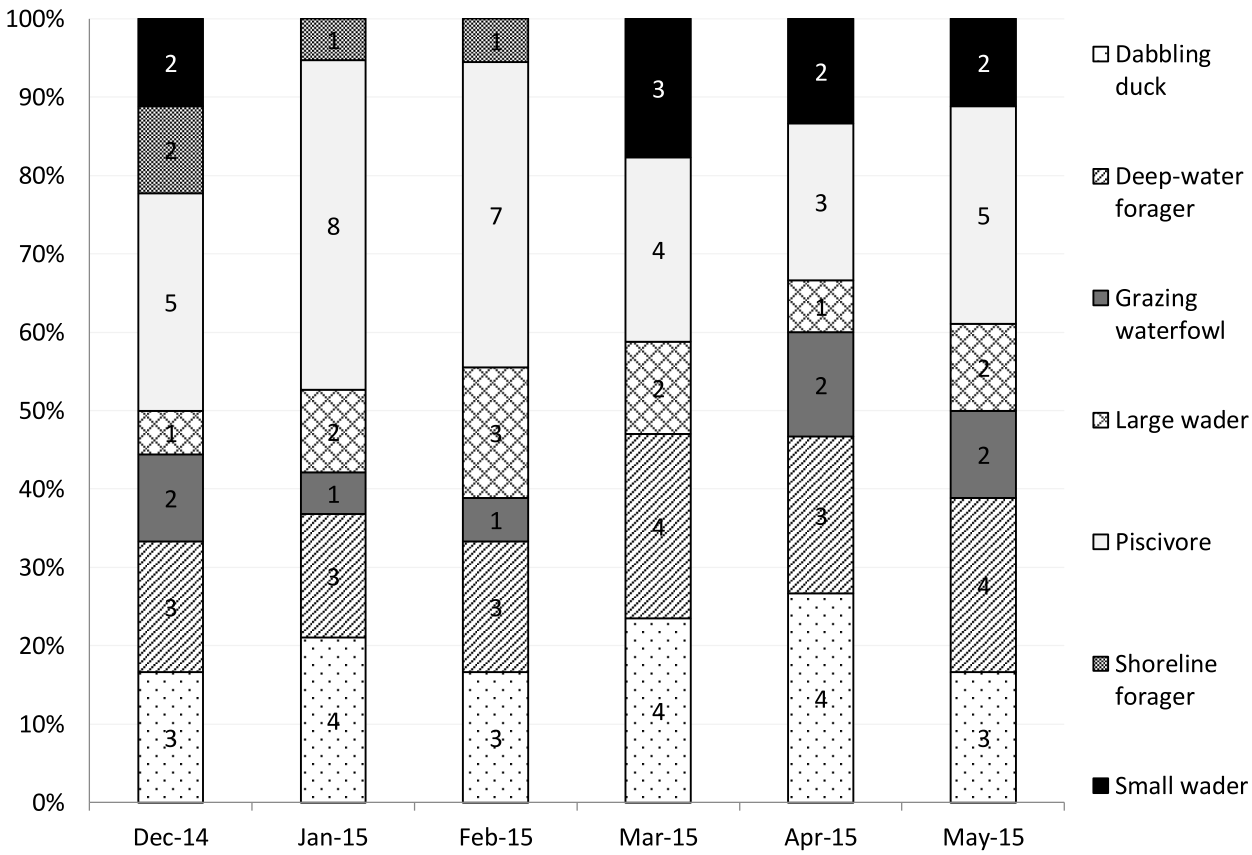


Figure 13. Proportion comprising waterbird functional group species richness, and number per functional group observed, Nikalapko Wetland, December 2014 to May 2015.

Waterbird Breeding

Waterbird breeding behaviours in the form of nesting, mating/display and/or, young/juveniles, was observed across some sites watered with environmental water. Four species were observed displaying breeding behaviour, with young, or dependent young and included:

- Australian wood duck (*Chenonetta jubata*) – observed with ducklings.
- Australasian darter (*Anhinga novaehollandiae*) – several successful nests, rearing of young and juveniles fledging.
- blue-billed duck (*Oxyura australis*) – recently fledged juvenile/dependent young observed.
- sacred kingfisher (*Todiramphus sanctus*) – observed dependent young.

Threatened Species

Nine species of conservation significance were observed across all of the watered sites. These were:

- Australasian darter – rare in SA.
- Australasian shoveler (*Anas rhynchotis*) – rare in SA.
- blue-billed duck – rare in SA.
- common greenshank (*Tringa nebularia*) – migratory (Migratory species: JAMBA, CAMBA, ROKAMBA).
- freckled duck (*Stictonetta naevosa*) – vulnerable in SA.
- glossy ibis (*Plegadis falcinellus*) – rare in SA.
- great crested grebe (*Podiceps crastatus*) – rare in SA.
- musk duck (*Biziura lobata*) – rare in SA.
- regent parrot (*Polytelis anthopeplus monarchoides*) – nationally threatened (EPBC) species.

Regent parrots

Although not considered a waterbird, the regent parrot is dependent upon river red gums that fringe the main river channel as well as many of the watered wetlands in the Riverland region. The species utilises these trees for nesting opportunities, feeding, roosting and resting. The regent parrot was observed at three of the four intensively monitored sites. These were Overland Corner, Markaranka Flat Wetland Complex and Nikalapko Wetland. The greatest abundance of regent parrots observed across these sites was at Markaranka Flat Wetland Complex, which is located directly opposite the Hogwash Bend Conservation Park, which supports South Australia's largest known breeding colony (Smith 2014). A total of 52 regent parrots were observed at Markaranka Flat Wetland Complex during surveys that occurred between December 2014 and May 2015. This was followed by 10 observed at Overland Corner Wetland Complex and two at Nikalapko. They were observed flying, resting and calling.

Conclusions

In total, 40 species of waterbird were observed across all monitored sites combined. Grey teal were the most abundant species observed, with a total of 2981 individuals recorded across all sites. This was followed by Eurasian coot (*total n=750*), pink-eared duck (*total n=742*), hardhead (*total n=598*), Australian wood duck (*total n=371*) and Australian pelican (*total n=314*).

The occurrence of breeding in some species (including species of conservation significance), and/or the utilisation of these sites by adult and juvenile birds indicates that resources required for breeding by these species were made available through environmental watering. In addition, the presence of species of conservation significance indicates that these types of watering activities may be beneficial for some threatened species. Across the sites, a diverse number of waterbird species from a range of functional groups were recorded indicating a range of suitable habitat was available for waterbirds across watered sites.

Part G: Frogs and Tadpoles

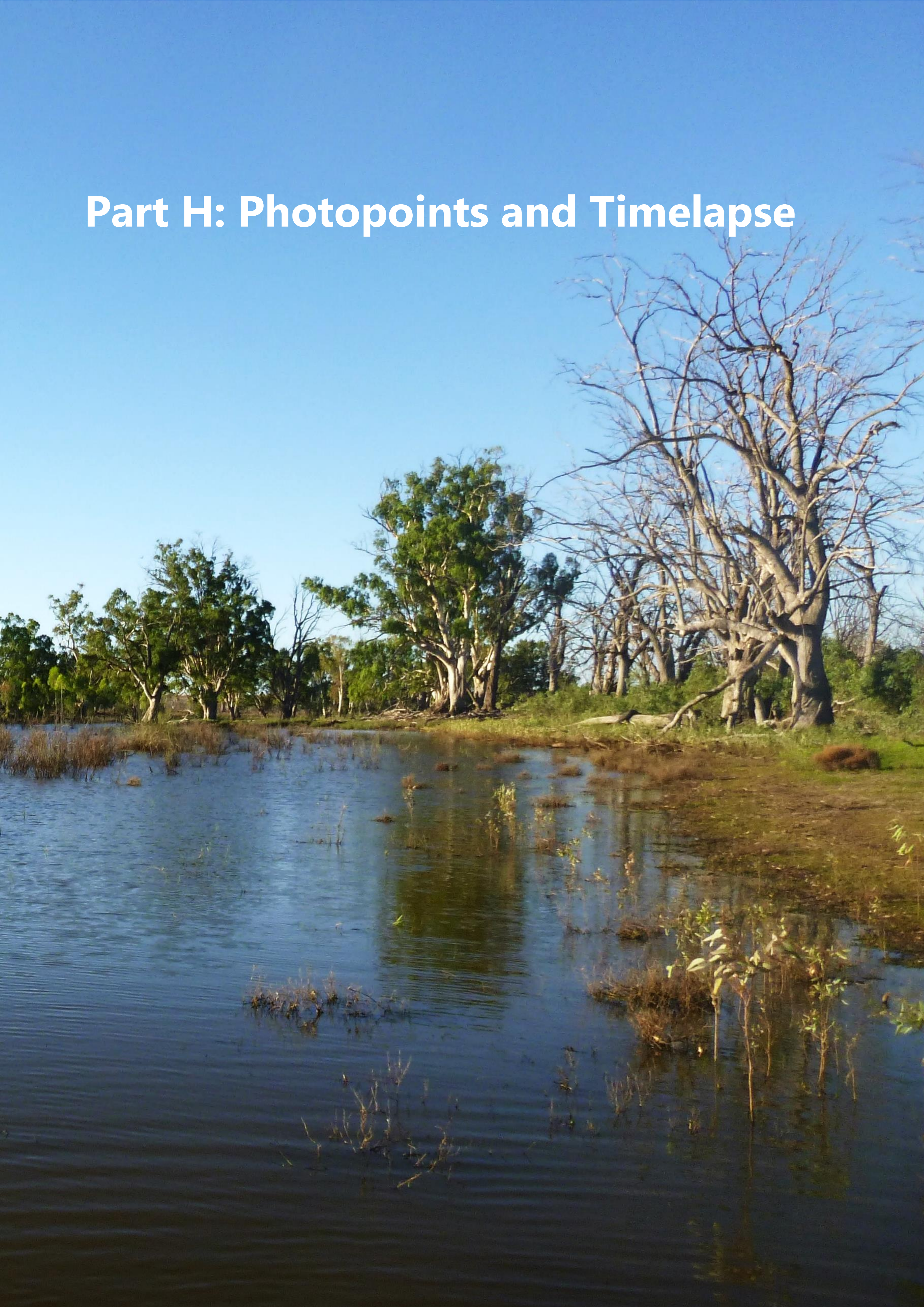
PART G: Frogs and Tadpoles

River regulation has severely impacted riverine ecosystems and flood dependent biota, including frogs that are sensitive to changes in hydrology and habitat alteration. Environmental water (e-water) is being increasingly used to try and re-establish a more natural flow regime and inundate wetland and floodplain areas to restore ecological processes that have been altered by river regulation. In November and December 2014, Natural Resources SA Murray-Darling Basin delivered water from Commonwealth Environmental Water Holder and State Environmental Water Reserve to over a dozen priority wetlands between Morgan and the South Australian border. This study aimed to monitor the breeding response of frogs to the environmental watering of temporary wetlands via pumping.

Monthly frog and tadpole surveys were conducted from December to April at up to 12 e-watered temporary wetlands and seven permanent wetlands. A total of seven frog species were detected at e-watered wetlands, including the threatened southern bell frog, *Litoria raniformis*. Successful recruitment was observed of all species through the presence of tadpoles and metamorphs. Initial evidence of metamorphosis for most frog species was recorded less than two months after wetland pumping commenced. The majority of frogs metamorphosed in three to four months following wetland inundation and there were few tadpoles remaining after five months of inundation. The abundance and diversity of tadpoles and frogs were greater at e-water wetlands than permanent wetlands during the survey period. *Litoria raniformis* was detected at seven out of twelve e-watered wetlands but was typically recorded in low abundances and metamorphs were only detected at two wetlands. Overall, the provision of e-water to temporary wetland sites over summer triggered and supported successful recruitment for all frog species detected in the study area.

A detailed explanation of the project and results is given in Hoffmann (2015).

Part H: Photopoints and Timelapse



PART H: Photopoints and Timelapse

Photopoint and time-lapse objective

Photopoints provide a visual reference of what has occurred at sites over a period of time ranging from days or weeks to years. These photos provide a visual record for reference and comparisons. These photos form an important basis for 'telling the story' of environmental watering and also are useful in supporting results of other ecological monitoring and observations (e.g. vegetation response and tree condition monitoring).

Photopoint and time-lapse monitoring methodology

Photopoint monitoring was undertaken at the majority of project sites (see Table 4). Photopoint monitoring provides an opportunity to observe changes at a site over time, by taking a photo from the same position and angle over a period of time. Photopoints were set up at sites prior to the commencement of pumping and then monitored several times over the course of the project either by manually taking a photo with a camera, or through the use of timelapse cameras set to take photos at specific times throughout the day. Given the number of sites where photopoint monitoring was to be undertaken, timelapse cameras were determined to be an effective substitute for manual photography. An example of photopoint monitoring is given below (Figure 14) as photopoint photos were too numerous to be included within this report.

Results and discussion

Figure 14 shows a clear response by the vegetation surrounding and within the wetland basin to the delivery of environmental water at Molo Flat in December 2014. Initially in November 2014 (Figure 14 a), the wetland basin was dry and the bed was dominated by terrestrial vegetation and the large river red gums at the base of the cliff displayed poor crown extent and density. Figure 14 (b) shows the wetland basin approximately four weeks following the delivery of environmental water. The lignum within the wetland basin displayed new tip growth while a slight increase in crown density in the trees on the far-side of the wetland basin was observed. Figure 14 (c) was taken in March 2015, four months following the commencement of watering at the site. The lignum in the foreground showed increased greening and growth while the river red gums in the background exhibited a notable greening and increase in both crown extent and density.

Figure 14. Molo Flat wetland basin MFPP04 a) November 2014; b) December 2014; c) March 2015.

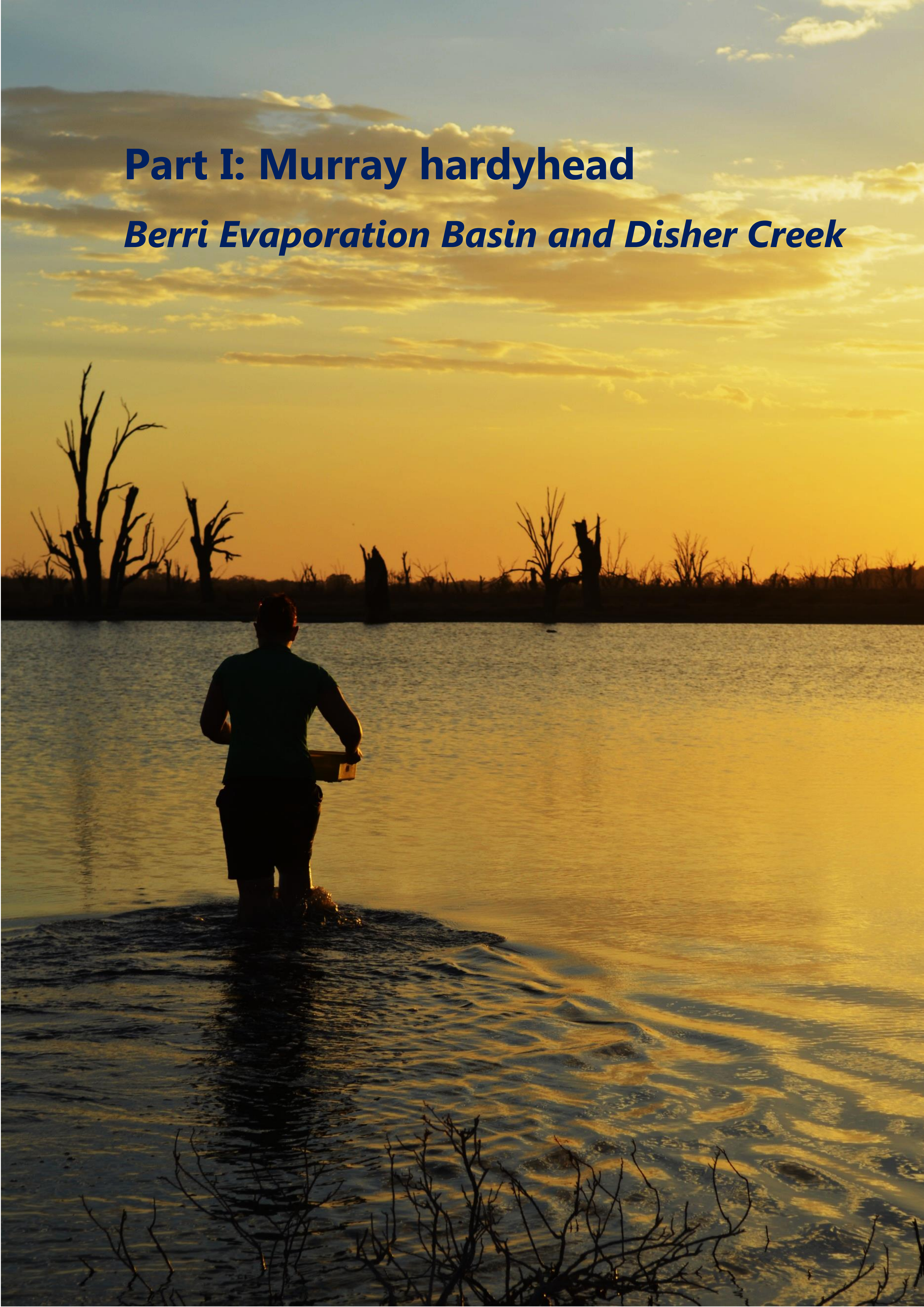
The following figure (Figure 15) demonstrates the vegetation response to environmental water delivery at Akuna Wetland. A large increase in tip growth and consequently the crown extent and density of the river red gums was observed over time, and an increase in the growth and cover of sedges fringing the wetland basin as water levels drew down at the site.

Figure 15. Time lapse photos at Akuna Wetland. a) 25 Nov 2014, b) 29 Nov 2014, c) 11 Nov 2014, d) 6 Dec 2014, e) 19 Dec 2014, f) 4 Jan 2015, g) 10 Feb 2015, and h) 1 Mar 2015.

Timelapse camera footage can be found at: https://www.youtube.com/channel/UCYZXUTj94Ofu-2gQap1xgvQ

Part I: Murray hardyhead

Berri Evaporation Basin and Disher Creek



PART I: Murray hardyhead - Berri Evaporation Basin and Disher Creek

Between September 2014 and June 2015, 1241 ML from the CEWH was allocated to the Berri Evaporation Basin which assisted in maintaining and improving the habitat and the population of Murray hardyhead (*Craterocephalus fluviatilis*) found at the site. Water was delivered to the site through irrigation and gravity fed infrastructure. Although in 2014/15 Disher Creek did not use water from the allocated volume due to unregulated flows in August 2014, the Murray hardyhead population at this site has benefitted from an environmental water allocation in years preceding 2014.

The Murray hardyhead (*Cratercephalus fluviatilis*) (McCulloch 1913) is a small freshwater fish endemic to the Murray Darling Basin. Due to numerous threats the Murray hardyhead have suffered a decline in distribution on both a state and basin wide scale (Ebner et al. 2003; Hammer et al. 2009; Ellis et al. 2013) (Figure 16). Murray hardyhead have not been recorded in New South Wales for the last decade and may be extinct in the state. Currently there are eight known sites within South Australia and Victoria where viable populations of Murray hardyhead exist. Five of these sites are sites where Murray hardyhead have historically been recorded (Round Lake, Cardross Basin 1, Berri Saline Water Disposal Basin, Disher Creek, and Rocky Gully) and demonstrates the importance of these three sites within South Australia for maintenance of the Murray hardyhead population.

The species is considered to be of conservation significance. It is listed as Endangered nationally under the *Environment Protection and Biodiversity Conservation Act 1999*, Endangered on the International Union for the Conservation of Nature Red List, threatened under the Victorian Flora and Fauna Guarantee Act, and critically endangered in South Australia (Ellis et al. 2013). The conservation of this species in South Australia at Berri Evaporation Basin and Disher Creek is undertaken in collaboration across Government agencies, water managers and researchers (Ellis et al. 2013).

Murray hardyhead grow to an average total length of 75mm (Ellis et al. 2013). Spawning occurs in late spring/summer with eggs laid upon aquatic vegetation (Ellis et al. 2013). The species is found in still or slow-flowing waters with elevated salinities, although has been recorded in low salinities (Ellis et al. 2013). Its diet is predominantly comprised of microcrustaceans (Ellis et al. 2013). Threats to the Murray hardyhead are numerous and range from, habitat degradation, competition with non-native aquatic species, lack of water availability caused by climatic conditions and decreasing irrigation run-off (through irrigation efficiencies), lack of funding to manage and monitor the species, to high salinity levels in remaining habitats (Ellis et al. 2013).

Regulatory structures and on-ground works were coordinated in 2009 by the SA government to increase available habitat by controlled diversion of environmental water (from the River Murray) and irrigation drainage to the sites (Suitor 2012 and Suitor 2009). Despite these efforts, drought induced critical water shortages threatened the viability of both populations in 2009 and Murray hardyhead were salvaged for captive maintenance at Murray-Darling Freshwater Research Centre facilities in Mildura. Disher Creek and Berri Evaporation Basin re-connected to the River Murray during flooding in 2010 and following subsequent disconnection, remaining captive bred Murray hardyhead were returned to the sites in 2012.

Watering objective

The objective for environmental watering for Murray hardyhead was to maintain the habitat and populations of Murray hardyhead. The maintenance of habitat (such as surface water quality at a particular salinity) is critical to the survival of the species and environmental water is important in achieving this. It is clear that the provision of environmental water during the 2014/15 water was critical for the survival of the species.

Monitoring methodology

Monitoring was undertaken in summer 2014/15 using fyke nets set at several sites within the two basins. Fish were sampled with 7 m single-leader fyke nets (6 mm mesh) set overnight. Nets were set approximately 10 m apart either perpendicular or parallel to the bank, and where possible in a number of habitat types to adequately characterise habitat utilisation by fish communities within each location. The total length (TL) of captured fish was measured to the nearest mm. Sampling was conducted under a *Section 115 Exemption* in accordance with the *Fisheries Act 2007* and the Department of Environment, Water and Natural Resources Animal Ethics Committee standards.

Rapid site assessments documenting the physical characteristics of the site were undertaken on each surveying occasion. Physical habitat cover was described through visual observations as the proportion of aquatic habitat area comprised of emergent and submerged vegetation, other physical structure (i.e. woody debris, rock) and open water. Substrate type and water flow was also recorded. The following water quality parameters were measured at each site: electrical conductivity (µS/cm), pH, dissolved oxygen concentration (mg/L), turbidity (NTU), and temperature (°C).

Site description

Disher Creek and Berri Evaporation Basin form part of a River Murray wetland system used for saline water disposal near Berri, in the Riverland region of South Australia. In recent decades, Murray hardyhead in this system were largely confined to a small (less than 1 ha) drainage outfall pond in Disher Creek and a similar sized section of creek adjacent to Berri Evaporation Basin.

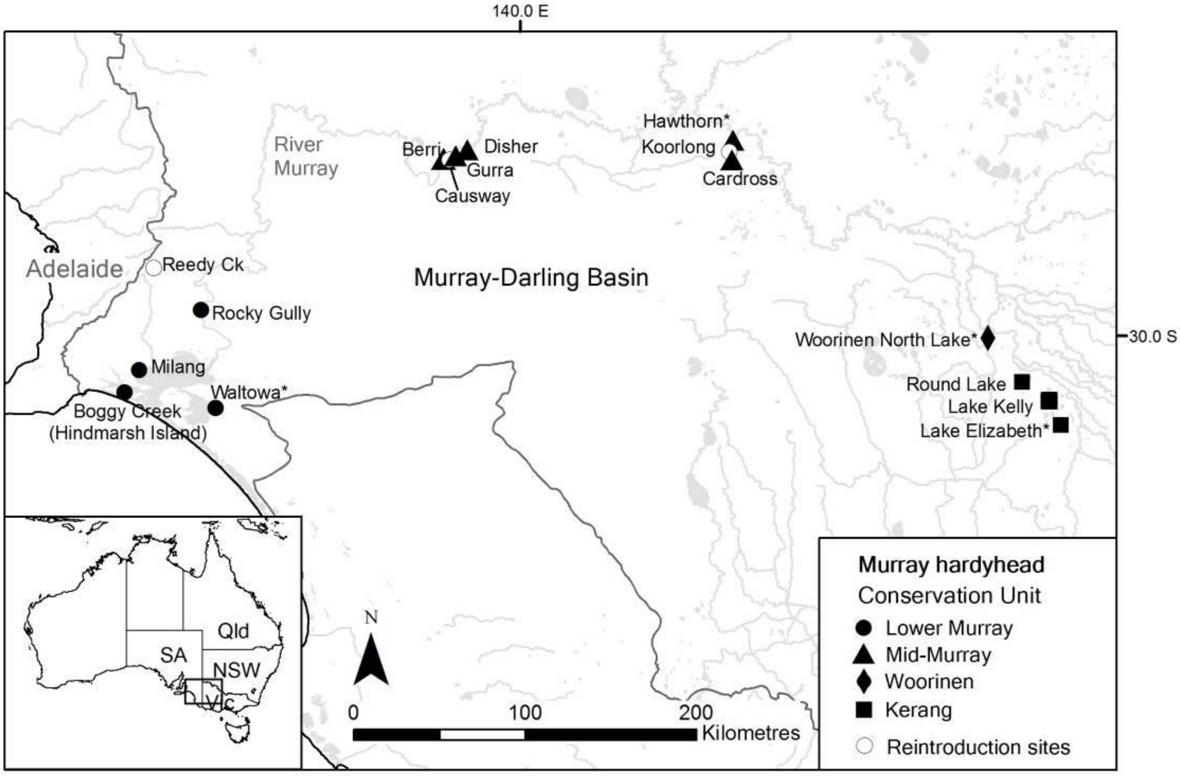


Figure 16. Location of known Murray hardyhead populations.

Results and discussion

Recent sampling efforts of Murray hardyhead at Disher Creek and Berri Evaporation Basin has seen a steady continuous increase in relative abundance since 2012. Catches have increased from around eight individuals from both sites in February 2012, to approximately 5000 fish captured from the Berri Basin site and approximately 10 000 fish captured from the Disher Creek site in February 2015 (Figure 17). This is a promising result in regards to the status and conservation of the species in the region, however the results must be viewed with caution as similar responses were not observed at the other sites within South Australia and Victoria where the species was formally found.

Overall, monitoring of both Riverland populations of Murray hardyhead in February 2015 identified high abundances, which are likely to reflect a positive response to the conservation efforts managed by DEWNR with an environmental water allocation from the CEWH.

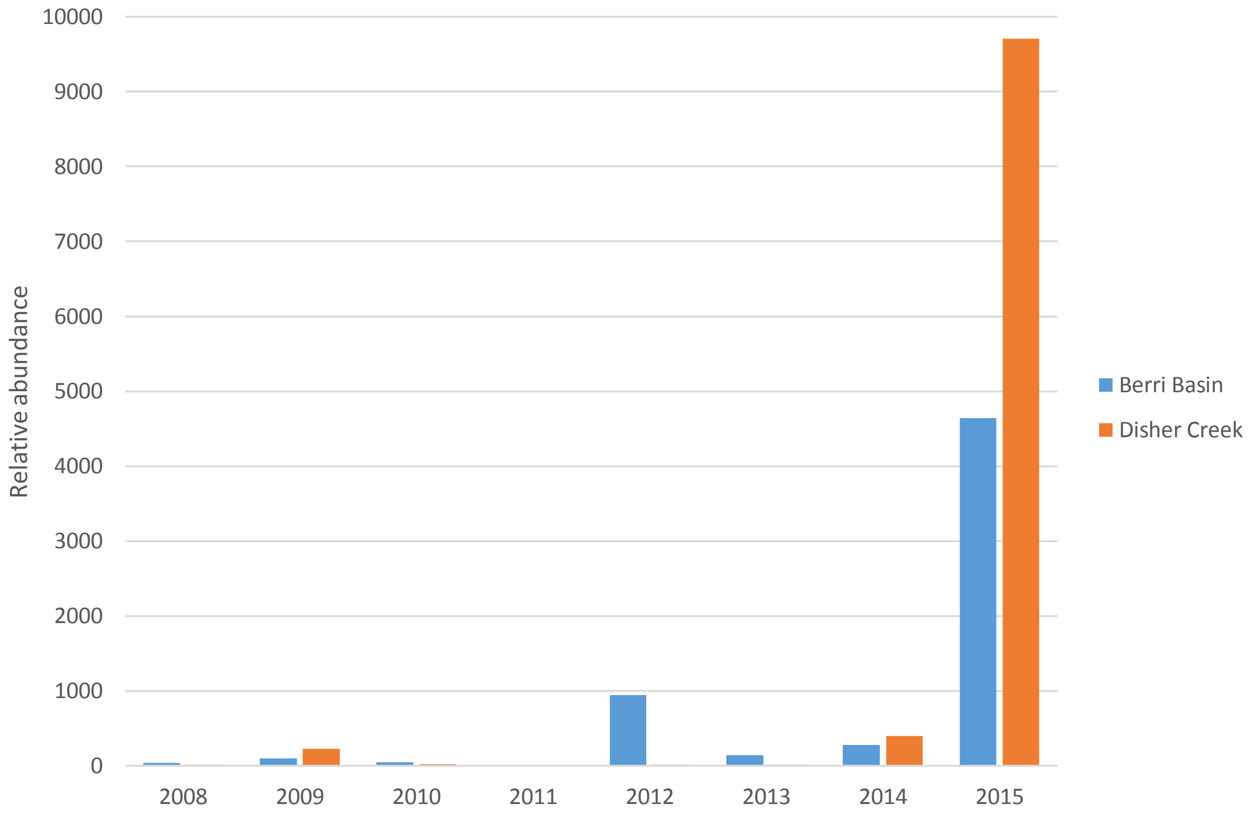


Figure 17. Abundance of Murray hardyhead captured at Berri Evaporation Basin and Disher Creek from 2008 to 2015.

Part J: Floodplain Dripper Irrigation Projects

Part J: Floodplain Dripper Irrigation Projects

The decline of tree health condition and widespread mortality is notable across the Murray-Darling Basin (Murray-Darling Basin Commission 2003). The impoundment of water in each River weir pool has resulted in the permanent flooding of many areas, and subsequent drowning of trees, while in other areas, the infrequency with which flooding now occurs has resulted in loss of trees from floodplain areas (Murray-Darling Basin Commission 2003). Water regime is particularly important for floodplain vegetation as it can determine both the condition, structure and assemblage of plants found upon it, however flooding conditions are now insufficient to maintain the condition and populations of trees across the region (Murray-Darling Basin Commission 2003).

Increasing attention has been focused on the decline in the condition of much of this long-lived vegetation in the South Australian Murray-Darling Basin region and has raised questions in regards to the actual scale and implications of this trend (Murray-Darling Basin Commission 2003). A popular method for maintaining these trees and other vegetation between such flood events as been to water through filling temporary wetland basins and floodplain depressions, and through weir pool manipulations (Gehrig and Nicol 2010). In recent times, other watering methods have been trialled to maintain or improve the condition of long-lived vegetation such as dripper irrigation or sprinkler watering. Natural Resources SA Murray-Darling Basin is currently undergoing black box watering trials at Markaranka, Gerard and Pike Floodplains, river red gum sapling dripper trial at Wiela Wetland, and sprinkler system watering at Whirlpool Corner Wetland.

The drought event of 2001 – 2010 caused irrecoverable stress to many trees and resulted in widespread mortality. A flood event in 2010 – 2011 and subsequent high-unregulated flow events between 2011 and 2012 resulted in the inundation of large areas of the floodplain of the SA Murray-Darling Basin, however many areas remained unflooded. Trees in these areas remain vulnerable to further decline in condition and mortality without larger flood events, sufficient rainfall to maintain or improve condition, and/or intervention actions. Due to the situation of black box trees higher on the elevation gradient, many black box trees have remained unflooded by the 2010/11 flood and previous events. Extremely low rainfalls were experienced across the Murray-Darling Basin between 2001 and 2010. As a result, during this period, recruitment rates were insufficient to maintain populations (Jensen et al. 2007).

The River Murray floodplain is dominated by two tree species: river red gum and black box (*Eucalyptus largiflorens*) (Murray-Darling Basin Commission 2003). Other long-lived vegetation species such as river cooba (*Acacia stenophylla*) and lignum (*Duma florulenta*) are also present across large swathes of the River Murray floodplain in South Australia. Both river red gums and black box trees are well adapted to an environment that is charactersed by frequent drought and flood periods (Murray-Darling Basin Commission 2003). Floodplain trees such as black box are dependent upon flooding to maintain health condition, and also recharge and export salts from groundwater and soils (Roberts and Marston 2011). Black box is a floodplain tree species found widespread across the inland and arid floodplains of the South Australian Murray-Darling Basin (Murray-Darling Basin Commission 2003). In this region, floodplain vegetation is dependent upon frequent flooding to maintain health condition of trees, as rainfall is generally insufficient to sustain this long-term (Murray-Darling Basin Commission 2003).

Part J.1: Gerard Floodplain Black Box Watering Trial

Part J.1: Gerard Floodplain Black Box Watering Trial

In June 2013, an opportunity arose to work in partnership with the Gerard Aboriginal Community, Gerard Aboriginal Learning on Country (ALoC) and Kungun ALoC within the Australian Governments Biodiversity Fund project which aimed to restore and protect long-lived floodplain vegetation along floodplains of the SAMDB. Over 12 months, the Natural Resources SA Murray-Darling Basin Wetland and Floodplain Team and community engagement staff worked with the Gerard Aboriginal Community Council, Aboriginal Lands Trust, Gerard ALoC and Kungun ALoC Teams, to the deliver this project. The project included:

- Set-up of a black box watering trial at the Gerard Floodplain: including identification of a priority area for the trial; identification, tagging and recording spatial information of trees; preparation and set-up of water shuttles and hoses; adjustment of watering rates per hose/tap combination.
- On-going maintenance of watering trial and infrastructure.
- Assistance in on-going monitoring program: collection of tree condition data, and photopoint monitoring.
- Identification of areas for conservation such as locations with sapling/seedling emergence as well as areas for further on-ground works, such as removing barriers to flow and other e-watering opportunities.
- Pest plant and animal mapping and control.

Within the Gerard Project the main objectives were to:

1) Determine whether the effects of watering via gravity fed infrastructure was sufficient to improve or maintain the condition of black box trees at the site.
2) Determine the impact of watering on understorey vegetation.
3) Develop a monitoring program that engaged the Kungun ALoC and Gerard ALoC in activities.
4) Identify areas of regeneration (i.e. seedlings and saplings) and areas for pest plant/animal management.
5) Contribute to the knowledge of black box water requirements.

Trial Site – selection and features

The Gerard-Katarapko Floodplain was selected as the study area due to the presence of black box trees, the close proximity to the township of Berri, and the interest shown by the Gerard Aboriginal Community Council (GACC) and Aboriginal Lands Trust (ALT) for such a trial to be undertaken at the site. Additionally, the site was deemed a high priority site for on-ground works due to the conservation and cultural significance of the broader floodplain and Mallee areas, through a project that was undertaken as part of the Biodiversity Fund project which analysed and identified high priority conservation and restoration potential for wetlands and floodplains along the River Murray. Additionally the study area is situated within the Katfish Reach Demonstration Reach boundary, a high priority site in South Australia.

The Gerard Floodplain (453706E, 6193665N), is located approximately 15 km south-west of the township of Berri in South Australia (Figure 18). The Floodplain is located at the downstream end of the Katarapko Floodplain, home to Katfish Reach, a demonstration reach for native fish under the Murray-Darling Basin Native Fish Strategy (Katfish Reach Steering Group 2008a). The Katarapko Anabranch system is one of three remaining floodplain systems in the SA Murray-Darling Basin region that supports a diversity of aquatic and floodplain habitat, and as such, the area is considered to have high biodiversity conservation value (Katfish Reach Steering Group 2008a). The Gerard Floodplain is located on lands held by the Aboriginal Lands Trust and managed by the Gerard Aboriginal Community Council although is included within the Katfish Demonstration Reach boundary (Katfish Reach Steering Group 2008b). To the east of the Gerard Floodplain, sand hills and Mallee are present in the highland, while to the north and west, the river lies alongside the floodplain. The Katarapko Floodplain and National Park boundary lies adjacent the southern edge of the Gerard Floodplain.

Across the study area, a number of temporary wetlands, depressions and floodrunners are present. Mostly healthy river red gum trees line the banks of the River Murray while a mixture of healthy and stressed river red gums fringe wetlands close to the main river channel. Lignum and river cooba are found in and around the floodplain depressions and other low lying floodplain areas that fill with rainfall runoff. Soils in these areas are generally comprised of grey clay. Black Box trees are found at higher elevations of the floodplain, many at the foot of the sandy Mallee areas to the south of the site. They are also found across the site on sandhills and along temporary floodrunner-wetland basins that varying in soils from sand to grey-clay. Black Box trees across the site generally ranged in condition from very poor to good condition, although most were observed to be in generally poor condition. Soil type in the study plot areas was predominantly sandy and no visible signs of salinisation were observed (e.g. salt scald). Understorey vegetation was prominent with organic material such as leaf and bark litter.

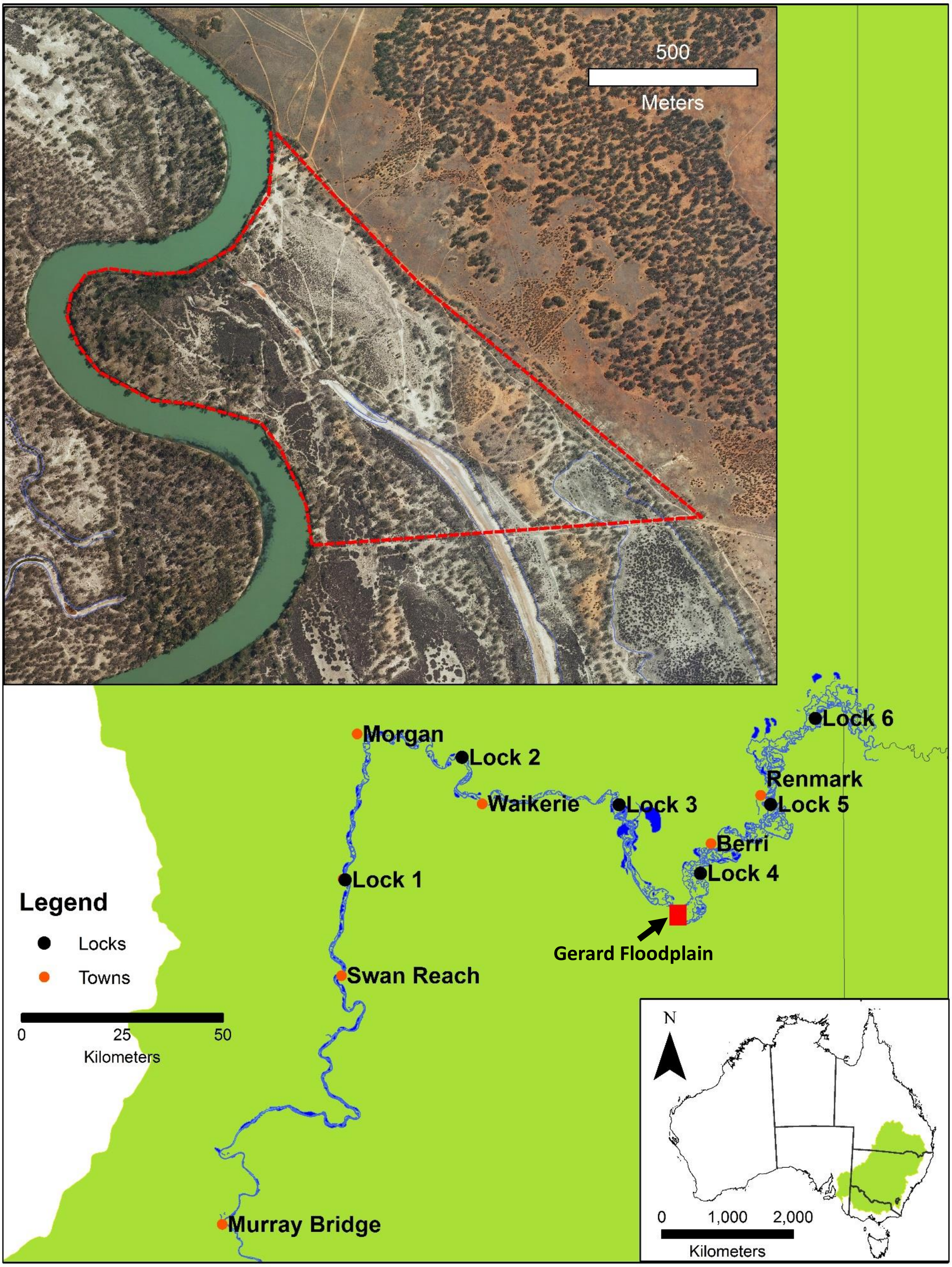


Figure 18. Location of Gerard Floodplain, near Berri, South Australia.

Trial species

Black box grows to between 10 – 20 m tall (Rogers 2011; Roberts and Marston 2011). Physically, the tree can be either single or multi-stemmed (Roberts and Marston, 2011; Rogers 2011). Leaves are typically green however can be blue and vary in size (Roberts and Marston 2011). The species is distributed throughout New South Wales, Queensland, Victoria and South Australia (Rogers, 2011). Black box may be found on the floodplains adjacent major rivers, fringing intermittently flooded depressions or in paleo-channels (Roberts and Marston 2011). A preference for clay soils has been noted (Roberts and Marston, 2011; Rogers, 2011). The species is able to access water from a number of sources including rainfall, floodwaters, stream water and groundwater (Holland et al. 2006). The species has a diamorphic root system which allows it to access multiple sources of water, or interchange between them (Holland et al. 2006), however long-term drought periods may result in a dependence on groundwater sources (Gehrig and Nicol 2010).

Trial set-up

A total of 90 black box trees were selected for the trial. They were recorded spatially and labelled with cattle tags with a unique number ranging from 1 to 90. Trees were allocated into plots, comprising of five trees each, totalling 18 plots across the study area. Trees in each plot were of similar health condition. Within each plot, trees used in the study were separated by at least 8 m and each plot was separated by at least 20 m (however generally more) in order to minimise the risk of a watering treatment applied in one plot influencing trees in an adjacent plot. Plots were randomly assigned into treatment groups.

Two treatments were trialled, with 30 trees (six plots) comprising each treatment group (Figure 19). Thirty trees allocated 'no treatment' acted as control trees against the treatment trees. The treatments were as follow:

- Treatment 1: 3000 L applied monthly
- Treatment 2: 3000 L applied bi-monthly
- Control: no treatment

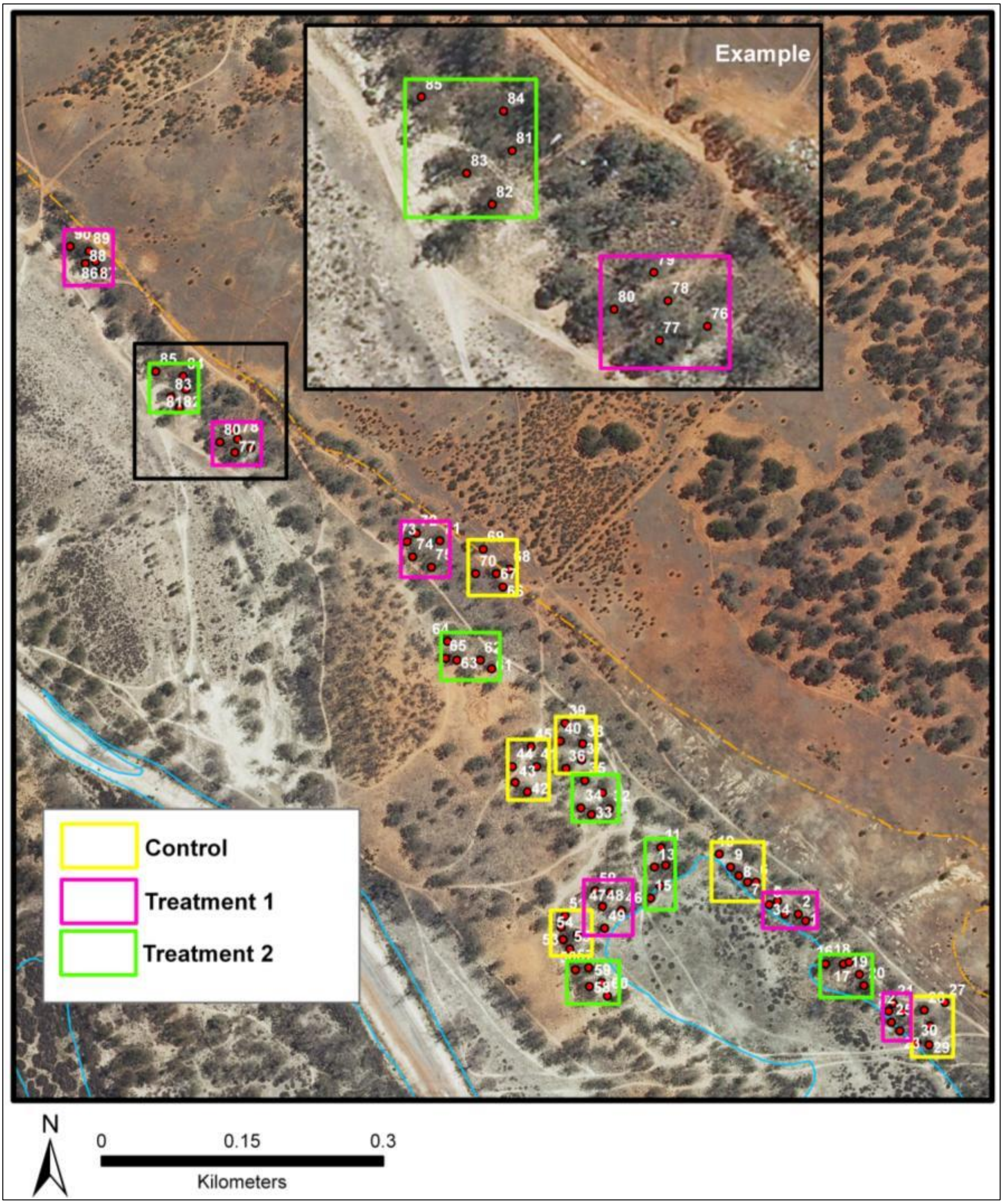


Figure 19. Watering plot set-up at Gerard Floodplain.

Water was delivered to the plots via gravity fed irrigation infrastructure. The infrastructure comprised of recycled agricultural shuttles (sourced locally) that were treated with an ultraviolet resistant paint spray to prevent deterioration while on site. Small hoses and taps leading to each tree were fed by a single main feeder hose from the water shuttle (Figure 20). Taps were adjusted so that the flow rate was the same for each tap and each tree in each plot received approximately the same volume of water during watering. Some shuttles were elevated where required using logs placed directly under each corner of the shuttle, to allow water to drain out via gravity to each treatment tree. At other plots elevation was sufficient to allow this to happen. Shuttles were filled with water allocated from the SA State Environment Reserve.

The majority of trees in the trial had received water during the 2010-11 flood event. Some of the trees were not inundated directly, but may have accessed water (possibly through the halo effect) as they were situated just beyond the edge of the peak flood level, high on the elevation gradient. It is likely that these trees have relied heavily on rainfall and groundwater for survival over the past 20 years, and as such, many in these areas are in extremely poor health condition (pers. obs. I. Wegener October 2013).

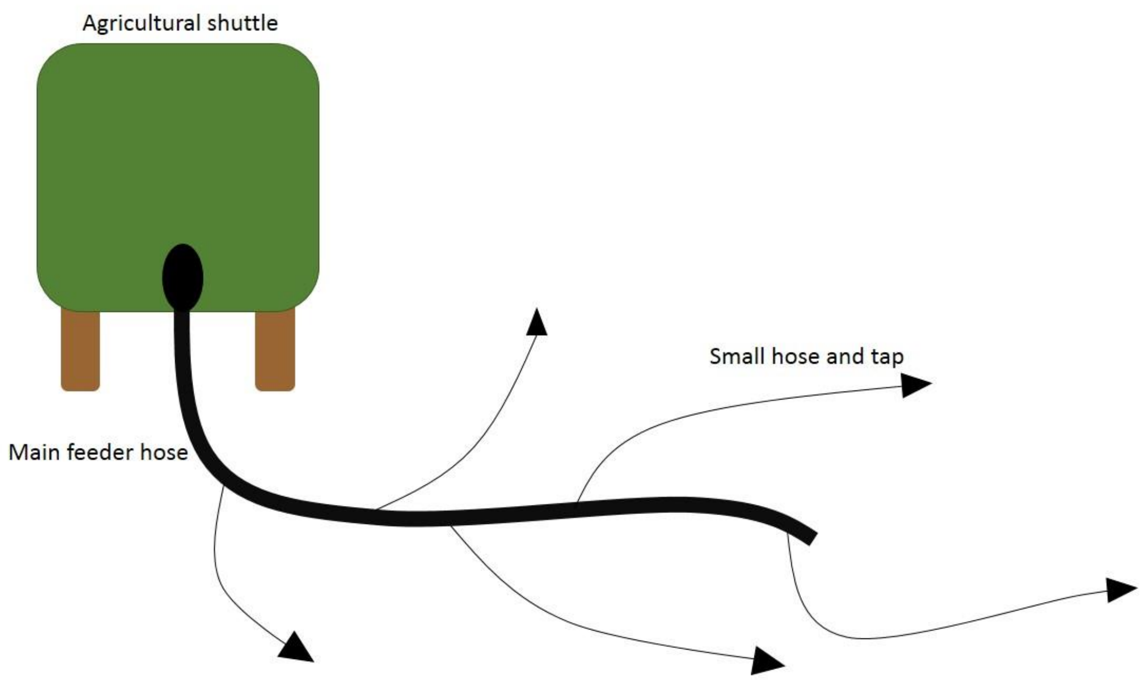


Figure 20. Shuttle and hose set-up (not to scale).

Monitoring methodology

Tree condition monitoring was undertaken for the duration of the trial, with one survey conducted before the trial commenced (in October) and then quarterly monitoring conducted from January 2014 to June 2015. Monitoring was undertaken by the Kungun and Gerard ALoC Teams and Natural Resources SA Murray-Darling Basin Wetland and Floodplain Program staff with technical assistance provided from the South Australian Research and Development Institute Plant Ecology Program. More detail on the tree condition method and analysis method can be found in Part E (pg. 42).

Results

The average condition score for each treatment during each monitoring event was calculated and plotted (Figure 21). Prior to watering, trees in the Treatment 1 group were in slightly higher average tree condition when compared to the condition of the Treatment 2 and Control group, however this difference was minimal. Treatment 1 trees generally showed the best condition over the monitoring period. A similar trend in average tree condition was observed in all groups over the monitoring period. Between the pre-watering and winter 2015 monitoring round, trees in the Control group, declined in average condition overall from 0.129 to 0.115 average tree condition index score. In the Treatment 1 from 0.162 to 0.240 average tree condition index score and Treatment 2 group increased marginally from 0.144 to 0.159 average tree condition index score.

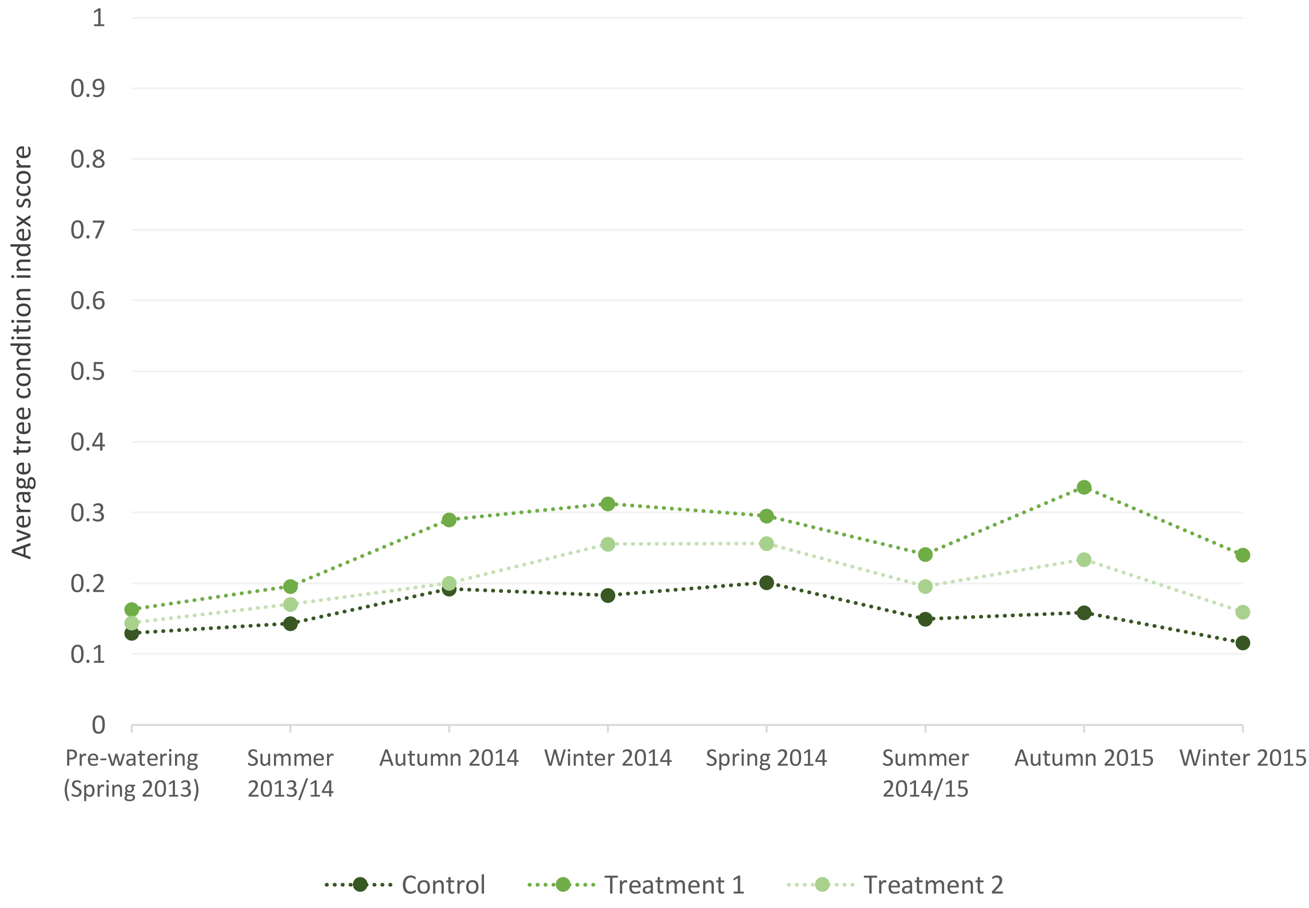


Figure 21. Average tree condition across treatments and monitoring events, pre-watering (spring 2013) to winter 2015.

Discussion

In the Control group, average tree condition decreased marginally within the study period, which likely suggests that without intervention trees will continue to deteriorate in condition. This could result in mass mortality of trees across the floodplain in the future if insufficient rainfall and flood events occur, or if intervention actions are not implemented. Treatment 2 trees showed little change in average condition index score pre-watering and in winter 2015. This may indicate that the amount of water these trees received, both environmental watering as well as rainfall was, under the conditions experienced, sufficient to maintain the condition of trees in this group, but insufficient to result in an improvement in condition over the trial period. The Treatment 1 group showed a marginal increase in condition in response to environmental water delivery and rainfall. However the downward trajectory observed over the summer 2014/15 to winter 2015 period, suggests that the water delivered to this group in the absence of substantial rainfall events was not sufficient to maintain the tree condition over the longer-term. Furture investigations could consider increasing the volume of water delivered as well as adjustments to the watering infrastructure (e.g. using soaker hose instead of taps, and placing soaker hose in the natural dripline of the trees canopy).

Improving the understanding of the water requirements of black box is important as a gap in knowledge exists concerning this. There are several situations in which a similar set-up to the one trialled at Gerard could be utilised: where there are a small number of trees requiring intervention; where there is insufficient existing infrastructure that may deliver water (e.g. mainline water supply); and where cost may constrain the watering options that can be implemented by community groups and landholders.

A comprehensive overview of this project is currently underway in Wegener (in prep.).

Part J.2: Wiela Dripper Trial

Part J.2: Wiela River Red Gum Dripper Irrigation Trial

Wiela is a temporary wetland complex situated between Lock 5 and Lock 6 approximately 21 km north east of the township of Paringa in South Australia. Wiela wetland is part of the Riverland Ramsar site and Riverland Biosphere Reserve, which are areas of particular ecological value for migratory waterfowl and are listed under the Convention on Wetlands of International Importance. The site supports threatened species such as the southern bell frog and regent parrots.

Wiela consists of temporary wetlands that are filled when river flows are greater than approximately 30 000 ML/day. River regulation and over-extraction has led to many wetlands, including Wiela, experiencing a reduced flooding frequency which has impacted natural wetland ecological processes and native flora and fauna. Following the 2010-11 flood event, extensive natural strandlines of river red gum seedlings were identified at Wiela Shedding Basin at Murtho Park/Wiela wetland complex. It was recognised that the site was of high conservation significance, and that the seedlings were vulnerable to desiccation in their first few years without watering intervention. The primary aim of this project was to investigate and trial the use of drip irrigation as a direct watering intervention technique to maintain the condition of river red gum seedling recruits.

Along two naturally occurring river red gum strandlines, two drip irrigation lines spaced two meters apart were installed (400 m long, drippers ever 0.5 m), while for a third natural strandline of trees, four dripper lines were installed (400 m long, drippers ever 0.5 m), one meter apart (Figure J-1) (Gehrig and Hoffmann in prep.). A control strandline was also selected outside of the strands where dipper irrigation was installed. Water was pumped from a nearby creek to deliver three watering volumes equivalent to 20 mm (T1), 40 mm (T2) and 80 mm (T4) rainfall per month. Water was delivered monthly from May and September 2014 and bi-monthly from October 2014 to February 2015 (Figure 22).

Figure 22. Dripper irrigation infrastructure delivering water to natural strandlines of river red gum saplings at Wiela Shedding Basin.

Monitoring was undertaken to compare the differences between watering treatments and included, measuring tree water stress (through sapling shoot water potential) as well as soil moisture, matric potential, pH and electrical conductivity. Monitoring was conducted before watering (April 2014), during watering (October 2014) and after watering (March 2015). Additionally, hemispherical photographs of each treatment group were taken monthly from April 2014 to March 2015 in order to detect changes in canopy density and growth of saplings over time.

Over the 2014-15 water year, 1.01 ML of water from the was delivered to the site through the dripper infrastructure. A detailed analysis of the results to date is currently being undertaken (Gehrig and Hoffmann, in prep.). Preliminary results suggest that trees watered with the two highest volumes had lower water stress when compared to the control, but there was potentially no difference between trees watered with the lowest water volume and the unwatered controls. Hemispherical photos documented a large amount of growth in height and density in trees receiving the highest water volume compared to the unwatered control (Figure 23).

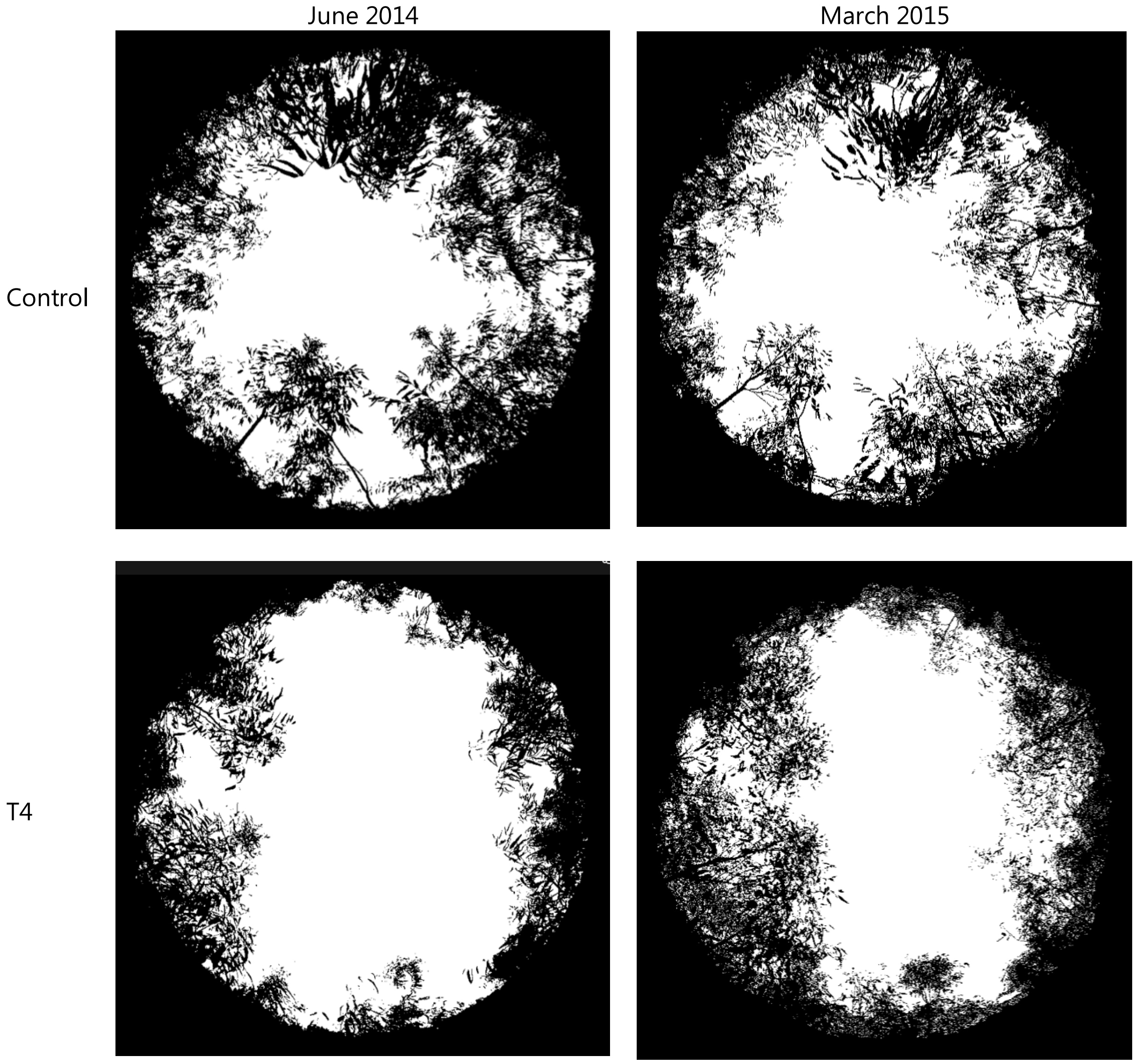


Figure 23. Hemispherical photographs of Control and T4 (80 mm rainfall equivalent) treatments at the commencement of watering (June 2014), and after watering (March 2015).

Part J.3: Markaranka Black Box Watering Trial

Part J.3: Markaranka Black Box Watering Trial

The following section is taken from the executive summary of *Investigating use of drip irrigation to improve condition of black box (Eucalyptus largiflorens) woodlands, Phase III: Variable watering regimes* (Gehrig and Frahn 2015).

From 2001 to 2009 the southern Murray-Darling Basin (MDB) experienced severe drought conditions and a concomitant dieback of floodplain trees (river red gums and black box). To improve floodplain eucalypt health during low flow periods and drought, regular watering interventions (e.g. filling of temporary wetlands, weir pool surcharge, groundwater freshening) were used as effective management intervention tools. In 2010/11 there was wide spread flooding across the MDB, peaking at 93 000 ML/day at the South Australian border, leading to improved catchment conditions. Nonetheless, many black box trees at higher elevations on the floodplain remained unflooded, leaving trees vulnerable to further decline without short- to medium-term interventions. To alleviate further declines in tree health, the use of drip irrigation as a direct watering technique for black box woodlands was trialled on the Markaranka Floodplain (lower River Murray, South Australia) over three years.

In the first year of the watering trial (November 2012 to May 2013), an experimental area of nine plots (55 x 55 m each, total area = 2.7 ha) was established. One of these plots was allocated as not monitored, while four were randomly assigned as controls (i.e. non-watered) and another four were watered weekly, at a rainfall equivalent rate of ~20 mm per week (total volume used = 4.2 ML). The effectiveness and feasibility of using drip irrigation as a direct watering technique was assessed by comparing the tree condition scores, tree water status and understorey plant communities amongst watered and control plots. Prior to watering in the first year, the population structure of black box within the experimental area was unbalanced with no evidence of young growth stages (i.e. no seedlings and one sapling <5 cm DBH, diameter at breast height). Despite seasonal variations, tree condition scores, tree water status and understorey species richness and percentage cover all significantly improved in watered versus non-watered plots, indicating the drip irrigation technique was effective and that the method can provide an accessible water source for stressed floodplain vegetation (see (Gehrig 2013).

Following the effectiveness of the first year, the watering trial continued for a second year (October 2013 to April 2014; 22 weeks). The objectives of this second year were to *i*) assess whether the improvements to black box condition had continued and *ii*) to expand the trial to include more treatments in order to test the minimal and/or optimal watering regimes required to improve black box woodland condition. Hence six new plots (55 × 55 m each) were established, for a total of 15 plots within the experimental area (total area = 4.5 ha). Within this expanded experimental area, the monitoring plot was unchanged; three plots continued as controls while the remainders were set up as treatment plots with four watering levels. Within the treated, watered plots; three plots continued to be watered at ~16 hour per week (W4 plots); three newly established plots received ~8 hours per week (W2 plots), while the other three plots were watered for ~12 hours per week (W3 plots) and finally one original control and one original treatment plot were trialled with a new minimal watering regime of ~4 hour per week (W1 plots) (see Gehrig 2014). The two year trial showed that watering via drip irrigation can significantly improve black box and woodland condition; however, the benefits may only be temporary and unlikely to persist without another watering the following year. It also appears that watering rates >20 mm rainfall per week are required to shift trees from poor condition into good or very good condition. Alternatively, water rates ≤5 mm rainfall per week may not be sufficient to improve tree condition.

In terms of optimal watering regimes a greater range of watering frequencies were trialled in the third year. Plots that had previously been watered weekly for 16 hours were unchanged and continued to be watered weekly in order to assess how three back-to-back watering periods might help to improve tree condition. Also to test whether watering less frequently, but for longer durations may improve tree/woodland condition, plots which were previously watered for four hours per week in the second watering period, were then watered for 72 hours every two months. Plots that were previously watered for eight hours per week in the second watering period were watered for 72 hours every month. To test whether tree/woodland condition may decline following a good watering season, watering was withheld completely from plots, which were previously watered for 12 hours every week in the second watering period.

The third watering period reiterated that watering via drip irrigation can improve black box and woodland condition. Overall, tree and understorey condition in the control plots has continued to deteriorate across the three years of the trial indicating that the woodland within the field site area may be in a continuing state of decline. In contrast, within plots that were watered, black box trees have maintained improved crown condition and water status and the understorey vegetation has remained more abundant and diverse. Watering applied via drip irrigation therefore appears to arrest the decline in condition and promote significant growth flushes, especially during the drier months.

Since the trees within the experimental area appear to be in a state of delcline, the benefits of continued watering of these plots may become more apparent in subsequent years. Overall plots that were watered weekly have demonstrated the most persistent improvements. Crown condition and water status of black box trees within plots watered less frequently, but for longer durations (i.e. every two months), were not significantly different by the ened of the third watering period indicating that less frequent applications are just as effective. Likewise, plots that were watered every two months received less than half the total volume of water delivered to plots watered more frequently (weekly) confirming that volumes around 50 m month^{-1} (via the drip method) are sufficient to induce marked improvements in tree condition. Crown condition of trees watered monthly was signficantly better compared to trees watered weekly every two months, suggesting that higher volumes (i.e. >80 mm per month), applied less frequently, may be more optimal regime. For future investigations the focus on testing and refining the minimum/ maximum volumes of water required for shifting trees from poor to good condition should be continued as results from this three year study suggest that watering less frequently and at volumes ≥ 40 mm month^{-1} but ≤ 100 mm month^{-1} may be the most optimal for promoting growth flushes in black box trees during the drier months.

The benefit of watering via drop irrigation are unlikely to persist for very long without follow up watering periods. For instance, black box trees that had previously been watered in the second year, however had water withheld in the third year, showed decreasing water status by the end of the third watering period (although slight improvement sin crown condition were still evident). In contrast, plots that were watered weekly received three consecutive watering periods and the highest volume of water across the trial, and crown condition remained largely unchanged prior to and across the third watering period. This suggests some upper limits in crown condition improvements have been attained and therefore it would be beneficial to determine whether these improvements would subsequently decline if watering were withheld the following year. Furture monitoring could help to elicit how long it might be before the condition of black box within these plots might again begin to decline and reach a similar condition to the black box within plots that have not been watered.

To fully elicit the benefits of drip irrigation for improving black box tree and woodland condition it is recommended that the current trial continue to determine the ideal volumes and frequency of applications needed to:

a) improve condition of black box populations from poor to good/very good condition

b) trigger reproduction

c) enhance regeneration.

Regular monitoring of tree condition, tree water status and understorey condition in response to various watering regimes is also recommended to not only capture the short- to medium-term responses of trees/woodlands to irrigation regimes, but also identify any natural regeneration that may be occurring and/or alert managers to any intervention management strategies (e.g. weed removal) that may be needed. It is recommended that in future trials, watering is withheld from plots that have received three back-to-back years of watering to further refine how long improvements in tree condition may continue to persist.

Part K: Bookmark Creek

Community Monitoring Summary 2014-15

Part K: Bookmark Creek - Community Monitoring Summary 2014-15.

This section reports on the monitoring undertaken at Bookmark Creek between July 2014 and June 2015.

Background

Bookmark Creek and Wetland Complex lies along the western edge of the township of Renmark in South Australia. The site is comprised of a permanently flowing creek, Bookmark Creek, and one temporary wetland basin referred to as 'Bookmark wetland'. The Creek is a flow-through system which by-passes Lock 5 at Renmark and therefore provides important flowing habitat within South Australia resulting from the head difference between Lock 5 upper weir pool (~16.3 m AHD) and lower Lock 4 weir pool (~13.2 m AHD). Water levels in the creek can be managed via a sluice gate at the upstream inlet structure. The adjacent wetland commences to fill when flows to South Australia reach approximately 60 000 ML/day, when the water level in the creek is sufficiently high enough so that the wetland commences to fill (pers. comm. T. Hersey December 2012), or when rainfall run-off fills the wetland.

Bookmark Creek and Wetland support a range of biota including species of conservation significance, and the site has high social value to the community given its close proximity to the township of Renmark. The site is considered a high priority in South Australia for management and on-ground works due to its flow-through and lock by-pass nature, and its high potential for fish passage between lock reaches, and the potential provision of a range of flowing water habitat types that may be utilised by large-bodied native fish species. The hydraulic head created by the difference in weir pool water levels results in diverse hydraulic environments across the length of the creek. Although providing important flowing water habitat for large-bodied native fish species, there are several flow-control structures which act as barriers to fish passage (Figure 24).

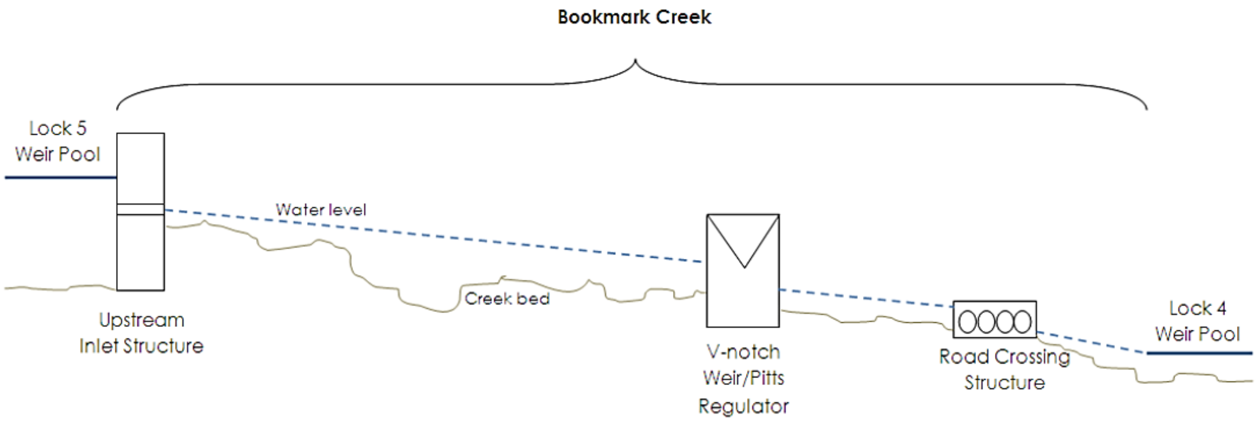


Figure 24. Cross-sectional diagram of Bookmark Creek (NOT TO SCALE).

The Bookmark Creek and Wetland are located within the Renmark to the Border Local Action Planning Association region. A community group, the Bookmark Creek Action Group (BCAG), has been involved in rehabilitation and management of the creek since 1997, and have more recently (since October 2011) become involved in wetland monitoring activities supported by the Natural Resources SA Murray-Darling Basin Wetland and Floodplain Program. The group has a large membership made up of a number of stakeholders (e.g. DEWNR through the River Murray Operations and Infrastructure) and local community members that continue to coordinate and undertake on-ground works along the length of the creek to maintain and enhance the aesthetic quality of the site.

Bimonthly meetings are held that inform and update Bookmark Creek Action Group members of monitoring results, any works proposed and management of the site. Representatives from DEWNR (River Murray Operations and Infrastructure), Natural Resources SA Murray-Darling Basin (Wetland and Floodplain Program), Renmark Paring Council, Renmark to the Border Local Action Planning Association, Renmark Irrigation Trust, Angoves Family Winemakers and interested community members comprise the BCAG.

Historically, Bookmark Creek was utilised as a saline disposal basin, however it has not been used for this purpose for a number of years. The creek has been flowing since October 2010 when flows to SA increased sufficiently to allow the creek to receive water under the hydrological guidelines for Saline Disposal Basins (Smith 2002). In April 2015, the inlet sluice gate was repaired allowing water levels in the creek to be managed. Within the 2014/15 water year, Bookmark Creek received an environmental water allocation from the State Environment Reserve.

Monitoring at Bookmark Creek and Wetland is undertaken at least quarterly where possible. In addition, some seasonal surveys of some parameters may be undertaken. Parameters monitored at Bookmark Creek and wetland include:

- surface water quality: electrical conductivity (EC) (µS/cm), pH, turbidity (NTU), dissolved oxygen (mg/L), temperature (°C)
- groundwater: depth (m AHD) and EC
- tree health condition
- fish
- frogs
- waterbirds (incidental).

Data collection has been undertaken by the BCAG, Renmark to the Border Local Action Planning Association, DEWNR and Natural Resources SA Murray-Darling Basin. Information gathered during monitoring is used to inform the management objectives and recommendations, as well as the on-going management of the site.

Water Levels (m AHD)

Water levels at the Creek are monitored at the 'Old Pumping Station' located between the main road between Berri and Renmark that cross the bridge, and Pitt's Regulator. The following figure (Figure 25) shows water levels in the creek within the 2014-15 water year.

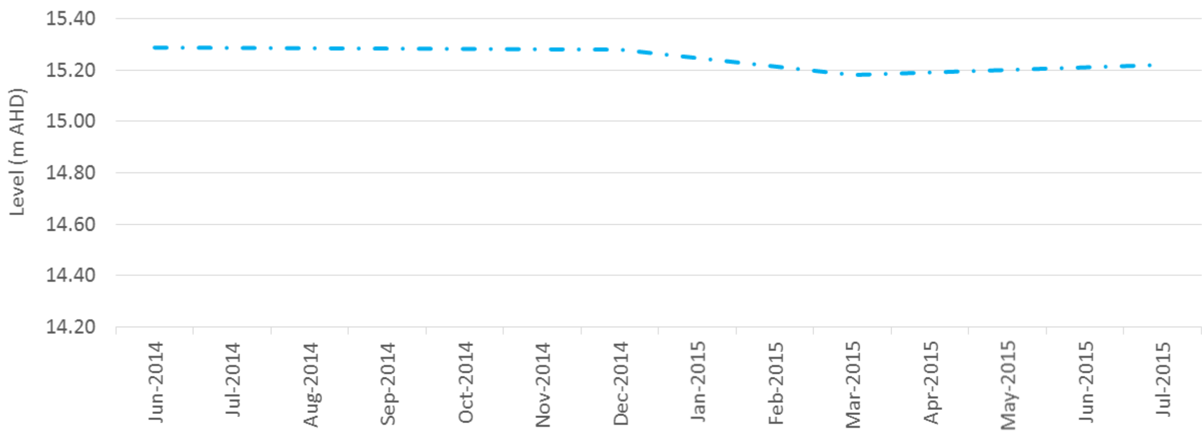


Figure 25. Water level (m AHD), Bookmark Creek, June 2014 – June 2015.

Surface water quality

Surface water quality was measured at a total of seven sites along Bookmark Creek seasonally (winter, spring, summer and autumn). An explanation of surface water quality parameters has previously been given in Part D (pg. 34).

Note: different scales are used in each of the following figures.

Surface water electrical conductivity

Average surface water conductivity ranged from 193 to 314 µS/cm (Figure 26). The maximum average surface water conductivity was recorded in winter 2014 while the minimum surface water EC was recorded in winter 2015. Generally, surface water conductivity increased at sites downstream and may indicate that salts may be mobilised from the banks and surrounding floodplain as water flows downstream in the creek.

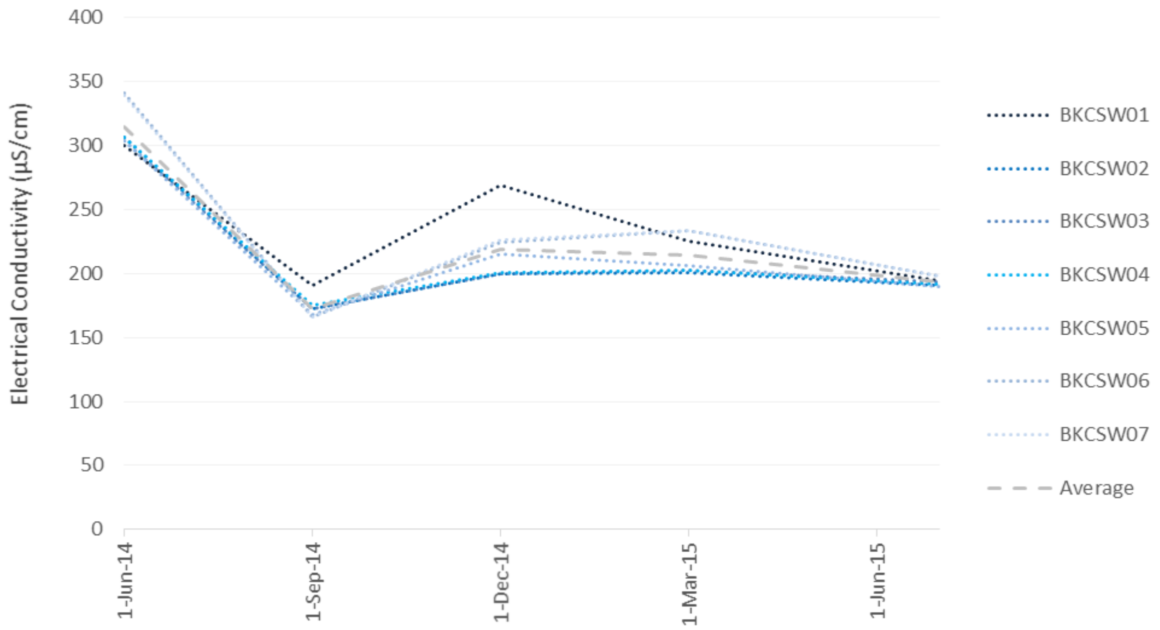


Figure 26. Surface water electrical conductivity (µS/cm), Bookmark Creek, June 2014 – June 2015.

Surface water pH

Average surface water pH ranged between 7.18 and 8.55 (Figure 27). This is considered neutral and within optimal range for aquatic biota. There was generally very little variation between pH along the length of the creek during surveying. The most alkaline average surface water pH was observed in winter 2015 while the most acidic average surface water pH was recorded in winter 2014.

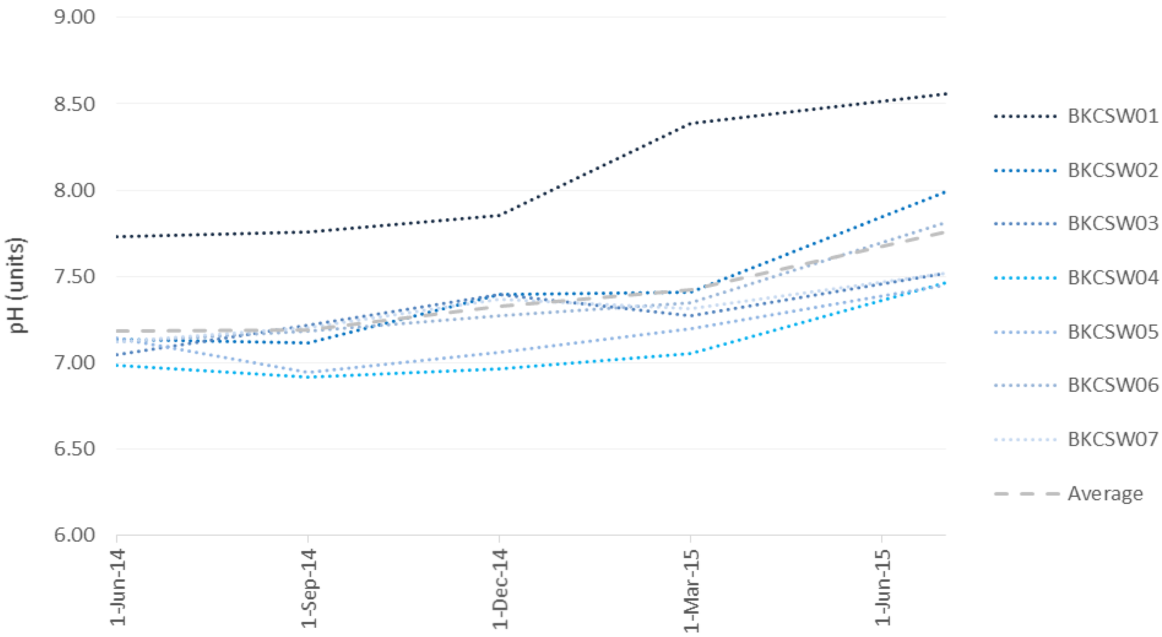


Figure 27. Surface water pH (units), Bookmark Creek, June 2014 – June 2015.

Surface water turbidity (NTU)

Average surface water turbidity ranged between 16.0 and 108 NTU (Figure 28). The greatest turbidity was measured in autumn 2015 while the lowest turbidity was recorded during winter 2015. Low surface water turbidity was observed at wetlands across the SAMDB region in winter 2015 (Natural Resources SAMDB unpublished data; pers. obs. I.Wegener July 2015). General surface water turbidity levels were recorded below 100 NTU which is important for the germination and growth of aquatic vegetation.

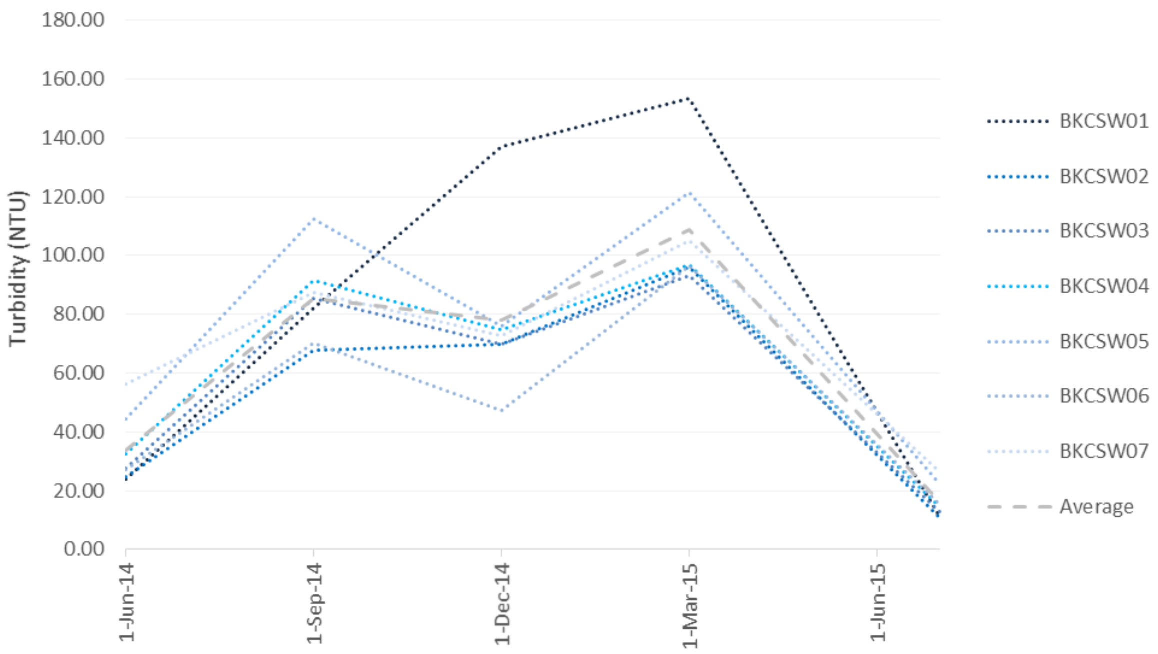


Figure 28. Surface water turbidity (NTU), Bookmark Creek, June 2014 – June 2015.

Surface water dissolved oxygen

Surface water dissolved oxygen was measured on three occasions. In summer 2015 and winter 2015 surface water dissolved oxygen was unable to be measured due to equipment failure. Average surface water quality dissolved oxygen ranged from 6.1 to 13.8 mg/L (Figure 29). The minimum average surface water dissolved oxygen reading was taken in autumn 2015, the maximum in winter 2014. Dissolved oxygen levels were generally recorded within levels critical to the survival of aquatic biota.

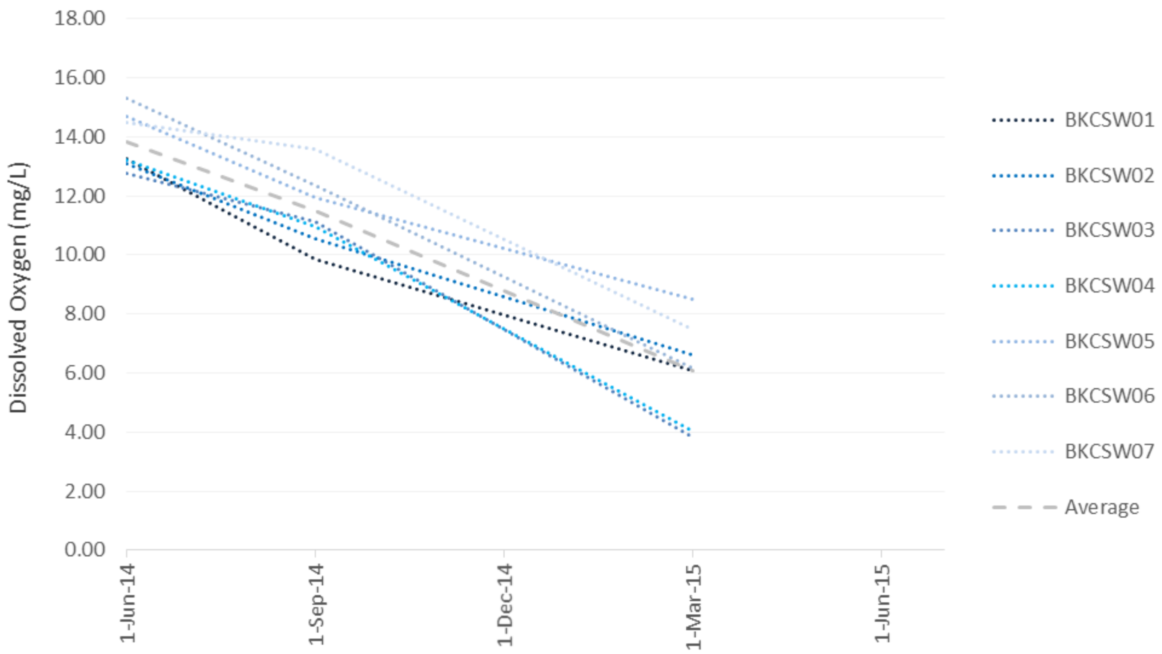


Figure 29. Surface water dissolved oxygen (mg/L), Bookmark Creek, June 2014 – June 2015.

Surface water temperature

Average surface water temperature ranged between 10.85 and 24.50°C (Figure 30). The maximum average surface water temperature was observed in summer 2014 while the minimum average surface water temperature was recorded in winter 2015. Surface water temperature showed seasonal changes

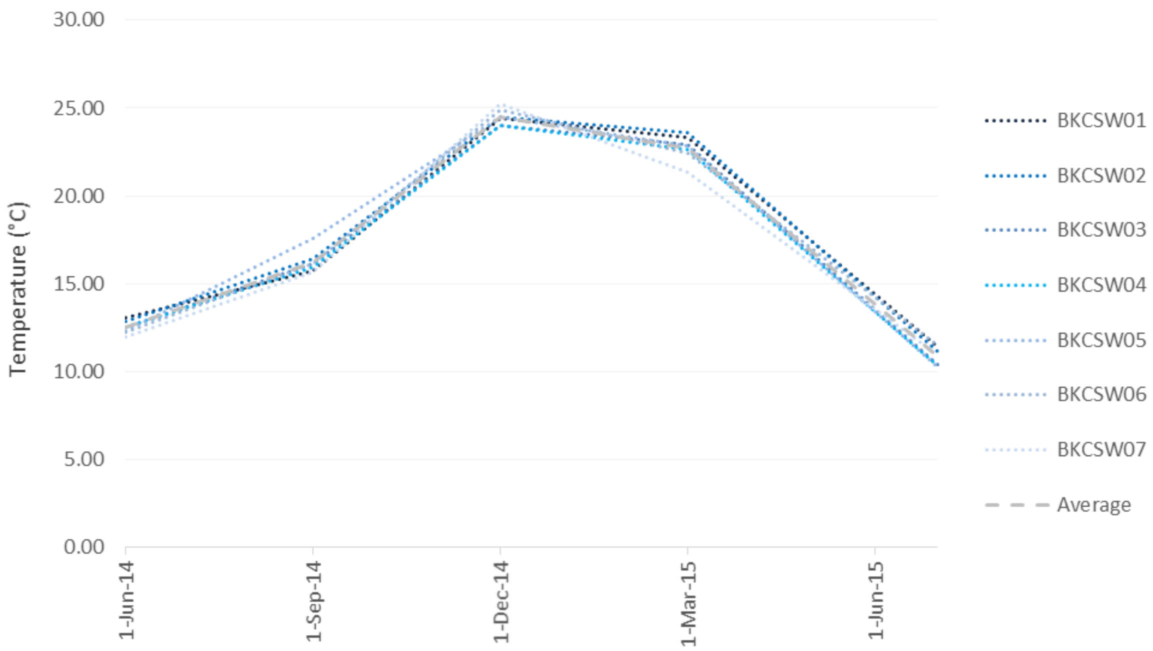


Figure 30. Surface water temperature (°C), Bookmark Creek, June 2014 – June 2015.

Groundwater

Six groundwater bores at Bookmark Creek were monitored in the 2014-15 year. Groundwater is a key monitoring component as the information can have implications for the way in which Bookmark Creek may be managed. Groundwater monitoring data can be used to determine the effect of groundwater levels and conductivity on the Creek such as identifying saline seeps, which can assist in explaining variations in water quality, flora and fauna communities and species abundance, and used to inform the management of the system.

Groundwater depth below ground level (m AHD) and electrical conductivity (µS /cm) is determined by several factors including; regional hydrology and wetland geomorphology, particularly the local geomorphology such as the texture and chemistry of the wetland bed and banks, groundwater flow geometry and extraction (Peters et al. 2005; Wallace et al. 2008; Jolly et al. 2008a).

Groundwater levels and gradient (m AHD)

Groundwater levels are measured by recording the depth of the water in the bore to the top of the piezometer. If the tops of the pipes are measured to a standard height (i.e. Australian Height Datum, AHD) this allows the water levels in the piezometers to be calculated and compared to each other as well as to the river water level. Groundwater gradients may be determined by comparing groundwater levels of two bores or more in a transect and their difference in height to each other. Movement of the groundwater is towards the lowest groundwater depth (Figure 31).

All six groundwater bores are situated in transects along Bookmark Creek. There are three transects comprised of two bores each. They are GW01 and GW02; GW03 and GW04, and; GW05 and GW06.

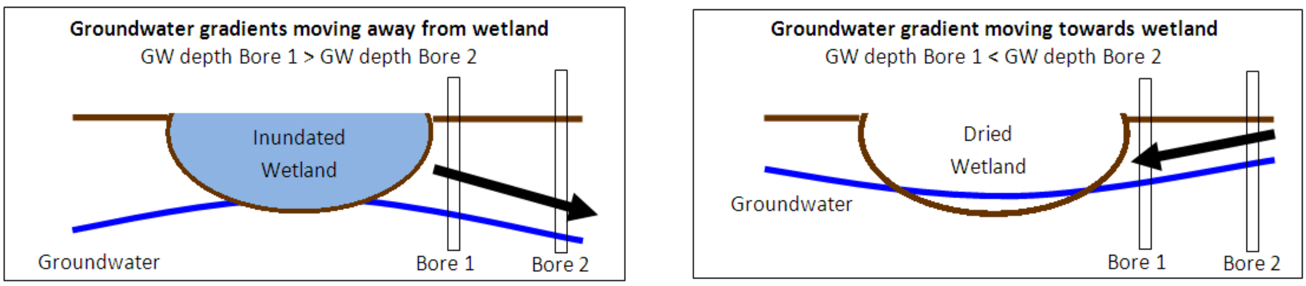


Figure 31. Conceptual diagram of groundwater gradients.

Groundwater depth at Bookmark Creek ranged between 13.508 and 16.013 m AHD within the monitoring period. Groundwater in bores GW1 and GW2 was consistently recorded between 15.0 and 16.0 m AHD while groundwater levels in bores GW3, GW4, GW5 and GW6 were usually recorded between 15.0 and 13.5 m AHD (Figure 32).

Groundwater levels in GW2 (situated furthest from the creek) were higher than in GW1 (situated closer to the creek) in September 2014 which indicates groundwater movement towards the creek at this time. During other monitoring events of these bores such as in autumn and winter 2015, no movement was observed, indicated by the almost identical water levels recorded in these groundwater bores. Groundwater in the GW3 and GW4 showed generally no clear gradient of groundwater movement and groundwater levels were consistent throughout the monitoring period. Groundwater in the third transect showed a gradient of groundwater trending towards the creek as the groundwater level in this bore (GW6) was always greater than that of GW5 which is situated closest to the creek.

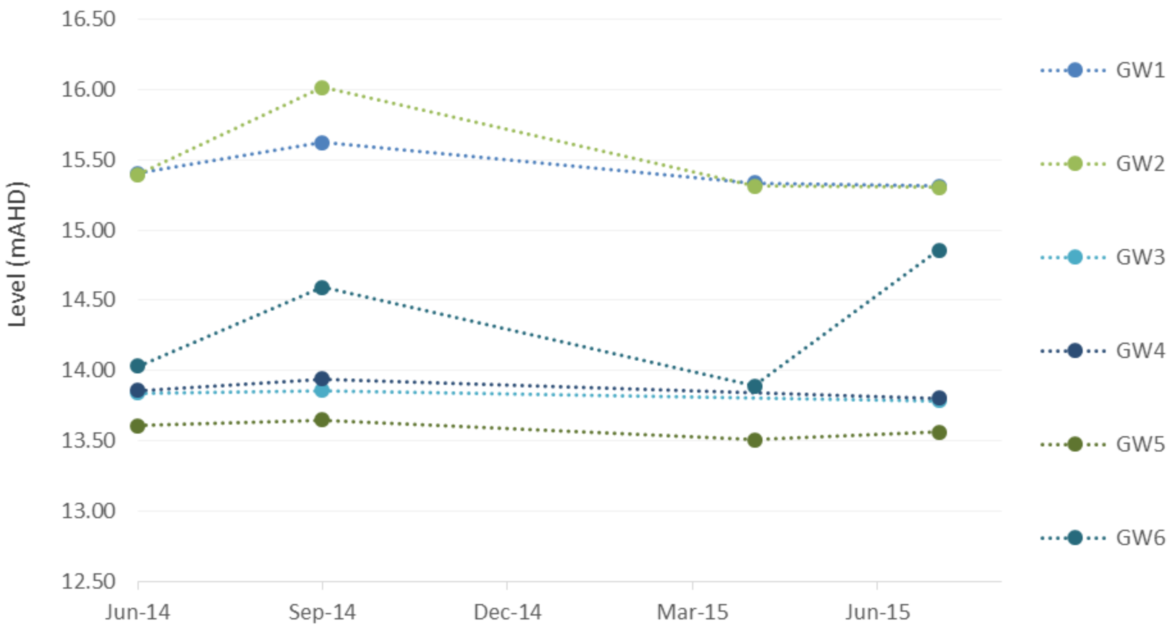


Figure 32. Bookmark Creek groundwater levels (m AHD), July 2014 to June 2015.

Therefore, groundwater gradient within transects along the creek were generally towards the creek over the monitoring period. This is likely to have contributed to the increased surface water electrical conductivity noted within the monitoring period (pg. 101).

Groundwater electrical conductivity

Groundwater electrical conductivity (µS/cm) was variable between monitored bores however generally consistent within individual bores within the monitoring period, perhaps only showing some small seasonal variations within the monitoring period. Groundwater conductivity ranged between 14 880 and 83 300 µS/cm within the monitoring period (Figure 33).

The lowest conductivity was consistently recorded in bores GW3 and GW4. These bores may be freshened by irrigation that is in close proximity to these bores.

The greatest electrical conductivity was recorded in bores GW1, GW2, GW5 and GW6. These bores are situated on the surrounding floodplain that is largely depauperate of deep-rooted vegetation.

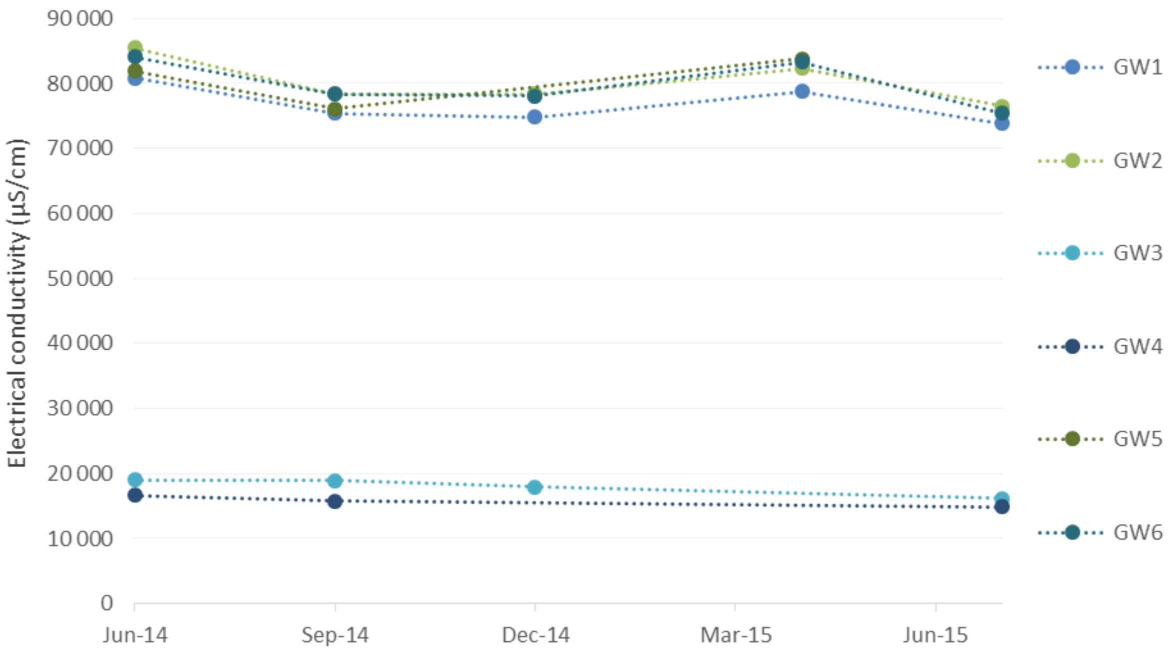


Figure 33. Bookmark Creek groundwater electrical conductivity (µS/cm), July 2014 – June 2015.

The highly saline nature of the groundwater recorded in GW1 and GW2, combined with the relatively shallow groundwater can result in salinisation of soil profile in the shallow horizon. This is likely to inhibit many flora species other than halophytic species, from establishing in this area and is likely contributing to the cause of the highly degraded nature of this area.

Tree health

There is a single tree health transect located along Bookmark Creek. The transect is comprised of 30 river red gum trees which are monitored annually using 'The Living Murray' tree health condition assessment methodology (Souter et al. 2010).

Tree health condition data analysis followed the methodology from Gehrig (2013) as discussed earlier in Part E (pg. 42) of this report.

The majority (n=19) of the trees in the transect were assessed to be in 'Poor' condition, with only one tree in 'Very poor' condition and ten trees in the 'Good' condition category (Figure 34). The condition of the trees has declined since the last tree health condition assessment was conducted and may be as a result of waterlogging around the root zone of the trees due to the creek not being able to be managed and as such tree roots remain waterlogged.

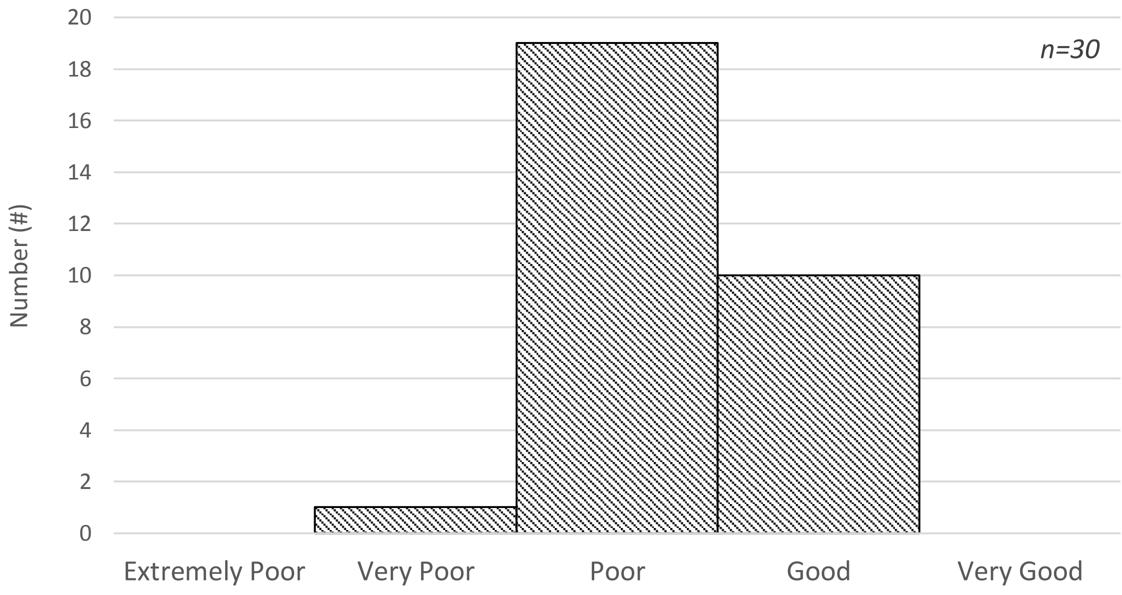


Figure 34. Tree health condition, Bookmark Creek BCKTH01, February 2015.

No epicormic growth was observed on any trees. Most (*n=20*) of the trees were observed with a little tip growth and the majority (*n=23*) of trees showed signs of reproduction such as buds and/or flowers. Three trees showed some signs of leaf die-back and one tree scored highly in the mistletoe category.

Waterbirds

No formal waterbird surveys have occurred within the monitoring period. A total of 32 waterbirds were observed incidentally at the site during other monitoring activities and by members of the community group. A range of species from a number of functional groups were observed (Table 13). The range of waterbirds from functional groups indicates the wide range of habitat that is available across the site including deep and shallow flowing water, still shallow water and wet mud.

Table 13. Waterbirds observed at Bookmark Creek and Wetland, July 2014 – June 2015.

Common name	Scientific name
Australasian darter [1]	*Anhinga novaehollandiae*
Australasian grebe	*Tachybaptus novaehollandiae*
Australasian shoveler [1]	*Anas rhynchotis*
Australian pelican	*Pelecanus conspicillatus*
Australian shelduck	*Tadorna tadornoides*
Australian white ibis	*Threskiornis molucca*
Australian wood duck	*Chenonetta jubata*
Black swan	*Cygnus atratus*
Black-fronted dotterel	*Elseyornis melanops*
Black-winged stilt	*Himantopus himantopus*
Caspian tern	*Hydroprogne caspia*
Dusky moorhen	*Gallinula tenebrosa*
Eurasian coot	*Fulica atra*
Great egret	*Ardea alba*
Grey teal	*Anas gracilis*
Hardhead	*Aythya australis*
Hoary-headed grebe	*Poliocephalus policephalus*
Intermediate egret [1]	*Ardea intermedia*
Little black cormorant	*Phalacrocorax sulcirostris*
Little egret [1]	*Egretta garzetta*
Little pied cormorant	*Microcarbo melanoleucos*
Masked lapwing	*Vanellus miles*
Pacific black duck	*Anas superciliosa*
Pied cormorant	*Phalacrocorax varius*
Pink-eared duck	*Malacorhynchus membranaceus*
Purple swamphen	*Porphyrio porphyria*
Red-kneed dotterel	*Erthrogonys cinctus*
Royal spoonbill	*Platalea regia*
Silver gull	*Chroicocephalus novaehollandiae*
Straw-necked ibis	*Threskiornis spinicollis*
White-faced heron	*Egretta novaehollandiae*
Yellow-billed spoonbill	*Platalea flavipes*

[1] species of conservation significance

Note: species list supplemented with observations made by community members D. Axon and C. Butler.

Fish

A fish survey was conducted at Bookmark Creek in October 2014. Two monitoring sites located in the temporary wetland were not surveyed as they were dry. One net was also stolen resulting in an irretrievable loss of data. Fish were sampled using methodology from Wedderburn and Suitor (2012).

In total, 12 species of fish were captured comprising of three non-native species and nine native species (Figure 35). In addition, two eastern long-neck turtles (*Chelodina longicollis*) were also captured. The most abundant species captured in the survey was carp gudgeon (*Hypseleotris* spp.) (n=308) followed by unspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*) (n=199), which are both native species. Low relative abundances of non-native fish species were captured: common carp (*Cyprinus carpio*) (n=4); eastern gambusia (*Gambusia holbrooki*) (n=3), and; goldfish (*Carassius auratus*) (n=6). One species of conservation significance, the freshwater catfish (*Tandanus tandanus*) which is protected in South Australia, was captured.

Fish were captured in a range of habitats including slow to fast flowing water, with physical habitat that was comprised of snags and a range of submerged aquatic vegetation. The majority of fish were captured downstream of the most downstream structure at Bookmark Creek, and may indicate that fish are attempting to move upstream through the system, however are being inhibited by barriers.

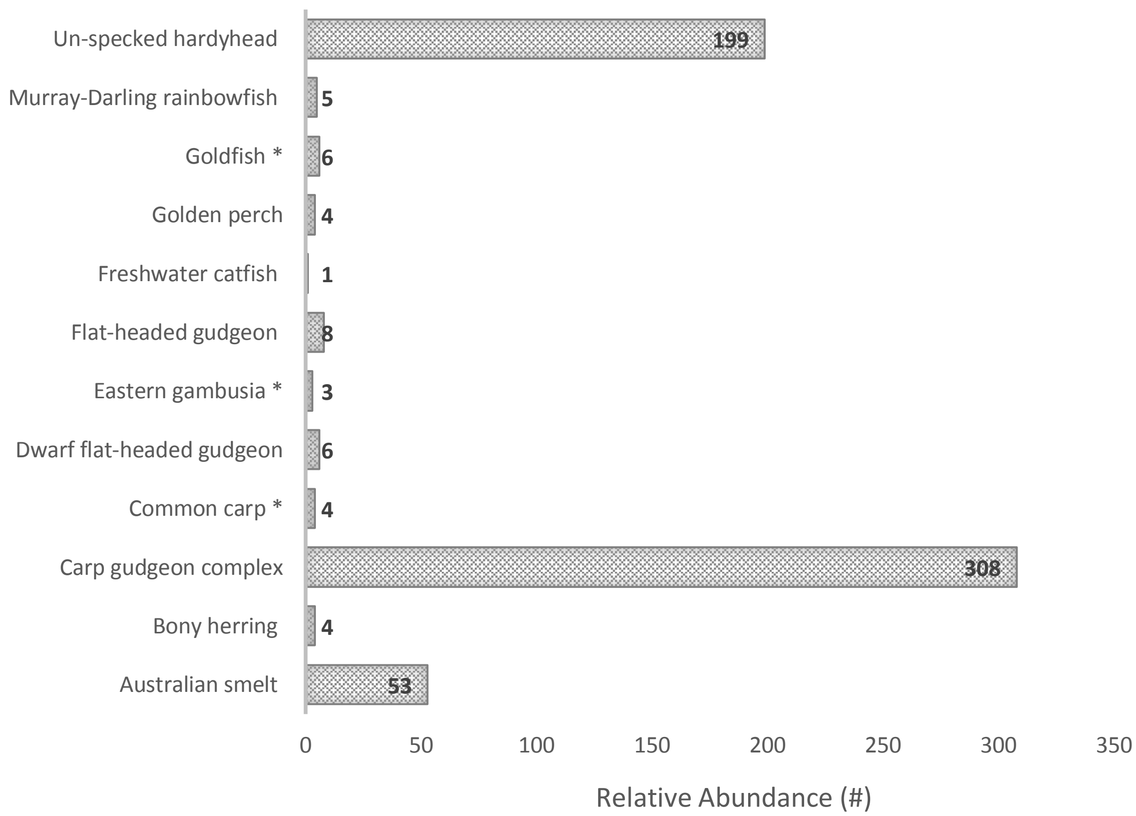


Figure 35. Species and abundances of fish captured at Bookmark Creek, October 2014.

Frogs

A total of four species of frog were recorded during two surveys carried out in October and December 2014 (Figure 36). Frogs were surveyed using the methodology from Wegener et al. (2014). They were: spotted grass frog (*Limnodynastes tasmaniensis*); eastern sign-bearing froglet (*Crinia parinsignifera*); long-thumbed frog (*Limnodynastes fletcheri*), and; Peron's tree frog (*Litoria peronii*). The eastern banjo frog (*Limnodynastes dumerilii*) was heard incidentally along Bookmark Creek.

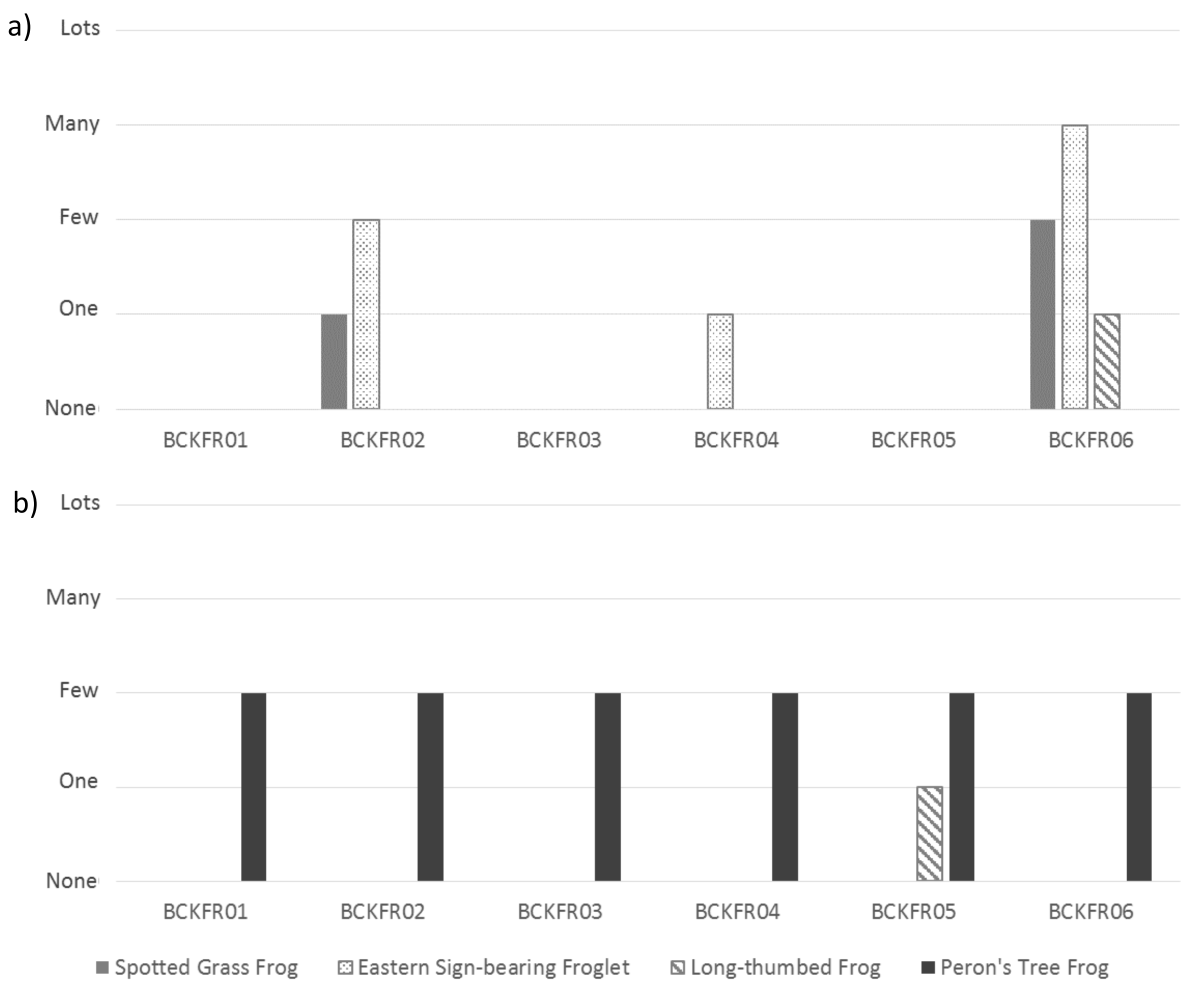


Figure 36. Frog species heard calling a) October 2014 and b) December 2014, at Bookmark Creek.

Photopoint Monitoring

Photopoint monitoring is undertaken half-yearly at eight sites along Bookmark Creek. An example of photopoint monitoring at the site is given below. Photopoint monitoring can assist in capturing visual changes in the physical nature of the creek over time, for example seasonal changes in vegetation as the below figure (Figure 37) shows.

Figure 37. Bookmark Creek photopoint BCKPP03 D/S a) September 2014 b) March 2015; Bookmark Creek photopoint BCKPP04 D/S c) September 2014 d) March 2015; BCKPP07 e) September 2014 f) March 2015.

Part L: Tolderol Game Reserve

Part L: Tolderol Game Reserve

Tolderol is a large wetland complex (~200 ha) located on the north-western shore of Lake Alexandrina (Rogers et al. 2008; Taylor 2009). The wetland complex is a component of the internationally important Ramsar listed Coorong and Lower Lakes region, and is comprised of a series of regulated artificial bays, channels and embayments (Rogers *et al*. 2008). Water is pumped into the bays, with water sourced from Lake Alexandrina via a channel (Rogers et al. 2008; Taylor 2009).

Prior to the millennium drought, Tolderol was one of the most ecologically diverse wetlands in the Coorong and Lower Lakes area, providing a variety habitats for an array of waterbird species, particularly migratory waders (SAMDB 2013). A total of 27 EPBC migratory bird species have been observed at Tolderol, along with a further 17 state listed species, including the critically endangered orange-bellied parrot (*Neophema chrysogaster*) and curlew sandpiper (*Calidris fuscicollis*) (Taylor 2009). Furthermore, the reserve has provided habitat for threatened fish species, such as the southern pygmy perch (*Nannoperca australis*) which is endangered in South Australia (Rogers et al. 2008; Taylor 2009), and the congolli (*Pseudaphritis urvillii*) which was listed as vulnerable in the 2009 Action Plan for South Australian Freshwater Fishes (Hammer et al. 2009). Whilst the nationally endangered Murray hardyhead has been captured nearby at Boggy Lake and Dog Lake (Rogers et al. 2008). In addition to this, the southern bell frog, nationally listed as vulnerable to extinction, was recorded at Tolderol in 2004 (Taylor 2009).

During drought the ability to deliver water to Tolderol became impeded by extremely low water levels in Lake Alexandrina. The annual water allocation for Tolderol was relinquished in 2008 due to drought, low flow conditions and over extraction from the River Murray. The prolonged dry period inevitably led to the ecological value of the wetland complex becoming significantly reduced (Taylor 2009). For over six years the Tolderol bays remained dry until water was delivered to three of the 16 bays on the 2 November 2014 (Figure 38), coordinated by Natural Resources SAMDB and the Goolwa-Wellington LAP with significant on-ground support from volunteers. The primary aim of the environmental watering trial was to provide foraging habitat for migratory wading birds during late spring to early autumn. It was also used to gauge the current condition of infrastructure to assess what resources are required to re-instate Tolderol's capacity as both a significant ecological and community asset. The ecological response to the environmental watering trial is detailed in the following section.

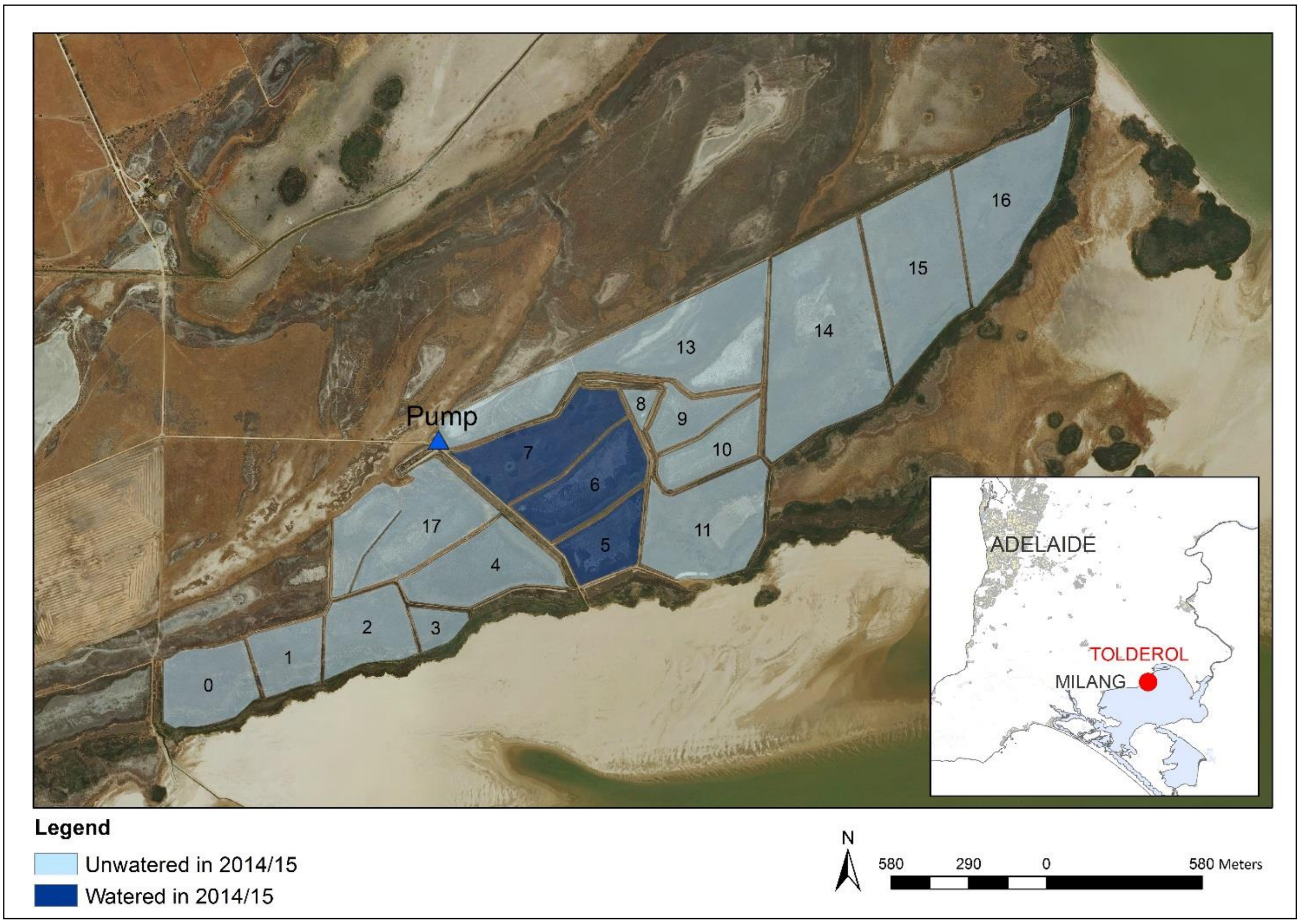


Figure 38. Map of Tolderol Wetlands displaying the basins that received environmental water in 2014/15.

Water level summary

Pumping commenced at Tolderol on 2 November 2014 with the aim to provide extensive areas of shallow water and mudflat for migratory waders to forage upon. Due to the design of the wetland complex, basins are often filled via another basin, requiring water levels to be taken higher than desirable in order to deliver water to the last basin in the sequence. This meant that the goal of providing shallow mudflats was not met until two months into the watering trial in January 2015. The three basins to receive water for the 2014-15 environmental watering trail were full by 28 November 2014. Mudflats first began to emerge on 11 December 2014, with small spits present following the water level falling in response to evaporation. Pumping continued on an as-needed basis throughout January, balancing between being able to deliver water to all basins while trying to maintain the exposed mudflats. Unfortunately, this ideal water level could not be maintained in late February and March as the low lake levels, as low as 0.472 m AHD (Figure 39) and extensive reed growth in the main supply channel made it difficult to maintain flow to the pump that feeds the basins. Ideally, low water levels and mudflats would have been managed with further pumping of water until the start of April, by which stage the vast majority of migratory waders would have started making their way to Asia.

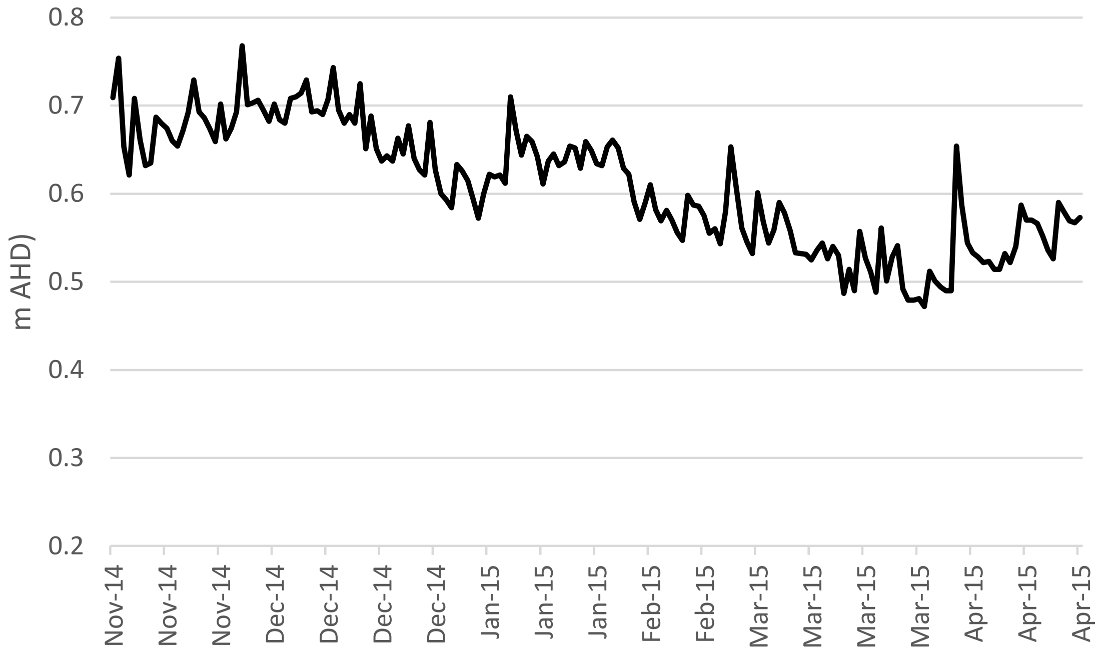


Figure 39. Lake Alexandrina water level data between November 2014 and April 2015 in metres Australian Height Datum (relative to sea level). Source: http://www.waterconnect.sa.gov.au/systems/swd/sitepages/home.aspx

Surface water quality monitoring

Surface water quality was monitored across 20 sites at Tolderol. This report focuses on the seven sites located within the bays which received environmental water between November 2014 and March 2015. The parameters of surface water quality measured were: electrical conductivity (EC), dissolved oxygen (DO), pH and turbidity. An explanation of surface water quality parameters is given in Part D (pg. 34).

Surface water salinity

Summary of surface water electrical conductivity results:

- The surface water salinity results were within the expected ranges during the duration of the watering trial (Figure 40).
- The EC of all the watered basins increased throughout the duration of the watering trial due to falling water levels from evaporation increasing the concentration of salts.
- Surface water EC was the highest in basin 5, as it has low connectivity and is therefore unable to export the salts which accumulate within this basin.

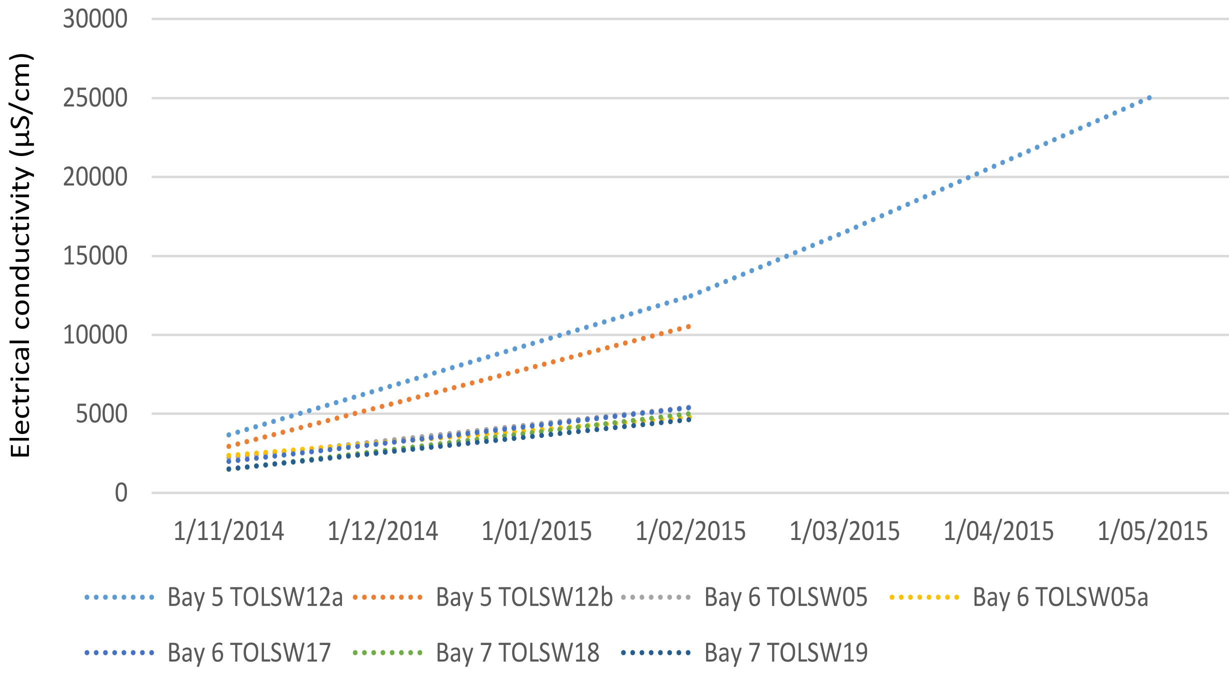


Figure 40. Surface water electrical conductivity (µS/cm) of sites within the Tolderol basins which received environmental water in 2014-15.

Surface water pH

Summary of pH results:

- Surface water pH results were within expected ranges given the prolonged period in which the basins have been dry and the amount of accumulated organic matter (Figure 41).
- Surface water pH was comparable between the fresh and salty channels as well as the watered basins.
- The highest pH recording of 9.26 occurred on 22 June 2012 at the Lake Alexandrina site (TOLSW08).
- High records of pH (>9) may have be the result of abundant algae, which reduce the acidity of water by removing carbon dioxide and also the time of day the water was sampled.
- The lowest pH recording of 6.52 occurred on 30 August 2013 in the south west corner of Bay 7 (TOLSW03).

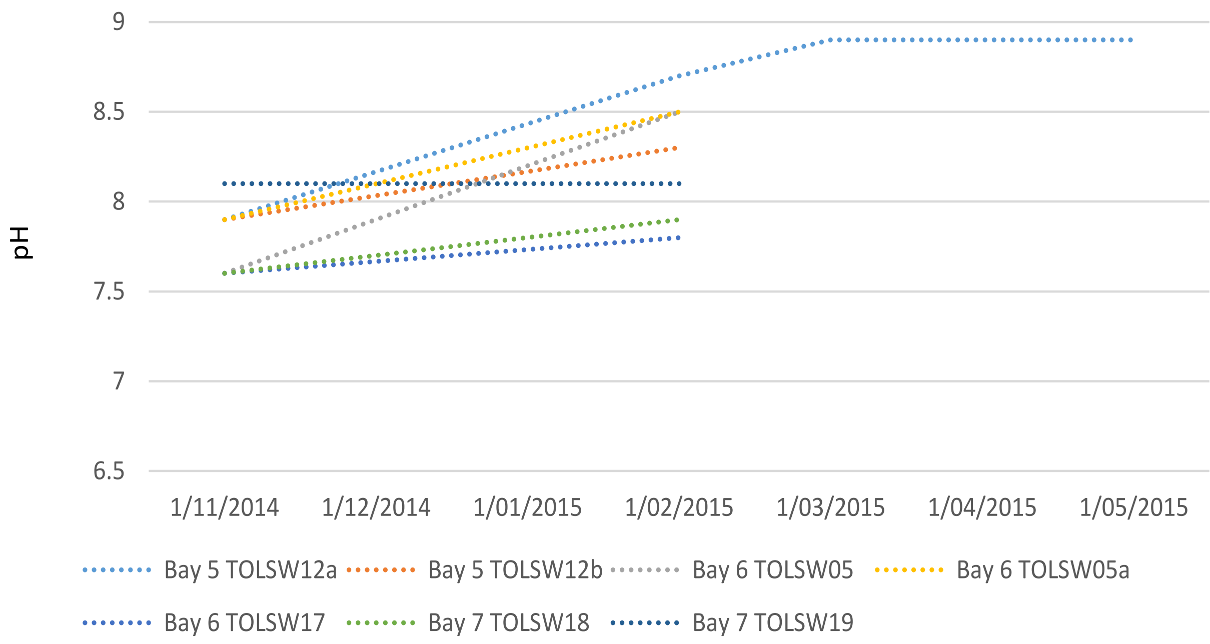


Figure 41. Surface water pH of sites within the Tolderol basins which received environmental water in 2014-15.

Surface water dissolved oxygen

Summary of water dissolved oxygen results:

- DO levels were highly variable both within and between sites at Tolderol (Figure 42).
- The DO levels were comparable for the fresh and salty channel sites as well as sites within the primary basins.
- Highest recorded DO value of 22.11 ppm was recorded in the open water of basin 5 (TOLSW12a) on 18 March 2015.
- Lowest recorded value of 0.63 ppm was recorded in the channel of the southwest corner of Bay 5 (TOLSW12) on 6 February 2015.
- While some of the low DO results are due to being surveyed in the morning when photosynthetic rates (and temperature) are low, others were surveyed in the afternoon, and the low DO results may be attributed to the shallow, hot and still water conditions often present within sites during summer. Decaying organic matter, such as that occurring in bay 5 following environmental watering, may also have led to low DO levels present at the channel in the southwest corner of bay 5 (TOLSW12) on 28 November 2014 and 6 February 2015.
- Surface water DO results were within expected ranges during the environmental watering trial, particularly taking into the account the long duration in which the

wetland was dry prior to watering and the accumulation of organic matter on the wetland bed.

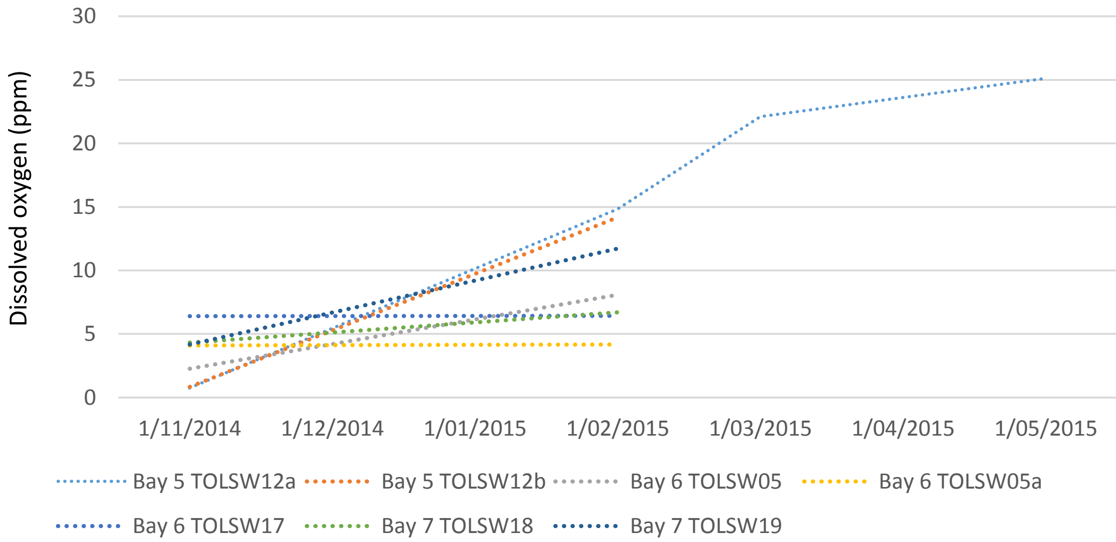


Figure 42. Surface water dissolved oxygen (ppm) of sites within the Tolderol basins which received environmental water in 2014-15.

Surface water turbidity

Summary of water turbidity results:

- The lowest turbidity reading was 0.2 NTU and occurred at a freshwater channel site (TOLSW02) on 10 July 2014 (Figure 42).
- The highest turbidity reading was 337 NTU and occurred at the shore of Lake Alexandrina (TOLSW08) on 22 May 2013.
- The cause of the six high recordings may be a result of the surveyor disrupting sediments, wind-seiching or abundance non-filamentous algae.
- Turbidity results were well within the expected ranges during the environmental watering trial.

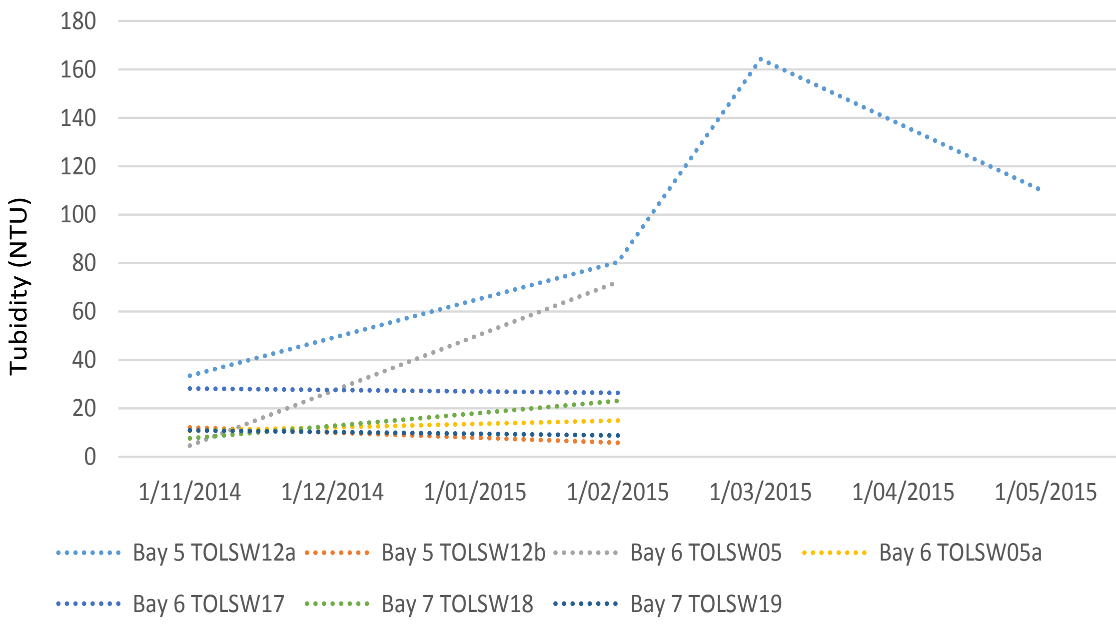


Figure 43. Surface water turbidity of sites within the Tolderol basins which received environmental water in 2014-15.

Implications for management – surface water quality and level

Water quality results during the environmental watering trial were generally expected and to date have not raised concerns for the delivery on environmental water in the next water year (201-/16). The prolonged dry period experienced at Tolderol during the last decade resulted in the salinisation of some areas, and the accumulation of organic matter in key watering areas, both of which have been likely influencing factors in surface water quality during the trial period.

More regular watering of selected basins, particularly those basins higher in elevation than average lake levels such as basins 6 and 7, may result in reduced salinity in these areas over time. However, it is not yet understood if reduced salinity would have a positive influence on food sources (zooplankton, macroinvertebrate communities) at Tolderol. This trial delivered water to three of the 14 basins (approximately eight of which have been watered in the past). The ability to be able to water alternate basins when the food sources in one is declining due to poor water quality would be of great advantage in providing quality foraging habitat for migratory birds over the summer and autumn period. As the primary objective of delivering environmental water at Tolderol is targeted at migratory waders (with opportunities for other fauna in the future), reduced water quality for short periods in some areas may not necessarily be considered of concern providing the severity and duration is moderated.

Future management recommendations are to:

- Cater for the delivery of water to alternate basins during the summer/autumn period to stimulate primary production in one area when other areas are declining.

- Continue to monitor surface water quality and at a high frequency during watering events.
- Install water level gauge boards in basins that are easily visible/accessible to increase data collection of water levels.

Waterbird monitoring

Waterbirds have been surveyed at Tolderol on eight occasions by Natural Resources SAMDB and GWLAP staff and volunteers since environmental watering commenced on 2 November 2014. Of the eight full surveys complete, six have been in the morning, starting before 9 am, and two have started in the early afternoon.

The survey method used to monitor waterbirds at Tolderol varied in response to the habitat characteristics and the abundance of birds at the site. For example, before excessive *Bolboschoenus caldwellii* growth in basin 7, the basin could be surveyed using multiple fixed point searches. However, a combination of fixed point searches and perimeter walks were used as *B. caldwellii* growth became increasingly dense, making the birds present more inconspicuous. The duration of each basin survey varied in response to the time required to count and identify all birds using the basin.

<u>Summary of waterbird monitoring results</u>

Since pumping started, 45 wetland dependent species were observed at Tolderol (Table 14). Seven of the species observed at Tolderol are listed as rare in South Australia: Australasian shoveler (*Anas rhynchotis*), elegent parrot (*Neophema elegans*), glossy ibis (*Plegadis falcinellus*), Latham's snipe (*Gallinago hardwickii*), long-toed stint (*Calidris subminuta*), pectoral sandpiper (*Calidris melanotos*) and wood sandpiper (*Tringa glareola*). In addition to this, the banded stilt (*Cladorhynchus leucocephalus*) and blue-winged parrot (*Neophema chrysostoma*) were observed, which are listed as vulnerable to extinction South Australia, and the curlew sandpiper which is nationally listed as critically endangered under the EPBC Act.

Table 14. The highest abundance of each waterbird and wetland dependent species observed on a single day at Tolderol Game Reserve basins 5 – 11 following environmental watering (November 2014 – March 2015).

Species	Date	Number	Species	Date	Number
Australasian grebe	30/12/2014	3	Long-toed stint	21/01/2015	8
Australasian shoveler	18/12/2014	50	Marsh sandpiper	22/01/2015	12
Australian pelican	18/12/2014	6	Masked lapwing	18/03/2015	35
Australian reed-warbler	11/12/2014	6	Pacific black duck	18/03/2015	8
Australian shelduck	28/12/2014	6	Pectoral sandpiper	19/12/2014	2
Australian spotted crake	28/12/2014	1	Pink-eared duck	18/12/2014	150

Australian white ibis	18/01/2015	60	Purple swamphen	18/12/2014	1
Banded stilt	Jan 2015	NA	Red-capped plover	28/12/2014	2
Black swan	18/01/2015	32	Red-kneed dotterel	28/12/2014	30
Black-winged stilt	30/12/2014	>200	Red-necked avocet	Jan 2015	NA
Buff-banded rail	12/01/2015	1	Red-necked stint	18/01/2015	144
Caspian tern	30/12/2014	12	Royal spoonbill	28/11/2014, 13/12/2014	1
Common greenshank	11/12/2014, 19/12/2014	4	Sharp-tailed sandpiper	18/01/2015	540
Curlew sandpiper	18/01/2015	203	Silver gull	11/12/2014	2
Glossy ibis	18/01/2015	72	Straw-necked ibis	12/11/2014	102
Golden-headed cisticola	28/11/2014, 02/11/2014, 18/01/2015	7	Swamp harrier	28/11/2014, 11/12/2014	4
Great cormorant	30/12/2014	10	Whiskered tern	11/12/2014	2841
Great crested grebe	29/11/2014	2	Whistling kite	28/11/2014	3
Grey teal	18/12/2014	450	White-faced heron	18/03/2014	42
Hoary-headed grebe	11/12/2014	27	White-winged black tern	16/01/2015	3
Latham's snipe	29/11/2014	1	Wood sandpiper	30/12/2014	5
Little grassbird	18/01/2015	4	Yellow-billed spoonbill	18/03/2015	6
Little pied cormorant	26/01/2015	5			

Note: little black cormorant (*Phalacrocorax sulcirostris*), pied cormorant (*Phalacrocorax varius*) have been recorded flying over Tolderol Game Reserve Basin 5 – 11.

Glossy Ibis

The glossy ibis was first recorded at Tolderol after the commencement of the environmental watering trial from 13 December 2014 to 6 February 2015, with the largest flock of 72 individuals recorded on 18 January 2015.

Migratory Waders

A total of nine EPBC migratory wader species were observed during the environmental watering trial: common greenshank (*Tringa nebularia*), curlew sandpiper, Latham's snipe, long-toed stint, marsh sandpiper (*Tringa stagnatilis*), pectoral sandpiper, red-necked stint (*Calidris ruficollis*), sharp-tailed sandpiper (*Calidris acuminata*) and wood sandpiper. Of these nine EPBC migratory waders, four are listed as rare in South Australia.

The most common species was the sharp-tailed sandpiper which was seen on 24 January 2015 in numbers approaching 4000 (P Koch pers comm), which is greater than 1 per cent of their total East-Asian Australian Flyway population of 160 000 (Bamford et al. 2008), making Tolderol a site of international importance for the species.

The critically endangered curlew sandpiper was observed on 18 January 2015, with 203 individuals foraging within the environmentally watered basins. This species has suffered over a 50% decline in the populations visiting southern Australia since the 1980s, which led to its listing as critically endangered in 2015 (Department of Environment 2015). Declining numbers of curlew sandpipers have been observed in the Coorong Lower Lakes and Murray Mouth region, with numbers decreasing during the millennium drought, but unlike most other regional waterbirds have not recovered since the return of flows (O'Connor and Rogers 2013).

Waterbirds from five functional groups were recorded at Tolderol Wetland over the monitoring period (Figure 44). Piscivores were often the most abundant functional group represented and this may indicate the presence of abundant food resources at the site for these species. The diversity of functional groups present throughout the monitoring period indicates the range of habitats and food resources present at the site throughout the monitoring period.

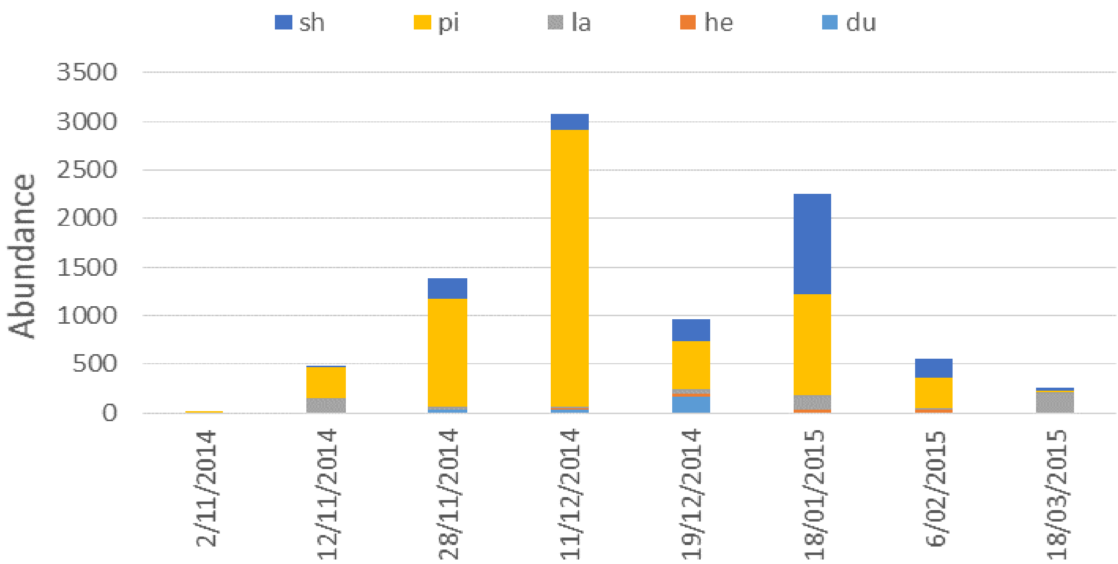


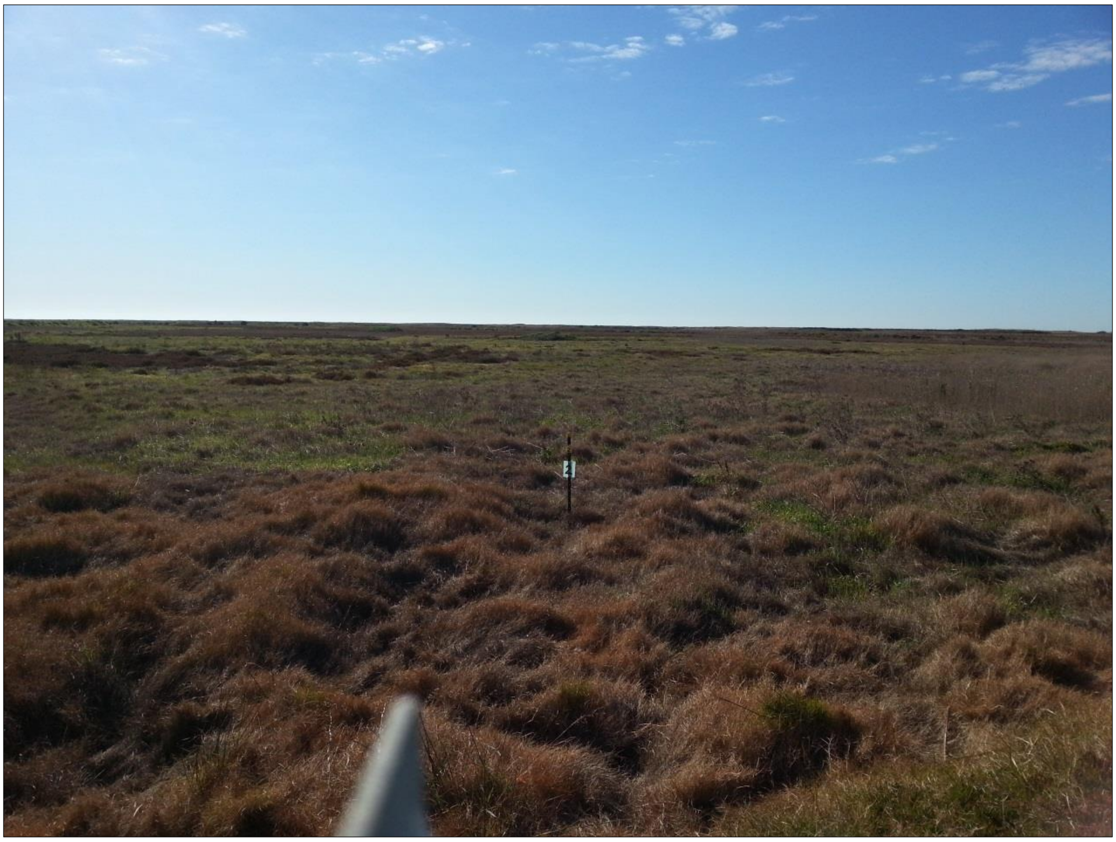
Figure 44. Waterbird assemblages at Tolderol Wetland with abundance catergorised into functional groups, November 2014 – March 2015. Note: sh – shorebirds; pi – piscivores; la – large waders; he – herbivores; du – ducks.

Photopoints

Photo point monitoring has been undertaken at three fixed points at Tolderol since November 2014 to record changes in vegetation, water levels, area of inundation and general habitat value for water-dependent species.

The changes to the watered basins at Tolderol following the pumping of environmental water have been significant. Basin 7, which was ploughed prior to pumping, underwent the greatest change with vast coverage of *Bolboschoenus caldwelli* now present. The growth of *B. caldwelli* is now at a density where it has reduced the available habitat for shorebirds, particularly migratory waders. Ploughing will once again take place in basin 7 prior to the 2015-16 watering season to try and control *B. caldwelli*, and re-instate areas of suitable exposed mudflat for foraging migratory waders. The changes in basins 6 and 5 were less pronounced, showing only a slight change in the coverage of *Phragmities australis* and *Paspalum sp.*, however the health of these plant species noticeably improved. Although not obvious from photo point 3, the terrestrial saltmarsh vegetation which was left un-ploughed in basin 5 has begun to decompose.

BASIN 7



22 August 2014

29 January 2015

BASIN 6

22 August 2014

29 January 2015

BASIN 5

2 November 2014

28 November 2014

Part M: Sugar Shack Temporary Wetland

Part M: Sugar Shack Temporary Wetland

The Sugar Shack Temporary Wetland (Wetland 6) is a small (7 ha), shallow wetland located within the Sugar Shack Pangki Wetland Complex, 5 km north of Swan Reach. The wetland receives water via rainfall and a flow path which connects to the River Murray. Prior to river regulation the wetland would have received water in 80 – 90 % of years according to the Robinson Model, however under a regulated flow regime the wetland only receives water during high flow events. Terrestrial vegetation has colonised the bed of the wetland, with the shrub layer dominated by lignum (*Duma florulenta*).

The Sugar Shack Pangki wetland complex, also called the Swan Reach wetland complex, was listed as a Key Environmental Asset in the Guide to the Basin Plan (Murray-Darling Basin Authority 2010). The area has an array of culturally significant and threatened species, including the southern bell frog (*Litoria raniformis*) and the regent parrot (*Polytelis anthopeplus monarchoides*) which are both listed as vulnerable to extinction under the *EPBC Act*.

The aims of environmental watering at Wetland 6 in 2014/15 were to:

- Increase the area of southern bell frog breeding habitat through the inundation of suitable habitat for a minimum of 3 months.
- Increase the area of suitable foraging habitat for state and EPBC listed cryptic water bird species through the inundation of vegetated areas.

The environmental watering ran from November 2014 to January 2015, with 41.9 ML pumped during this time, allocated from the State Environment Reserve. The parameters monitored to assess the ecological response to pumping were surface water quality and waterbird surveys.

Results

Surface water quality

Surface water quality parameters have previously been described in Part D (pg. 34).

The water quality of Sugar Shack Temporary Wetland was influenced by the River Murray source water as well as the floodplain vegetation and topology. Surface water electrical conductivity levels varied from 441 to 1064 µS/cm with the EC of the surface water increasing throughout the environmental watering as salts became concentrated with falling water levels (Table 15).

All pH results were in the range of 6 and 9 considered to be optimal for aquatic fauna survival, varying between 6.7 and 7.6 within the wetland. The pH results were more neutral than expected, as decaying terrestrial vegetation increases the alkalinity of water through the release of CO_2.

The surface water turbidity was variable, ranging from 16.1 to 344 NTU. Low turbidity measures were at the early stages of pumping at the inlet channel to the wetland, where water was deeper (~40 cm). High turbidity measures were taken at the fringe of the middle of the wetland, where water levels were shallower (<15 cm). A combination of wind-seiching and bioturbation, partially through the movements of cattle, were the causes of turbidity readings reaching 344 NTU.

Dissolved oxygen concentrations were often below levels considered optimal for aquatic biota. This would have been attributed to the consumption of oxygen by microbes during the decomposition of the terrestrial vegetation on the wetland bed.

Table 15. Surface water conductivity, pH, dissolved oxygen and turbidity at Sugar Shack Wetland 6, November – December 2014.

Date	Site	Electrical conductivity (µS/cm)	pH	Dissolved Oxygen (ppm)	Turbidity (NTU)
19 November 2014	SUG6WQ01	441	7.5	2.39	36.4
24 November 2014	SUG6WQ01	512	6.7	6.05	16.1
2 December 2015	SUG6WQ01	689	7.6	2.56	319
	SUG6WQ02	673	7.6	3.16	242
15 December 2015	SUG6WQ01	1043	7.6	10.75	248
	SUG6WQ02	1064	7.3	9.61	344

Waterbirds

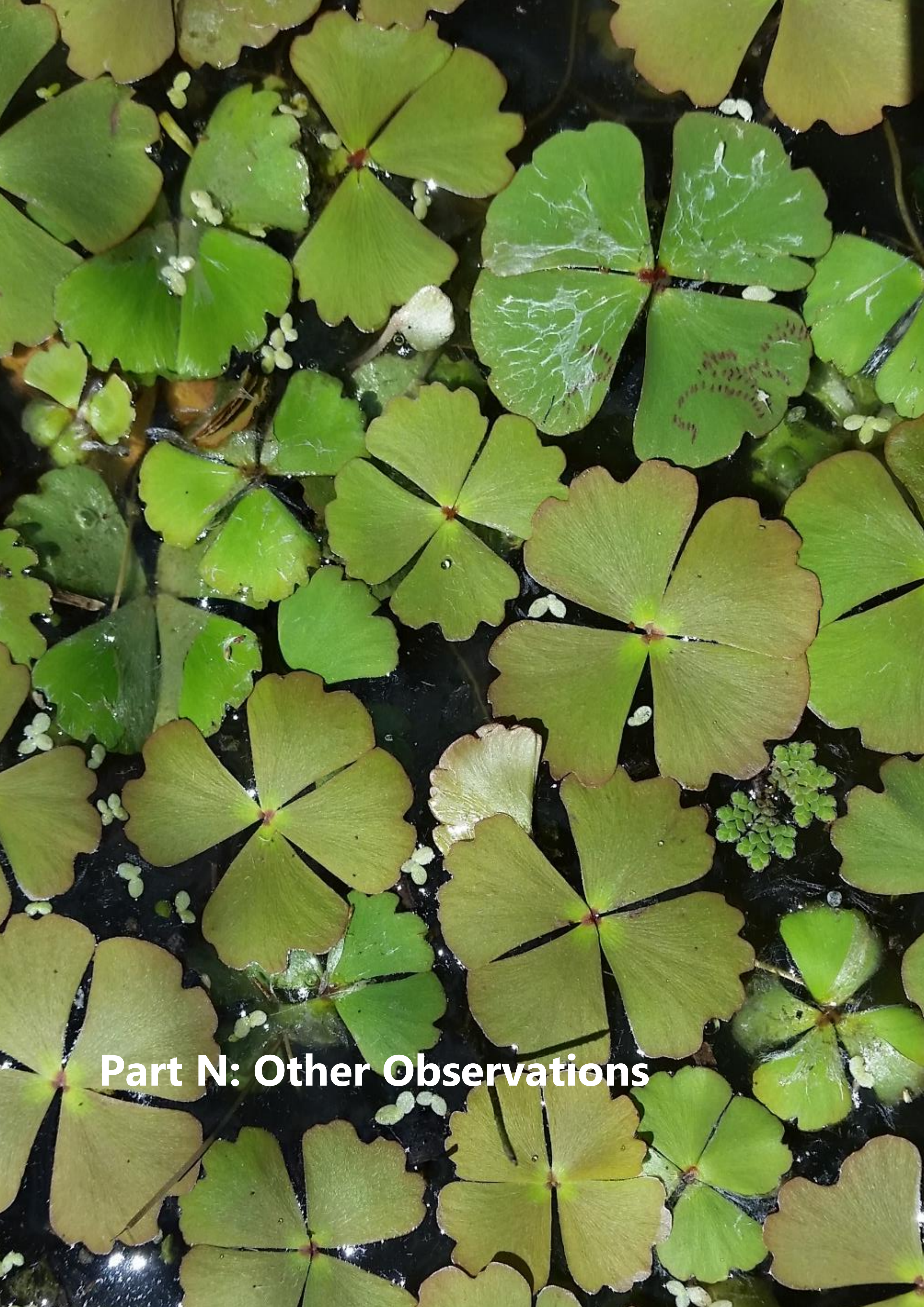
A TOTAL OF FOUR BIRD SURVEYS WERE PERFORMED AT SUGAR SHACK WETLAND 6 DURING THE ENVIRONMENTAL WATERING PERIOD, WHICH INVOLVED WALKING A COMPLETE LAP AROUND THE CONDUCT EACH SURVEY. OVERALL A TOTAL OF 14 WETLAND DEPENDENT BIRD SPECIES WERE OBSERVED (TABLE 16

Table 16), which included species that are state listed as rare such as the white-necked heron (*Ardea pacifica*) and peregrine falcon (*Falco peregrinus*). The black-tailed native hen (*Tribonyx ventralis*) and the red-kneed dotterel (*Erythrogonys cinctus*) were observed using the wetland as foraging habitat just weeks following the commencement of pumping. These species share similar habitat preferences, including shallow temporary wetlands with exposed margins (Rogers 2011). Black-tailed native hens also utilise lignum habitat which was present in the wetland, which they use for cover from predators and as a nesting platform (Rogers and Ralph 2010). The environmental watering stimulated the growth and reproduction of lignum (Figure 45). The improved health of the lignum in turn provided habitat for the Australian reed-warbler (*Acrocephalus australis*) and little grassbird (*Megalurus gramineus*), both of which were recorded at higher abundances following lignum growth and whilst water remained.

Figure 45. Lush lignum growth at Sugar Shack Wetland 6 following environmental watering, December 2014.

Table 16. The waterbirds observed at Sugar Shack Wetland 6 following the environmental watering of the site in November 2014

	10November 2014	24 November 2014	2 December 2014	15 December 2015
Australian pelican				2
Australian reed-warbler			5	2
Black-fronted dotterel		3	7	2
Black-tailed native hen	40	30	37	45
Grey teal			5	38
Little grassbird		5	21	1
Masked lapwing			1	2
Peregrine falcon				2
Red-kneed dotterel	3	5	19	32
Royal spoonbill			1	6
Whistling kite		2	1	1
White-faced heron			3	5
White-necked heron			1	1
Yellow-billed spoonbill			16	16
Total abundance	**43**	**45**	**117**	**155**



Part N: Other Observations

Part N: Other Observations

In addition to the formal monitoring program, Wetland and Floodplain Program staff also recorded incidental observations during the course of monitoring across the e-watered sites. This section briefly summarises these incidental observations and includes:

- fish captured during tadpole surveys
- aquatic macroinvertebrates captured during tadpole surveys
- mammals observed at sites
- snakes.

Fish

During tadpole surveys conducted as part of the e-watering monitoring program, fish were captured as by-catch. It is most likely that fish entered the wetland through the pumps temporarily installed at sites to pump water from the River Murray into the watered wetlands. The size, capacity and location of the pump intake as well as the size of mesh screens used could have important implications for the species and various life-history stages of species that find themselves vulnerable to abstraction (Baumgartner et al. 2009).

In total, across the monitored sites, 11 species of fish were captured (Table 17). Carp gudgeon, a small-bodied native fish species, were the most abundant species captured across sites in each survey round. Three species captured (common carp, eastern gambusia (*Gambusia holbrooki*) and goldfish (*Carassius auratus*)) are considered non-native species. The remaining eight species are considered native species. Two fish species of conservation significance were captured. These were the freshwater catfish (*Tandanus tandanus*) protected in South Australia and Murray cod (*Maccullochella peelii peelii*) vulnerable under the *EPBC Act*.

Table 17. Sum of fish captured across all e-watered monitored sites, 2014-15.

	Carp gudgeon	Flathead gudgeon	Dwarf-flathead gudgeon	Unspecked hardyhead	Common carp *	Australian smelt	Freshwater catfish	Eastern gambusia	Bony herring	Goldfish	Murray cod
Dec-14	91	15	0	10	58	5	2	0	0	0	0
Jan-15	745	27	5	2	15	2	1	0	75	1	0
Feb-15	3060	73	4	0	13	88	1	0	283	1	1
Mar-15	3436	71	0	3	0	285	1	1	76	0	0
Apr-15	2904	71	21	0	0	20	0	23	16	1	0

Aquatic macroinvertebrates

A diverse assemblage of macroinvertebrate species was also captured across watered sites (Table 18). Although not specifically targeted through the monitoring programs, it is noteworthy that a diverse range of macroinvertebrates was captured and contributed to the overall productivity of sites.

Table 18. Macroinvertebrates presence collectively across all monitored watered sites for each survey round.

	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15
Backswimmer	P	P	P	P	P
Caddifly larvae		P	P		
Damselfly		P	P		
Damselfly nymph		P	P	P	
Dragonfly		P	P		
Dragonfly nymph		P	P	P	P
Giant water bug	P	P			
Leech		P	P		
Mussel larvae	P				
Needlebug	P	P	P	P	
Non-biting midge larvae	P	P	P		
Other diving beetle	P	P	P	P	P
Prawn	P	P	P	P	P
Predatory diving beetle	P	P	P	P	P
Predatory diving beetle larvae	P	P	P	P	P
Seed shrimp	P		P		
Shield shrimp	P				
Shrimp	P	P	P	P	P
Snail	P	P	P	P	P
Water boatmen	P	P	P	P	P
Water cricket		P			
Water scavenger beetle	P	P	P	P	P
Water scorpion	P	P	P	P	P
Water spider	P				
Waterflea	P		P		
Yabby	P	P	P	P	P
Zooplankton	P				

(*P = presence*)

Mammals

Two species of kangaroo, the eastern grey (*Macropus gigantus*) and red kangaroo (*Macropus rufus*) were sighted at wetlands receiving environmental water. Activities observed being undertaken at sites included: feeding; watering and; resting. Echidnas were also observed at several watering sites, although it is unclear if the species utilised resources associated with the delivery of environmental water at these sites.

Snakes

Two snake species were incidentally observed at several wetland sites. These were the eastern tiger snake (*Notechis scutatus*) and the eastern brown snake (*Pseudonaja textilis*) and may have been capitalising on the abundance of frogs as prey at watered sites.

Part O: Communications and Community Engagement

Part O: Communications and Community Engagement

Communicating the importance of wetlands, their ecological values, threatened species and the River Murray system is important for building community knowledge of aquatic ecosystems, natural resources and contributes towards greater participation in natural resources management within the SAMDB region. The Natural Resources SAMDB Wetland and Floodplain Program staff have facilitated this within the environmental watering program by providing technical assistance at community monitoring days at wetland sites, producing reports and fact sheets that are distributed across the community, and state and federal government agencies, meeting with landholders to discuss environmental watering (including providing regular updates via letter, phone call or email) and through media releases that are published in local and state media (newspapers). In addition, social media (both Facebook, Twitter and Instagram) has been utilised this year to report upon some of the outcomes of environmental watering to the broader online community.

In addition, Wetland and Floodplain Program staff regularly engaged with other departmental staff and branches including: Policy, River Murray Operations, Major Projects, regional Media and Communications and Community Engagement (including Aboriginal Engagement), District Team, Sustainable Irrigation Team, Administration and Finance. In addition, cross-agency collaboration is also undertaken with staff from research organisations such as SARDI and CSIRO. Staff from the program liaise with federal government staff (from the Commonwealth Environmental Water Office) and other non-government organisations such Local Action Planning Associations and community wetland groups.

Pivotal to the success of the environmental watering program is community support particularly from private landholders and community groups where many wetlands are situated. Wetland and Floodplain Program staff engage with and encourage participation of landholders and community groups in planning and decision making processes. Improved understanding by community members is paramount to the conservation of wetlands and floodplains in South Australia. This water year, the Wetland and Floodplain Program have also conducted site visits and wetland tours both within DEWNR and externally.

A primary focus of the environmental watering program this year, has been to engage the First Peoples of the River Murray and Mallee in the watering program. Along the length of the River Murray in South Australia, the First Peoples have a strong spiritual and cultural connection to wetlands and floodplains. These communities value healthy and functioning river and floodplain ecosystems which provide many important resources. The value of environmental watering goes beyond simply consumptive use, it is a complex spiritual and cultural relationship (DEWNR 2014). Working together to deliver environmental water at the right time and place to optimise environmental watering outcomes is important, and harnessing the local knowledge about land and water is an important aspect of delivering environmental water at specific sites. First Peoples communities and groups have been engaged within the environmental watering program, and at some sites take active ownership of the delivery of environmental water (e.g. Gerard Floodplain). This forms a good basis for future partnerships to be able to successfully deliver further environmental projects at these sites.

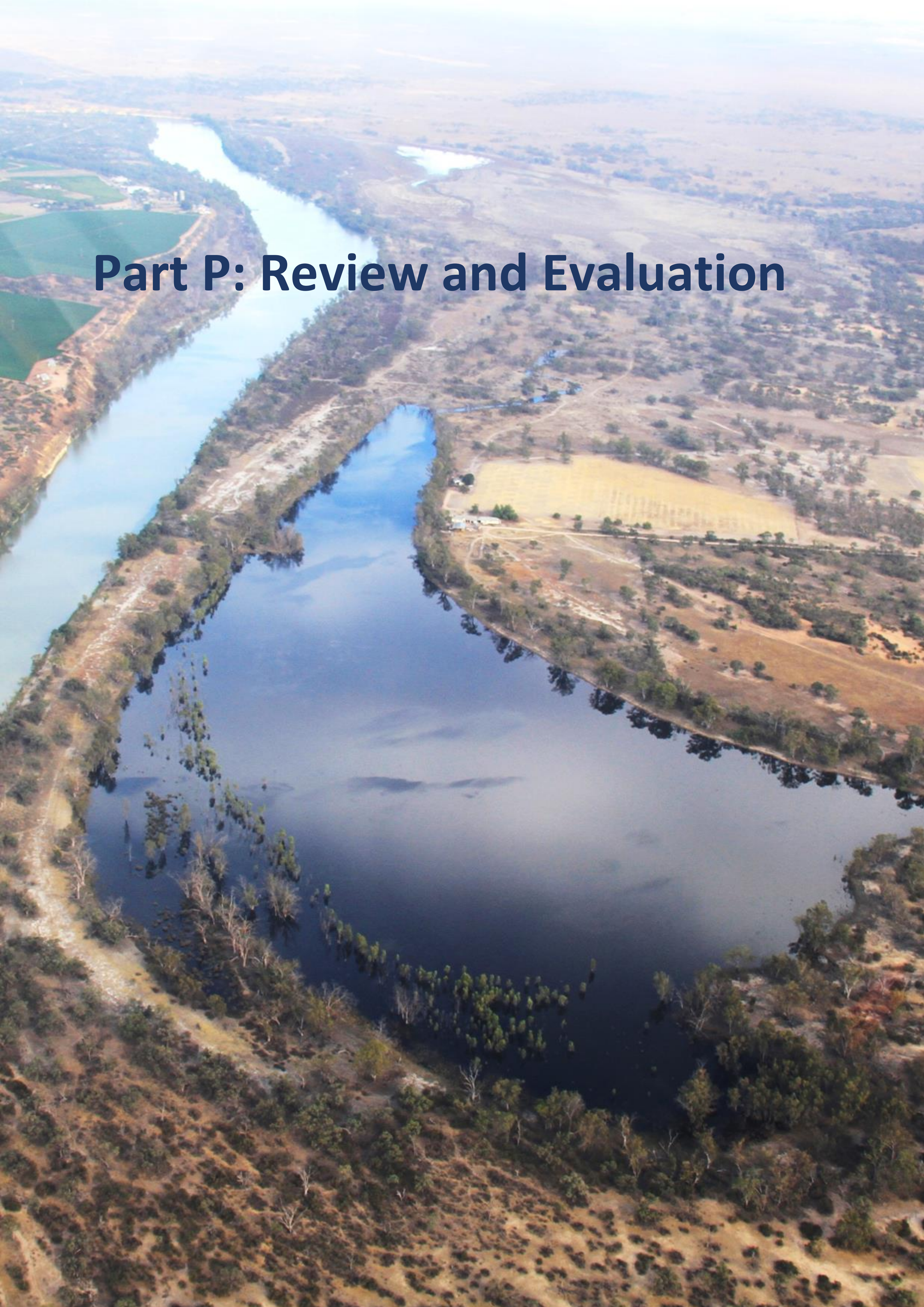
Local community engagement at e-watering sites has resulted in both positive ecological and social outcomes being achieved. Substantial positive feedback from community members (both verbal and written) has been received by staff regarding the environmental watering program. A summary of the communication activities undertaken by the Wetland and Floodplain Program are included in the table below (Table 19).

Table 19. Communications and community engagement activities for the environmental water program 2014-15.

Activity	Description
Direct communication	Communication was in-person and generally involved a site visit with the landholder/stakeholder group, or larger meeting with stakeholders (e.g. Bookmark Creek, where up-to 20 individuals comprised of LAP, local and state government, industry, and community members have been engaged throughout the year).
Telephone calls	Telephone conversations with stakeholders.
Emails	Emails sent to stakeholders.
Letters	Letters sent to stakeholders advising and updating on progress of environmental watering activities for each site.
Media releases	Media release regarding environmental watering planning, activities and progress, and community engagement.
Radio Interviews	Radio interviews conducted with local media outlets regarding environmental watering and community engagement.
Community monitoring summaries	Community monitoring summaries summarise the data collected through monitoring days/events at watered sites.
Newsletters articles	Local Action Planning Association newsletters included updates on environmental watering in respective LAP regions.
Reports	Several have been or are in the process of being developed as a result of environmental water delivery.
Peer reviewed journal papers (in prep.)	Data collected within the monitoring program implemented as part of the environmental watering program is currently being analysed for use in peer review literature/papers.
Community monitoring days/ workshops	Community monitoring days are undertaken at sites where a wetland community group exists (e.g. Whirlpool Corner Wetland Group). Members are involved in collecting a range of data which is used to produce monitoring summaries that guide wetland management.
Tours	Several tours have been undertaken within the environmental watering program. These tours have involved local wetland community groups, Aboriginal groups (First Peoples), local, state and federal government employees, SAMDBNRM Board members, and other stakeholders.
Other Activities	Riverland Field Days (2 days), River Murray Roadshow (3 days).

Engaging local communities and the wider community as a broader entity at environmental watering sites and in environmental watering in general is important in order for the Natural Resources SA Murray-Darling Basin environmental watering program to be successful. Direct communication through meeting in-person on site with landholders and stakeholders, while time consuming, resulted in the best outcomes, enabling wetland staff to consult and develop watering projects and monitoring programmes that involved individuals in the broader environmental watering program. Within the environmental watering program, at least 190 people have been engaged through direct communication.

Part P: Review and Evaluation



Part P: Review and Evaluation

A review and evaluation of the environmental watering program is important to ensure the best use of resources (i.e. funding, water, staff) is achieved, for effective and efficient future environmental watering projects. In addition, the adaptive management feedback loop is important to ensure that opportunities for improvement are noted and can be implemented in the future in order to achieve effective watering outcomes.

Future considerations

Implementing targeted monitoring projects at the majority of the e-water sites resulted in the collection of comprehensive data sets which were able to be used to critically assess the ecological outcomes of watering activities. This has enabled a review and evaluation of current watering and management practises, and may assist with guiding future monitoring and projects. Some aspects of the recent monitoring program required considerable staff resources, such as the frog and tadpole monitoring component. Nevertheless, this monitoring was a valuable opportunity to investigate some of the knowledge gaps, and the information gained from these intensive projects has provided a good knowledge basis for further work as well as contributing to a greater understanding of the ecology of specific flora and fauna in the SAMDB as it relates to the delivery of environmental water.

Trophic dynamics/productivity

Temporary wetlands receiving environmental water are productive hot-spots across the landscape. Primary productivity is higher in these wetlands than in the main river channel (under certain conditions) and higher productivity supports a more abundant zooplankton community that is important food for fish, and has important food web implications.

Potential investigations could be undertaken to assess the feasibility of releasing environmental water from selected sites back to the main river channel that may provide benefits in-channel, just downstream from e-water sites. Investigations should consider (but are not limited to) the following risks: increased surface water EC; black-water events; risks of false cues for wetland fauna breeding e.g. frogs breeding which over multiple events could result in localised extinction of species; ecological benefit versus (dollar) cost and ecological risks of actions; community perceptions; and, policy restrictions. The few sites that have the potential to release water would require a thorough risk assessment prior to any action of water release back to the river.

Regent parrots

Potential future collaboration could be undertaken with the Regent Parrot Recovery Team to investigate the relationships between tree condition, watering frequency, and habitat selection by the nationally threatened regent parrot.

Remote sensing

Remote sensing could be a potential method to examine the extent of impact from environmental watering. Often the full extent of water infiltration cannot be easily determined through on-ground monitoring. Remote sensing could be utilised to better understand the infiltration of water through the soil profile and the geographical extent to which vegetation is effected by watering.

Frogs

Potential further analysis of data collected during the 2014-15 project could include assessing different components of the frog survey methodology (e.g. aural survey, active search and tadpole surveys) as well as the timing of surveys to determine optimal survey methods to assist with the design and planning of future monitoring projects. Furthermore, analysis could be carried out investigating potential habitat associations of frog species as numerous environmental covariates were collected during surveys including vegetation, water quality, and presence of fish and macro-invertebrates. This information may contribute to a better understanding of frog requirements and with optimising site selection to support important frog habitat and breeding opportunities. Further investigation into the specific requirements of southern bell frog could be carried out, although there is limited data due to the low number of occurrences during this study. In future, more detailed studies could be conducted at sites where southern bell frog is now known to occur to get a better understanding of the species ecology and behaviour.

Vegetation and tree health

Consideration should be afforded to the benefits of undertaking tree health and vegetation surveys across watered sites (and control sites) to better understand the response of vegetation to watering activities. Tree health and vegetation is a key objective for delivery of environmental water. Consideration should be given to establishing longer-term control tree health transects to compare to both temporary and permanent managed wetland and floodplain sites.

In addition, at sites where dripper trials are being undertaken, particularly Gerard floodplain, several improvements and changes to the trial could be considered. This includes: changing the tap system to soaker hose system; moving the soaker hose to the canopy dripline, and; increasing the volume of water being delivered to sites.

Camera trapping

Incidental observations of terrestrial fauna can assist in establishing a picture of how environmental water can benefit many other species, not simply wetland or flood dependent species. Cameras are currently used for time-lapse photopoints. Further investigation into the contribution to existing knowledge a discrete project designed to determine use of watered wetlands by terrestrical or cryptic fauna could be investigated. The project could potentially be undertaken as an honours or master's thesis project.

Aboriginal/Cultural Values

A project investigating the cultural values that are derived from watering of specific wetlands could serve to better link together and understand the values associated with the provision of environmental water for cultural heritage values in South Australia.

Waterbirds

It is clear from the results of this watering year (2014-15) that waterbird assemblages are diverse and respond differently to environmental water delivery at selected monitored sites. As only four sites were surveyed regularly and due to the different physical nature of each watered site, this data can only provide a snapshot of the response of waterbirds to watering events at these sites under these conditions. Future monitoring would be beneficial for gaining a greater understanding of waterbird use of these sites during watering events particularly in regards to habitat use and associations, food resources and other drivers behind species presence and community composition. Consideration should be given to increasing the number of sites where waterbird surveys are undertaken in order to build a better understanding of the importance of these sites for waterbirds.

Weir pool raising and natural flows

Weir pool raising and natural flow pulses stimulate important cues in wetland biota. Possible considerations could be given to investigating how weir pool manipulation and pumping of wetlands affect biological triggers, for example, the cue for movement of southern bell frogs into temporary wetland areas. Investigations into complementing weir pool actions by prolonging inundation in some wetlands through pumping following weir pool raising could also be considered at selected sites.

Part Q: Conclusion

Part Q: Conclusion

In summary, this report clearly demonstrates that the watering program undertaken in 2014-15 resulted in numerous highly beneficial ecological outcomes being achieved across the SAMDB region. It also provides further evidence that environmental water is important for maintaining wetland and floodplain ecosystems and processes in the absence of flood events within the SAMDB region. The value of flood events for maintaining and/or improving the condition of wetland and floodplains of the SA Murray-Darling Basin is indisputable (see Ye et al. 2014). It is evident that the combination of river regulation, over extraction and allocation, coupled with below average rainfall and future predicted climate change, will place even further stress upon a system that is already likely irrecoverably altered. The value of environmental water for maintaining the habitat of species of conservation significance and important ecosystem processes and services must therefore not be underestimated.

Communications activities undertaken in conjunction with environmental water activities has continued to improve the communities understanding of the importance of environmental watering. It has allowed community members to advocate for the use of environmental water at sites, wetland management, and water allocations for the environment within their regional communities (e.g. Bookmark Creek). This forms an important foundation for future watering activities particularly so during future drought years.

The evaluation of the 2014-15 environmental watering and monitoring program has highlighted several potential areas where future monitoring efforts could be directed, as well as questions that could be investigated to further build upon the knowledge of how environmental water contributes to the maintenance and improvement of River Murray wetland and floodplain ecosystems.

Part R: References

Part R: References

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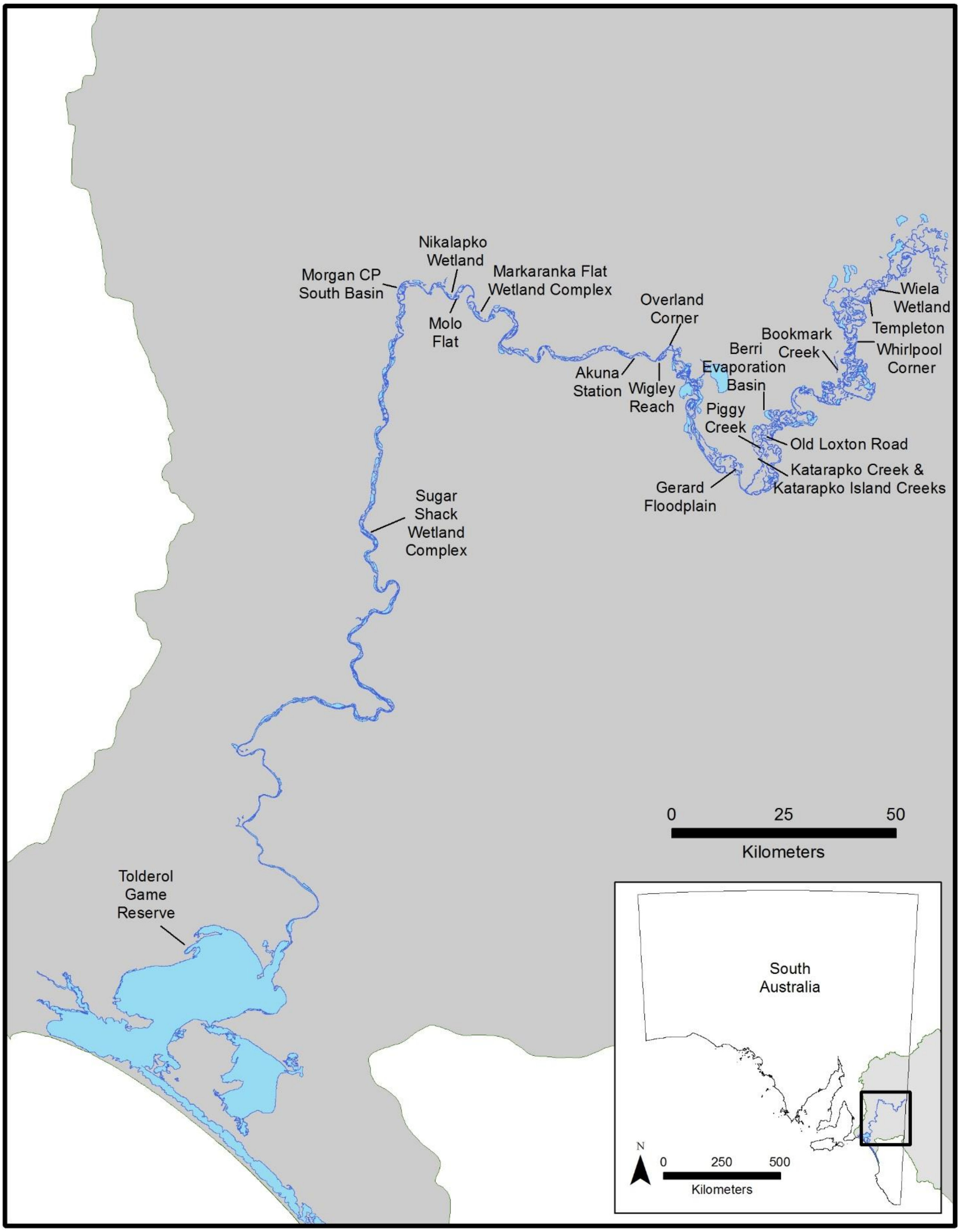
Part S: Appendix

Appendix A

Map of environmental watering sites 2014/15.



Appendix B

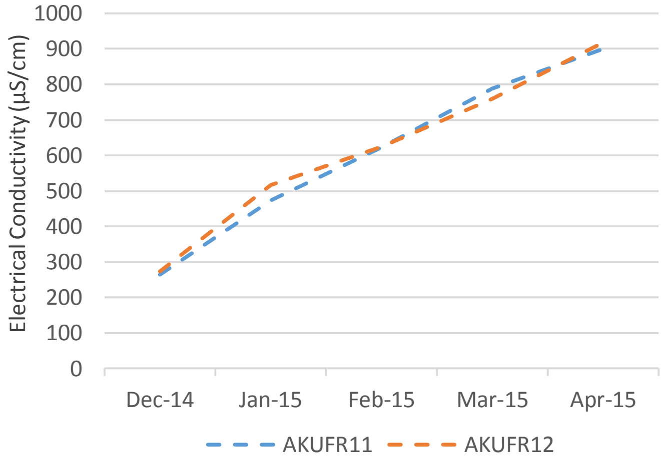
Environmental watering schedule 2014/15.

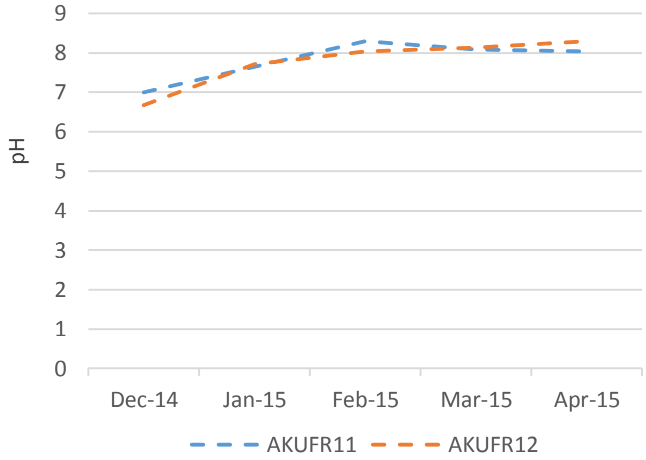
Wetland	Start date	End date	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15
Akuna Wetland	26-Nov-14	04-Dec-14												
Berri Evaporation Basin	01-Sep-15	30-Jun-15												
Bookmark Creek	01-Sep-14	30-Jun-15												
Gerard Floodplain Black Box trials	01-Jul-14	30-Jun-15												
Katarapko Creek (North and South)	27-Jan-15	02-Feb-15												
Katarapko Island Creeks	25-May-15	29-May-15												
Markaranka & Markaranka South Basins	01-Dec-14	23-Dec-14												
Markaranka Black Box Trials	18-Dec-14	14-May-15												
Markaranka East Basin	06-Jan-15	23-Jan-15												
Molo Flat (Western & Eastern Basin, Eastern Channel)	03-Dec-14	23-Dec-15												
Morgan CP (south)	18-Nov-14	01-Dec-14												
Morgan East	27-Nov-14	08-Dec-14												
Nikalapko Wetland	10-Nov-14	28-Nov-14												
Old Loxton Road	02-Jun-15	12-Jun-15												
Overland Corner	17-Dec-14	16-Jan-15												
Overland Corner Lignum Basin	14-Apr-15	15-May-15												
Piggy Creek	11-Nov-14	24-Nov-14												
Sugar Shack - temporary basin	02-Nov-14	16-Nov-14												
Templeton Wetland	29-Oct-14	26-Nov-14												
Tolderol	02-Nov-14	20-Jan-15												
Whirlpool Corner	02-Dec-14	06-Jan-15												
Wiela Wetland	12-Nov-14	23-Nov-14												
Wiela Wetland - Dripper	17-Jul-14	26-Feb-15												
Wigley Reach (Central and Western Channels)	13-Nov-14	30-Nov-14												

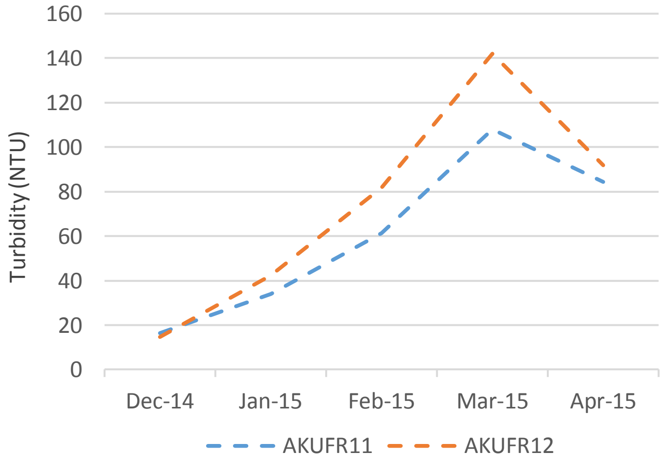
Appendix C

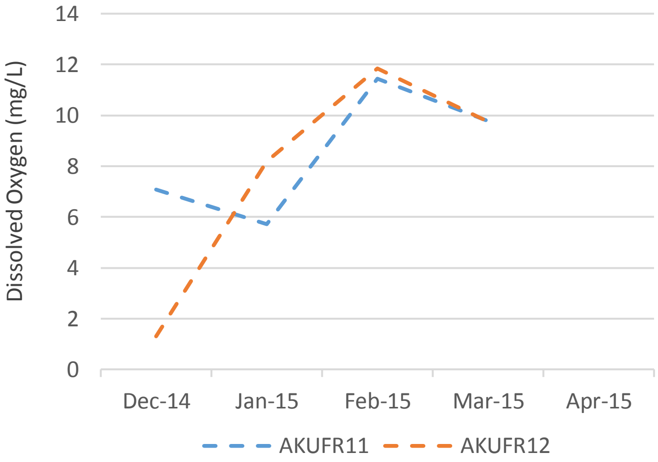
Surface water quality at selected sites, 2014/15.

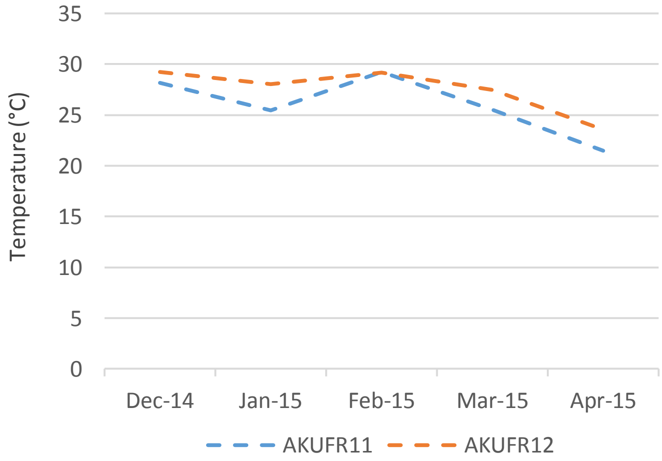
1. Akuna Station Wetland surface water quality, December 2014 – April 2015.



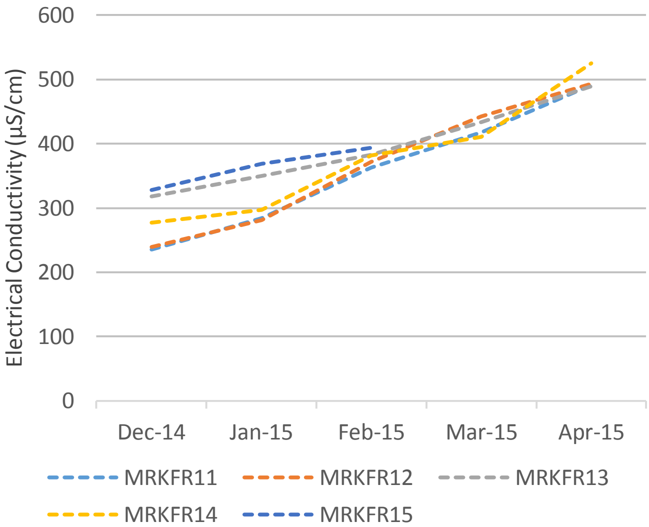


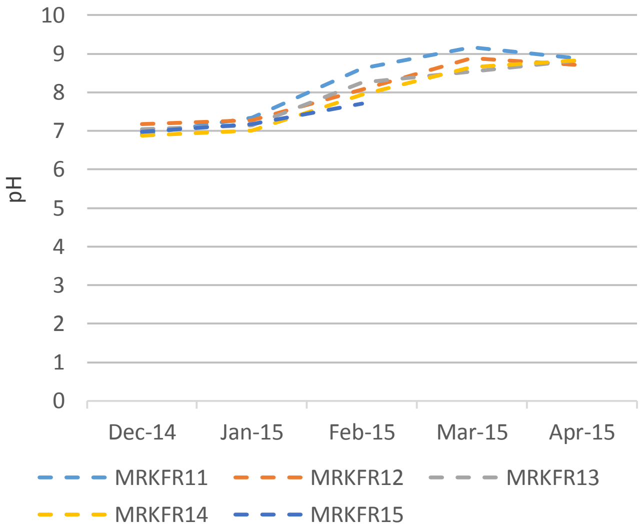


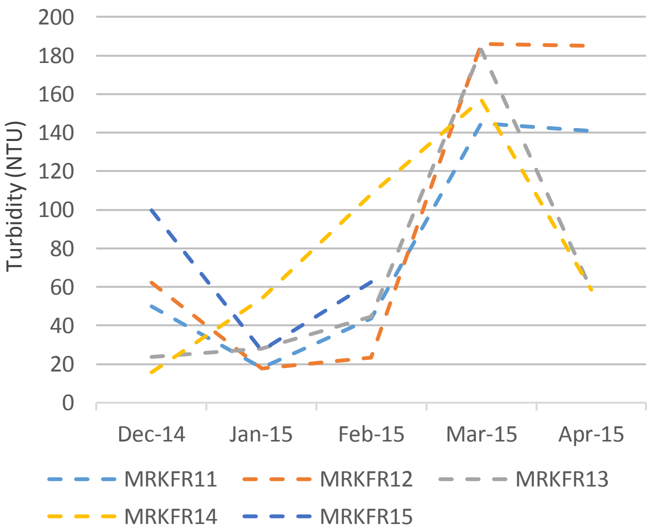


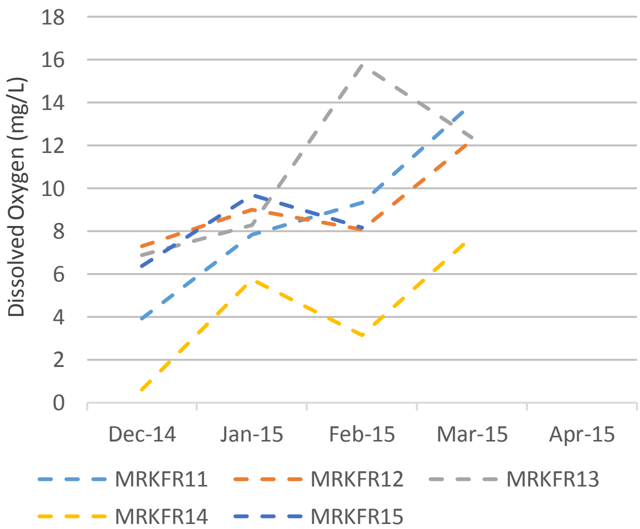


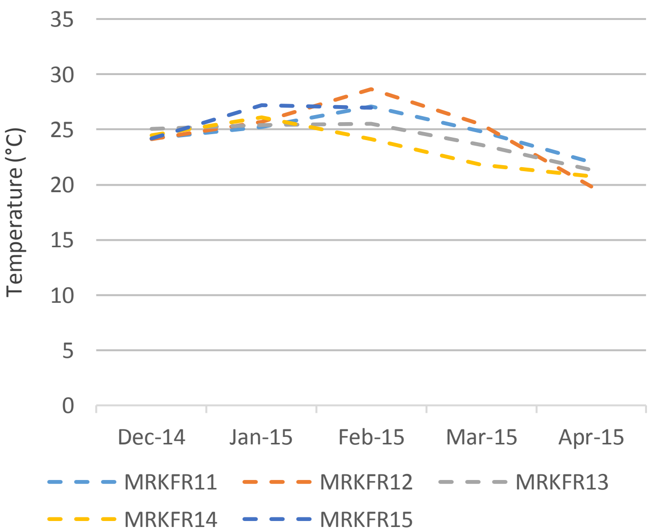
2. Markaranka Flat Wetland Complex surface water quality, December 2014 – April 2015.



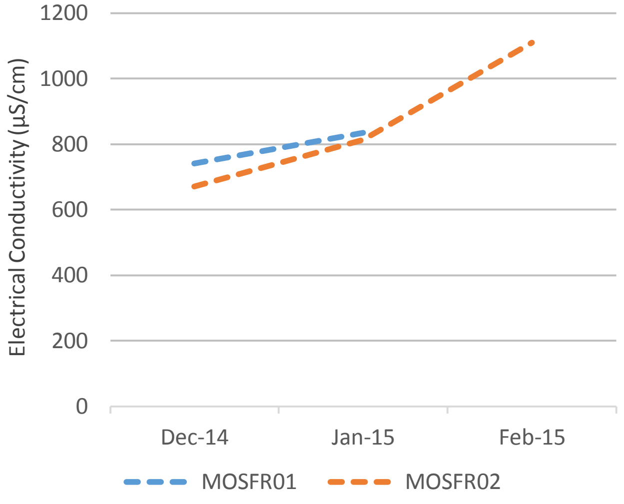


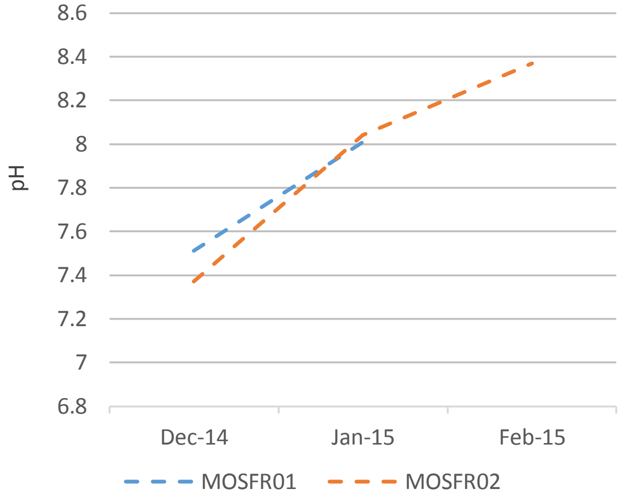


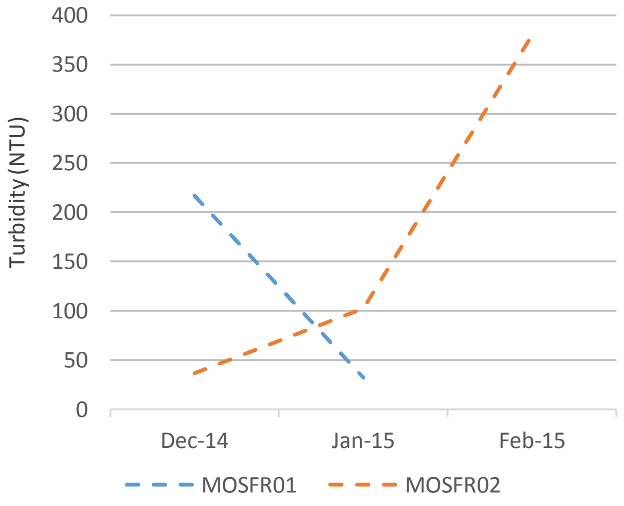


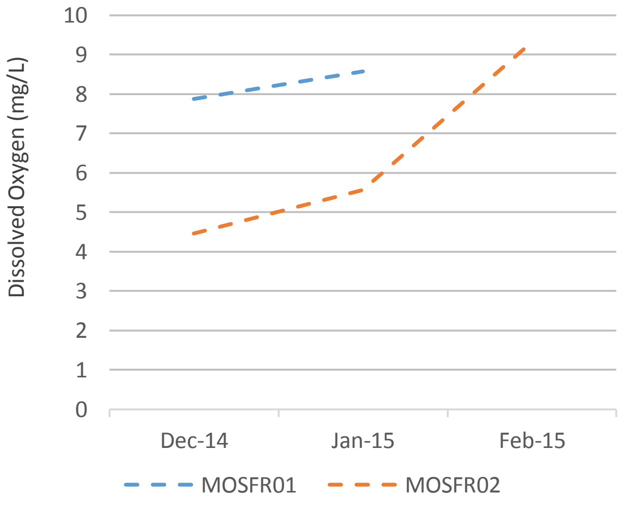


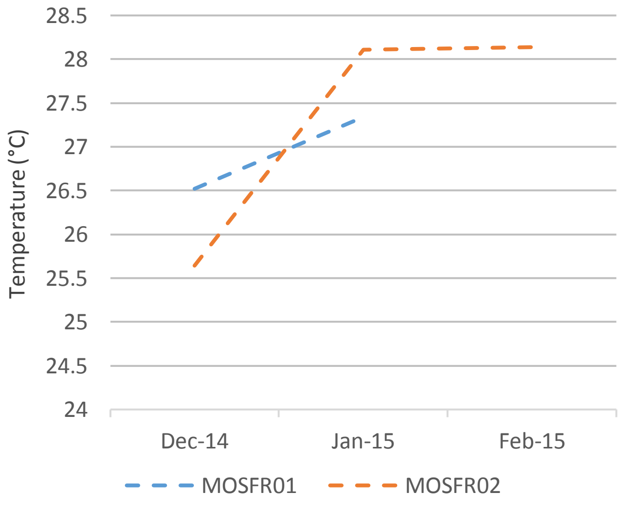
3. Morgan Conservation Park (South Basin) surface water quality, December 2014 – February 2015.



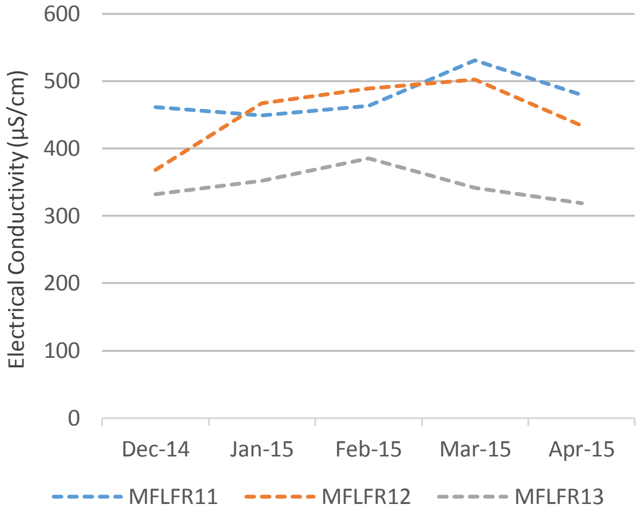


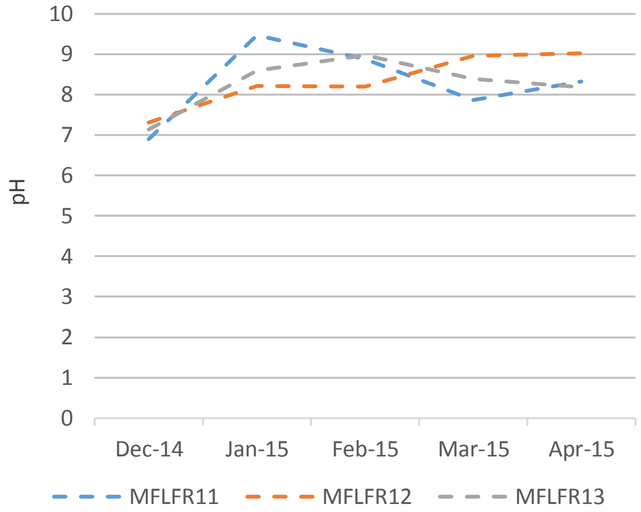


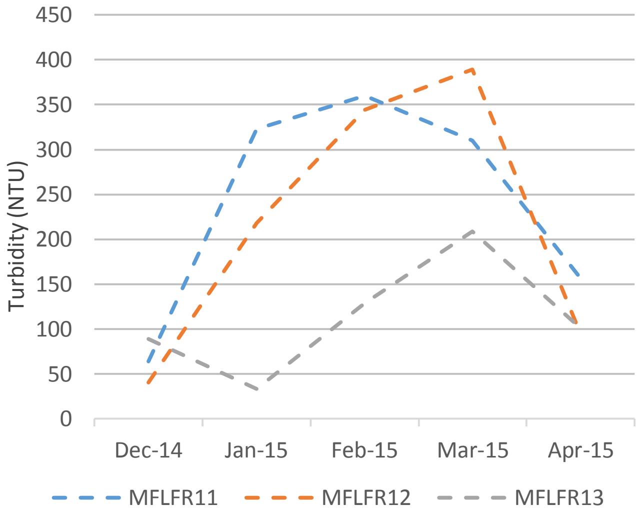


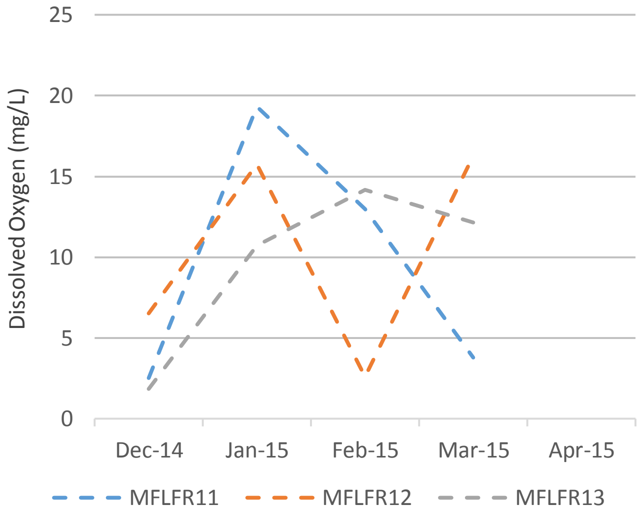


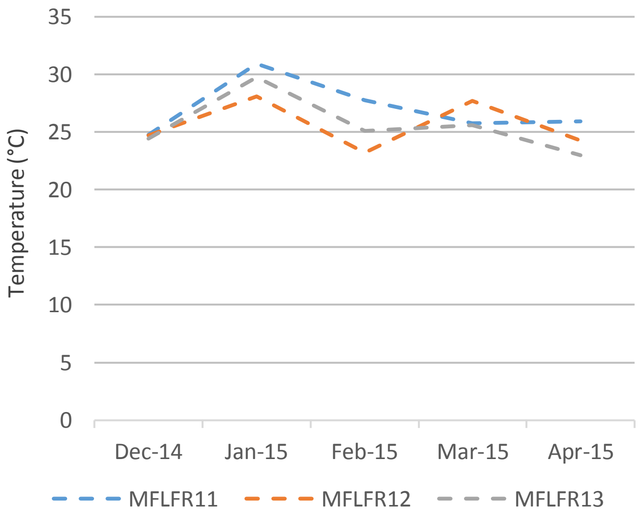
4. Molo Flat Wetland Complex surface water quality, December 2014 – April 2015.



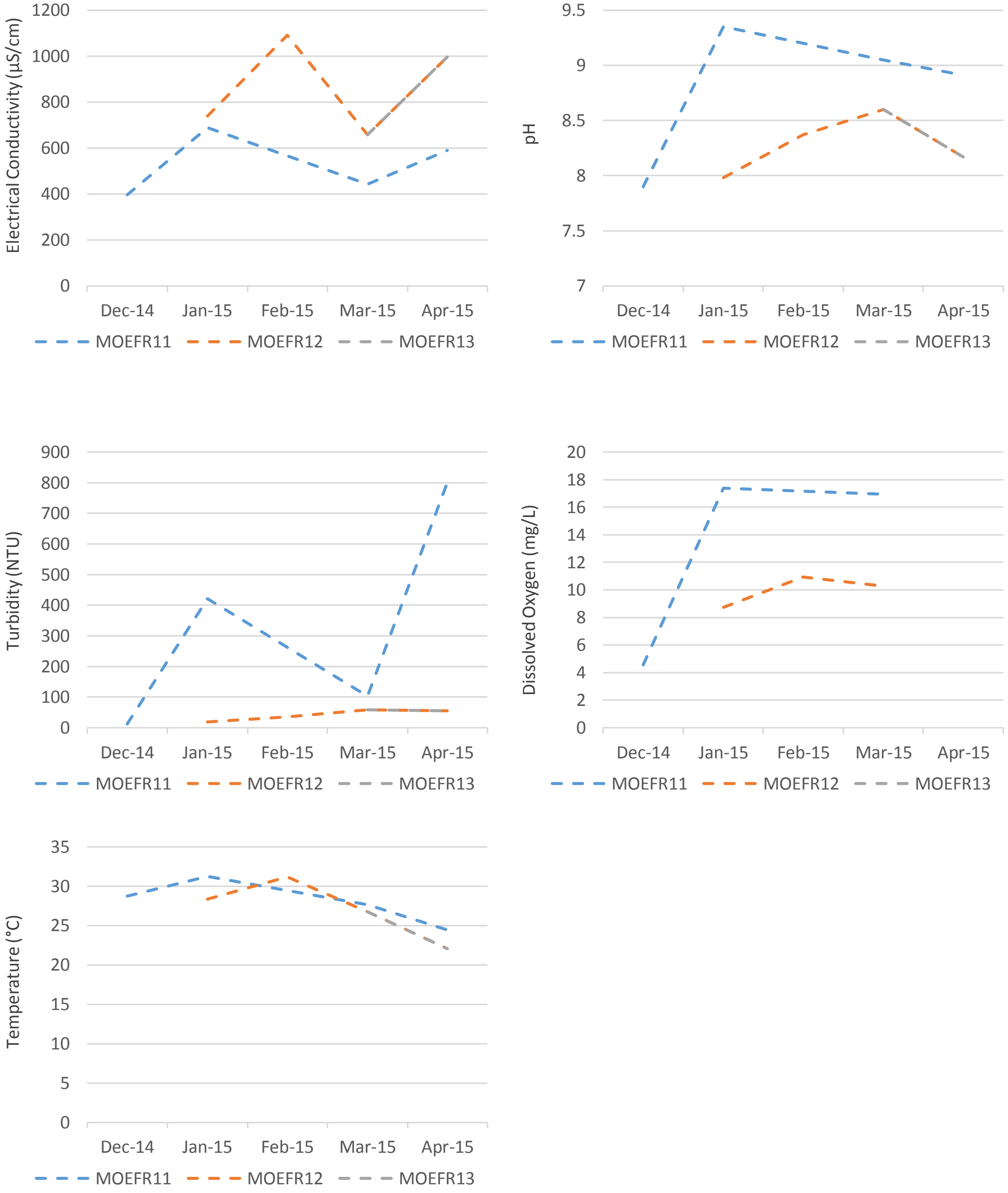




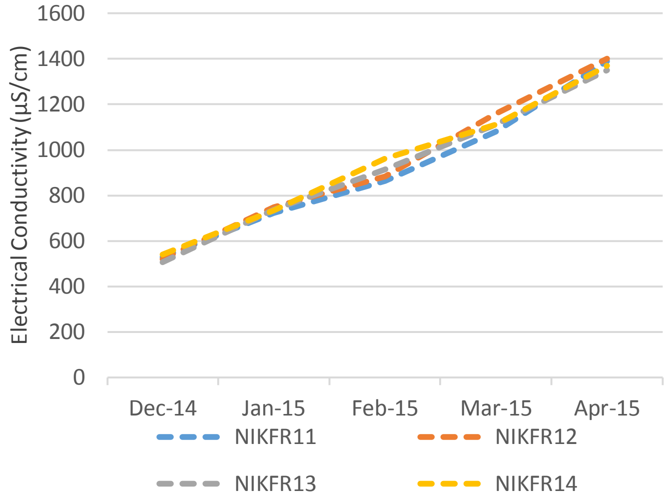


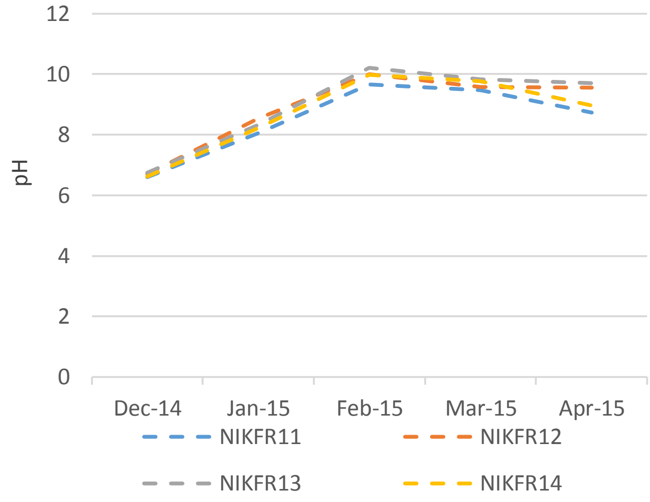


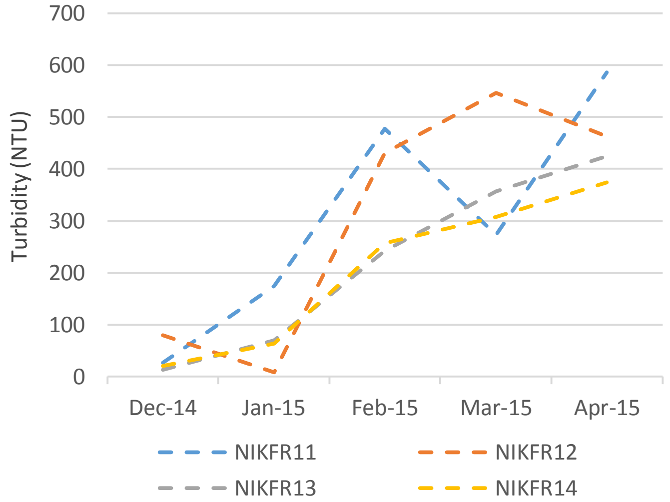
5. Morgan East Wetland surface water quality, December 2014 – April 2015.

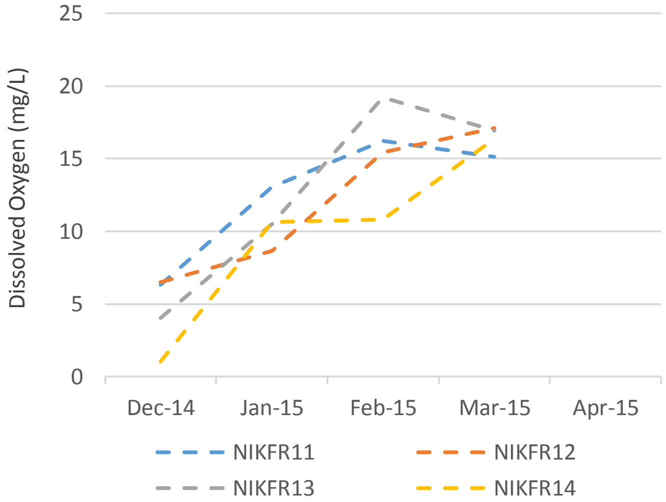


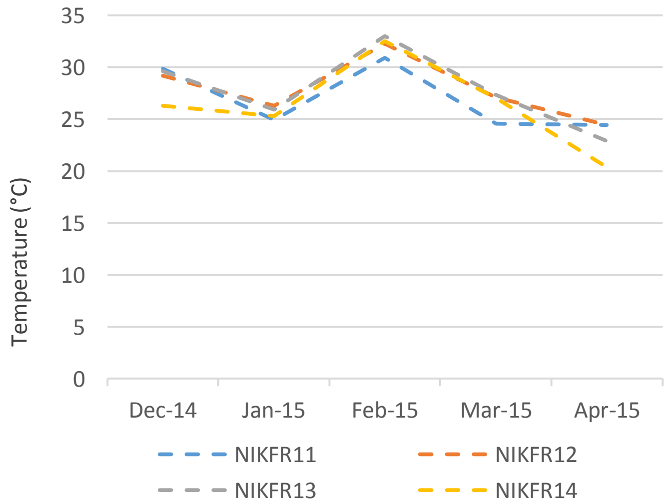
6. Nikalapko Wetland surface water quality, December 2014 – April 2015.



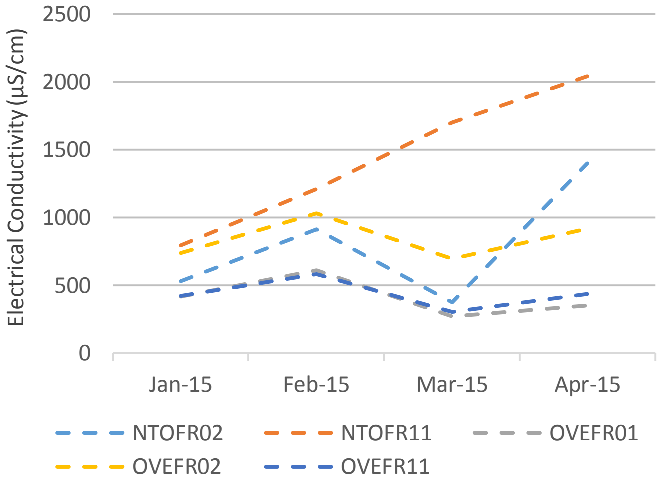


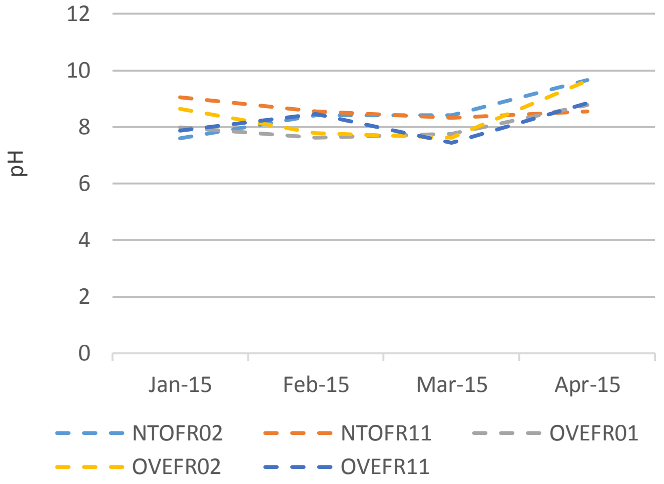


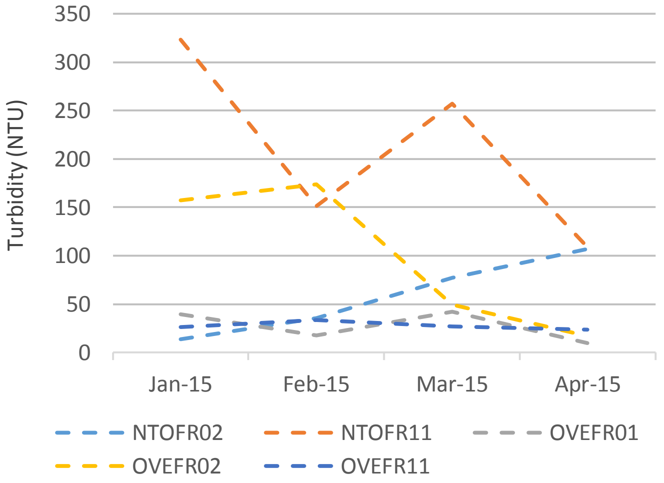


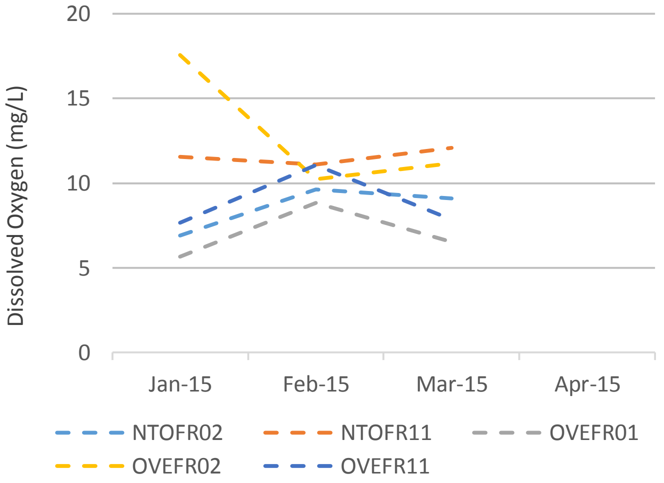


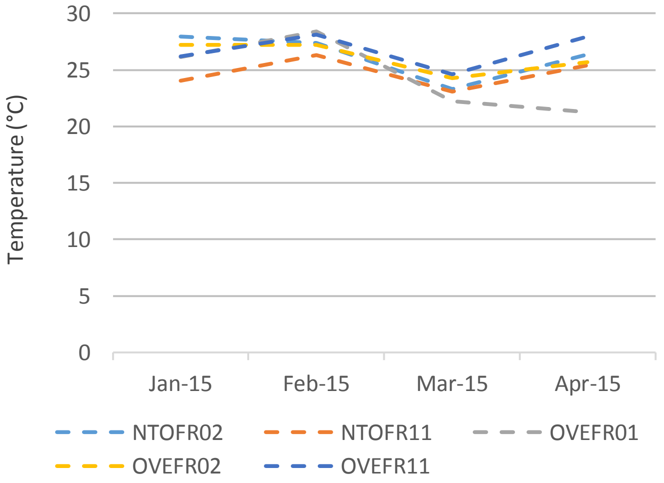
7. Overland Corner Wetland surface water quality, January 2014 – April 2015.



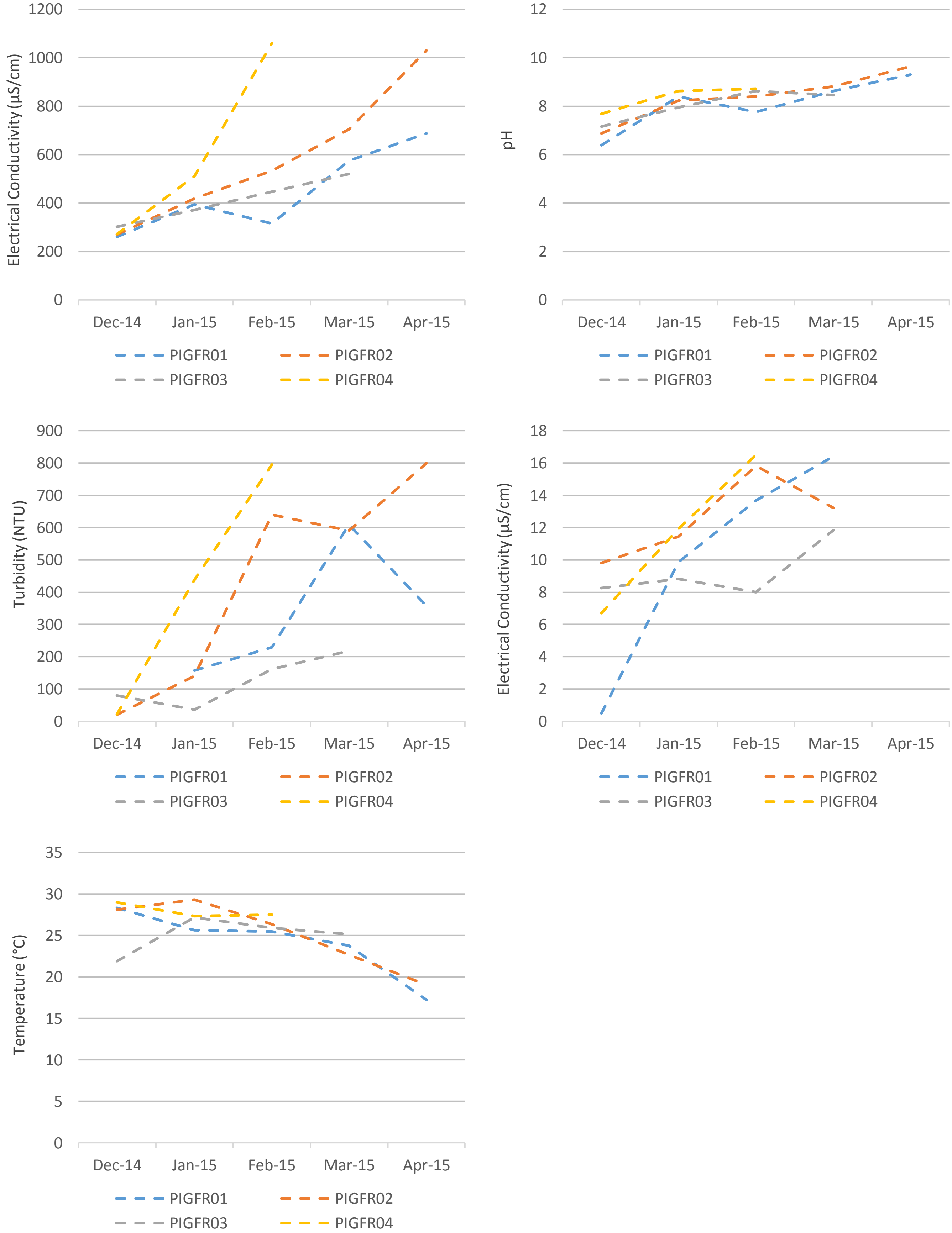




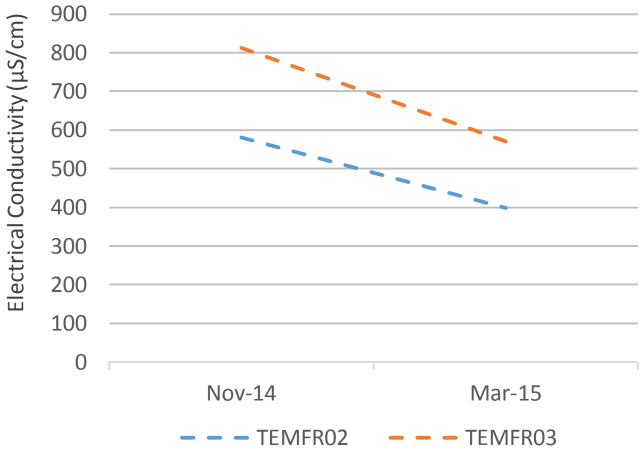


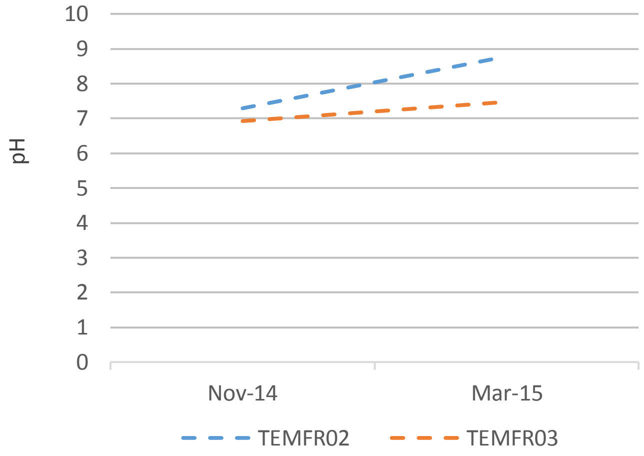


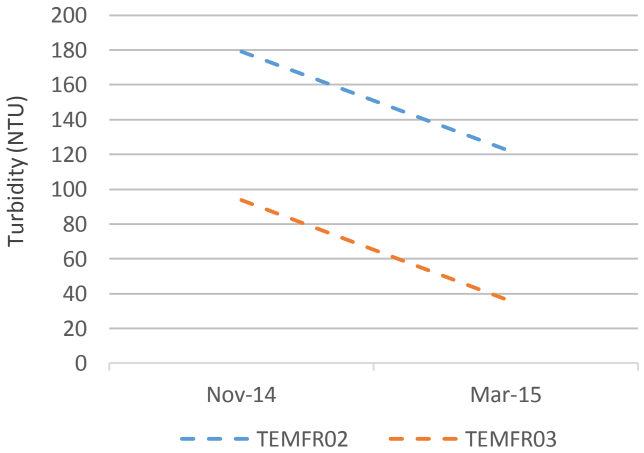
8. Piggy Creek surface water quality, December 2014 – April 2015.

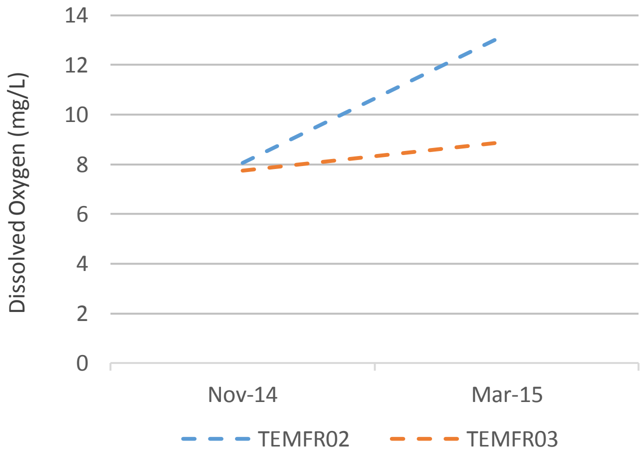


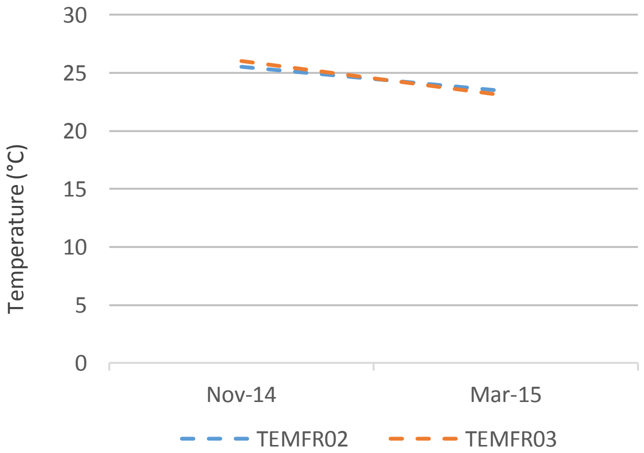
9. Templeton Wetland surface water quality, November 2014 – March 2015.



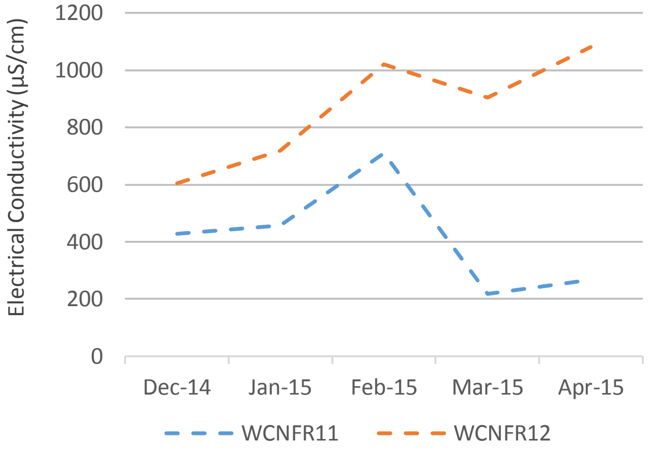


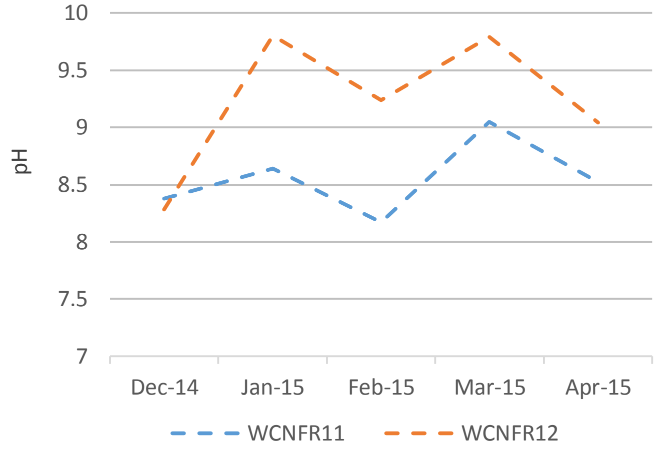


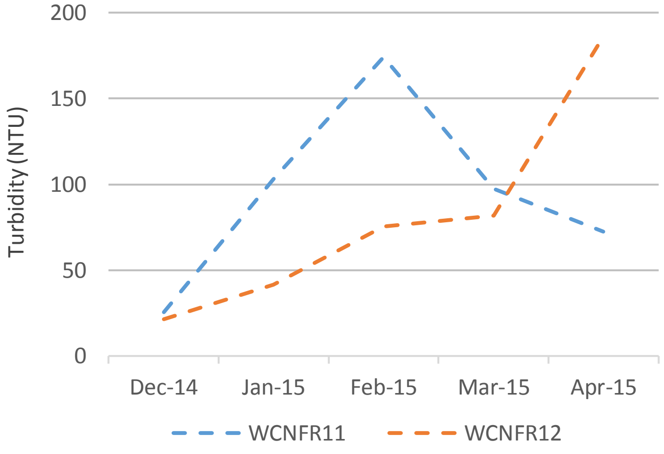


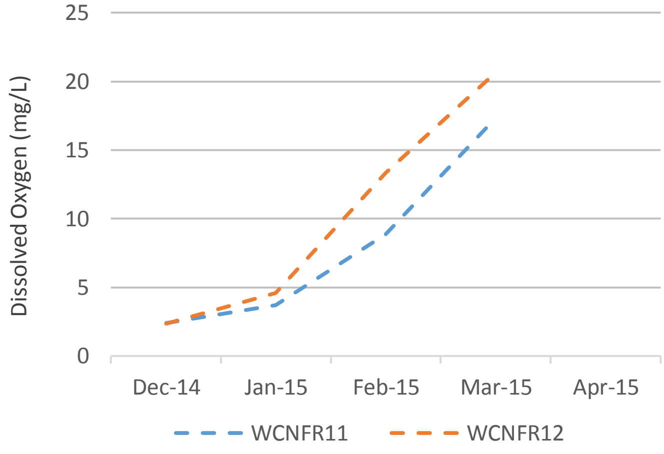


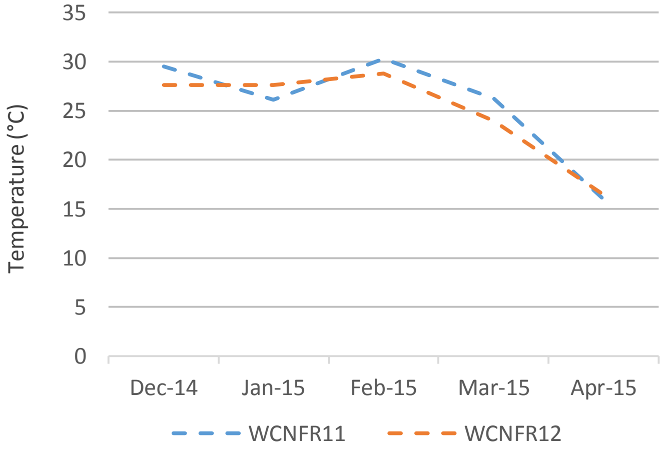
10. Whirlpool Corner Wetland surface water quality, December 2014 – April 2015.



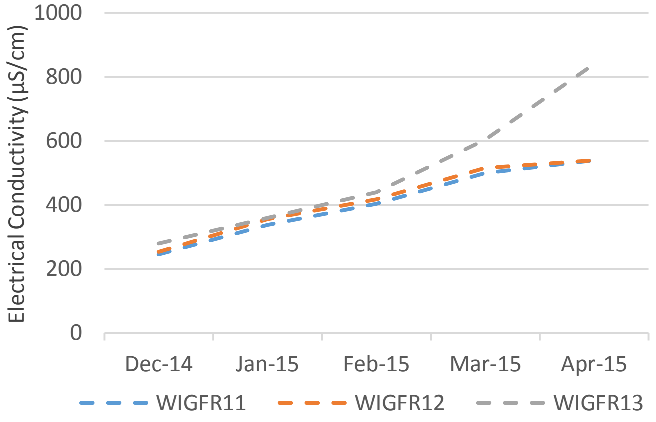


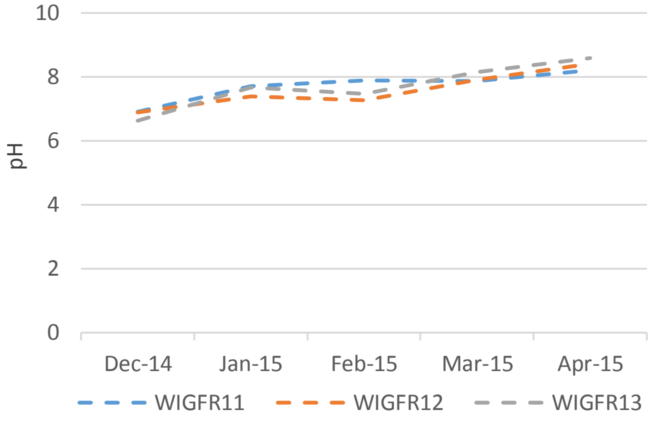


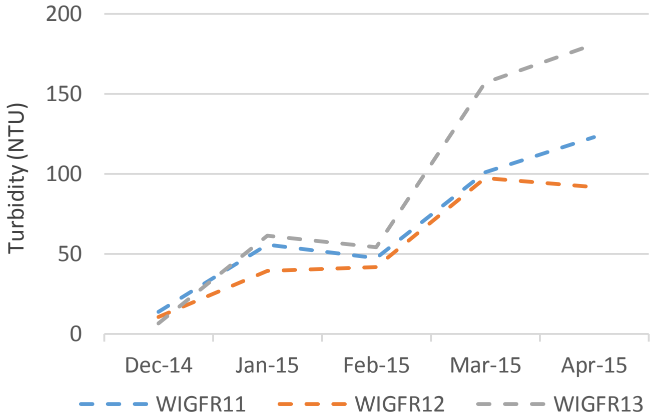


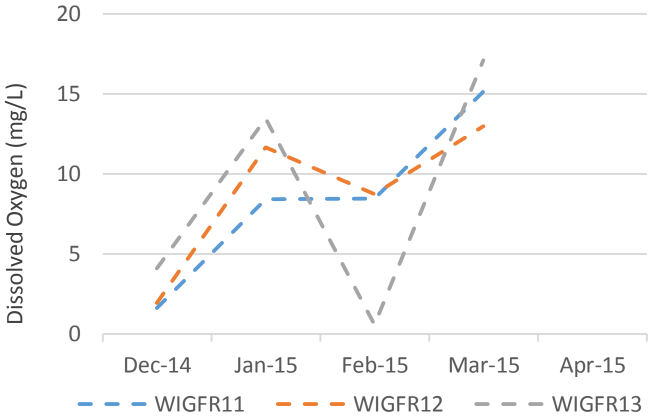


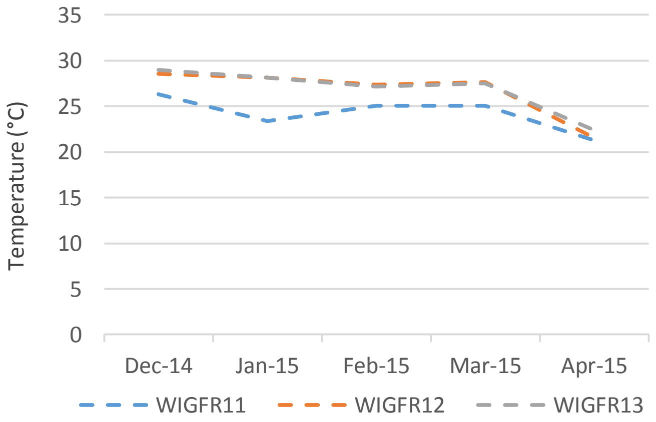
11. Wigley Reach Wetland Complex surface water quality, December 2014 – April 2015.











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