

# **2014–15 Basin-scale evaluation of Commonwealth environmental water – Generic Diversity**

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## **Final Report**

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## 2014-15 Basin-scale evaluation of Commonwealth Environmental Water — Generic Diversity

Report prepared for the Commonwealth Environmental Water Office by The Murray–Darling  
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The Murray–Darling Freshwater Research Centre offices are located on the land of the Latje Latje and Wiradjuri peoples. We undertake work throughout the Murray–Darling Basin and acknowledge the traditional owners of this land and water. We pay respect to Elders past, present and future.

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# 1 Introduction

The Murray-Darling Basin (the Basin) contains over 200,000 aquatic ecosystems, including approximately 8000 lakes and 34,000 floodplain wetlands (Brooks et al. 2013). Sixteen wetlands of international importance, listed under the Ramsar Convention are within the Basin, as are over 200 nationally important wetlands (Leblanc et al. 2012). These ecosystems support a broad range of species and ecological communities that are inundation dependent, or dependent on vegetation communities that are classified as wetland or floodplain systems. The Basin's aquatic ecosystems also support a large number of nationally and internationally significant plant and animal species, including 95 species listed as threatened under national or State legislation (Leblanc et al. 2012).

One objective of the Basin Plan is to protect or restore biodiversity that is dependent on the Basin's water resources. This is achieved through supporting listed threatened species or listed threatened ecological communities and ensuring that representative populations and communities of native biota are protected and, if necessary, restored (Basin Plan, section 8.05 (3)).

Species and communities can be dependent on flow and water regimes for all or parts of their lifecycles. Most of the biota within the Basin are adapted to cycles of wetting and drying, with many important breeding, migration or germination cues linked to water regime (Brock and Casanova 1997, Young et al. 2001, Roberts and Marston 2011). In a climate of increasing pressures on water resources, environmental watering actions can play a crucial role in maintaining species and ecosystem diversity (Beesley et al. 2009, Brandis 2010).

The Generic Diversity component of the Commonwealth Environmental Water Office's (CEWO) Long Term Intervention Monitoring (LTIM) Project aims to evaluate the contribution of Commonwealth environmental water to achieving diversity related objectives of the Basin Plan. This is accomplished through the consolidation of information from multiple sources to provide a summary of species and communities that potentially benefited from Commonwealth environmental water to address the following evaluation question:

- What did Commonwealth environmental water contribute to species diversity?
  - How did Commonwealth environmental water affect the presence, distribution and abundance of plant, fish, waterbird, frog, turtle and aquatic ecosystem dependent mammal species?
  - What listed threatened species and ecological communities benefited from Commonwealth environmental water?
  - What migratory species listed under international agreements (Bonn Convention, CAMBA, JAMBA or ROKAMBA) benefited from Commonwealth environmental water?

## Summary of water actions in 2014-15 with Expected Outcomes for biota

Commonwealth environmental water contributed to 78 watering actions in the 2014-15 with Expected Outcomes related to aquatic ecosystem dependent plant and vertebrate species (Appendix A). Of these 62 watering actions had Expected Outcomes for fish; 65 for plants species or vegetation communities; 33 for waterbirds, 20 for frogs, 3 for turtles and 1 for mammals (rakali).

More than two-thirds of the Commonwealth environmental watering actions took place within the LTIM Selected Areas (Edward–Wakool river system, Goulburn River, Gwydir river system, Lachlan



river system, Lower Murray River, Murrumbidgee river system and Junction of the Warrego and Darling rivers). Monitoring of vegetation diversity responses occurred with respect to seven of these watering actions (see Capon and Campbell 2016) and monitoring of short-term response to fish occurred for nine watering actions (see Stoffels et al. 2016). Monitoring of waterbirds occurred for one watering action in the Gwydir river system Selected Area and monitoring of frogs and waterbirds occurred for two watering actions in the Murrumbidgee river system Selected Area. Although there was no defined watering action in the Warrego-Darling Selected Area, management decisions made by the CEWO resulted in water flowing down the Western Floodplain during February–March 2015 and monitoring of frogs and waterbirds occurred (Table 1).

**Table 1.** Summary of monitored watering actions related to waterbird, frog and turtle diversity at Selected Areas in 2014-15.

Selected Area (Watering Action Reference) <sup>1</sup>	Water delivery dates (start – end) <sup>1</sup>	Flow component type <sup>1</sup>	Commonwealth environmental water volume delivered (GL) <sup>1</sup>	Expected ecological outcome <sup>1</sup>	Monitored site(s) <sup>2</sup>	Expected Outcome <sup>2</sup>	Observed ecological outcomes <sup>2</sup>	Influences <sup>2</sup>
Gwydir (10016-01)	17/09/14 – 07/03/15	Base flow; fresh flow; wetland inundation	30	Provide refuge habitat for waterbirds, fish and other aquatic species	Nineteen wetland sites along Gwydir and Gingham watercourses		Fifty-two species of wetland-dependent species recorded  Three international migratory species listed under agreements  Two species listed as vulnerable in New South Wales (NSW) (brilga and magpie goose)  Eleven species recorded breeding	Spatial and temporal extent of wetland inundation (CEWO 2015a)
Murrumbidgee (10023-02)	23/10/14 – 10/04/15	Wetland inundation; floodplain inundation	74.512	Maintain and improve the diversity and condition of native aquatic fauna, including fish, waterbirds, frogs, turtles and invertebrates through maintaining suitable habitat and providing/supporting opportunities to	Yanga National Park — Mercedes Swamp, Two Bridges Swamp, Waugorah Lagoon and Piggery Lake	Local increases in the abundance and diversity of waterbird species, including species of conservation significance (i.e. threatened species, and JAMBA, CAMBA and ROKAMBA species) and some small- scale colonial waterbird breeding	Twenty-six species of waterbird  No breeding recorded by LTIM monitoring, but small scale heron and cormorant breeding recorded by Office of Environment and Heritage aerial surveys	Low abundances and diversity due to small- scale nature of inundation events (Wassens et al. 2015)

Selected Area (Watering Action Reference) <sup>1</sup>	Water delivery dates (start – end) <sup>1</sup>	Flow component type <sup>1</sup>	Commonwealth environmental water volume delivered (GL) <sup>1</sup>	Expected ecological outcome <sup>1</sup>	Monitored site(s) <sup>2</sup>	Expected Outcome <sup>2</sup>	Observed ecological outcomes <sup>2</sup>	Influences <sup>2</sup>
				move, breed and recruit		Support species richness  Promote calling behaviour and tadpole occurrence  Trigger breeding activity of the southern bell frog	Five species of frog recorded  Breeding of spotted and barking marsh frogs  Eastern long-necked turtles observed at all sites; broad shell turtle recorded at Waugorah Lagoon	Potentially low dissolved oxygen or the presence of oriental weather loach may be contributing to the absence of southern bell frogs  Deeper, more persistent inundation favours spotted and barking marsh frogs (Wassens et al. 2015)
Murrumbidgee (10023-04)	04/12/14 – 22/01/15	Wetland inundation	1.15	Secondary: provide feeding habitat for waterbirds	Yarradda Lagoon	Local increases in the abundance and diversity of waterbird species, including species of conservation significance (i.e. threatened species, and JAMBA, CAMBA and ROKAMBA species) and some small-scale colonial waterbird breeding	Twelve species of waterbird recorded  Dominated by dabbling ducks with lower abundances of diving ducks and fish-eating species  Breeding of Pacific black duck	Low abundances and diversity due to small-scale nature of inundation events (Wassens et al. 2015)
				Secondary: provide feeding habitat for frogs	Yarradda Lagoon	Support species richness	Breeding of Peron's tree frogs, inland banjo frogs and spotted marsh frogs	Duration and timing of inundation sufficient to allow breeding activity (Wassens et al. 2015)

Selected Area (Watering Action Reference) <sup>1</sup>	Water delivery dates (start – end) <sup>1</sup>	Flow component type <sup>1</sup>	Commonwealth environmental water volume delivered (GL) <sup>1</sup>	Expected ecological outcome <sup>1</sup>	Monitored site(s) <sup>2</sup>	Expected Outcome <sup>2</sup>	Observed ecological outcomes <sup>2</sup>	Influences <sup>2</sup>
						Promote calling behaviour and tadpole occurrence  Trigger breeding activity of the southern bell frog	No southern bell frogs recorded	
Junction of Warrego and Darling	02/15 – 03/15	Floodplain inundation	0	Maintain wetland vegetation and waterbird habitat	Sites on Western Floodplain		Sixteen species of waterbird, including the NSW threatened brolga  Dominated by dabbling ducks  Six species of frog  Low abundances of birds and frogs	Low extent and duration of inundation  Initial boom in productivity upon wetting, but short-lived (CEWO 2015b)

<sup>1</sup> As reported in CEWO unpublished.

<sup>2</sup> As reported by the Monitoring and Evaluation (M&E) team for each Selected Area in Selected Area reports for 2014–15.

Note: CAMBA = China–Australia Migratory Bird Agreement; JAMBA = Japan–Australia Migratory Bird Agreement; LTIM = Long Term Intervention Monitoring; ROKAMBA = Republic of Korea – Australia Migratory Bird Agreement.

## 2 Method

### 2.1 General approach

The main output of the Generic Diversity evaluation is an aggregated list of species and communities that potentially benefited from Commonwealth environmental water each year. This list has been derived from a number of sources including: other Basin Matter reports, Selected Area reports, other monitoring programs (external to LTIM) and predictions based on wetland ecosystems watered, known species distributions/records and habitat requirements.

Determining if a species or community benefited from Commonwealth environmental water is not straightforward. The presence of a species at a site that received Commonwealth environmental water does not necessarily indicate that the species benefited, nor does it provide any indication of the temporal or spatial scale over which that species may have benefitted. . The Generic Diversity Basin Matter undertakes a qualitative evaluation of expected outcomes of water actions undertaken by the CEWO. Within the broad heading of qualitative evaluation, the approach taken depends on the amount of information available concerning both the community or species' water requirements and the hydraulic outcomes of water actions. Broadly, there are three approaches used each associated with its own levels of uncertainty.

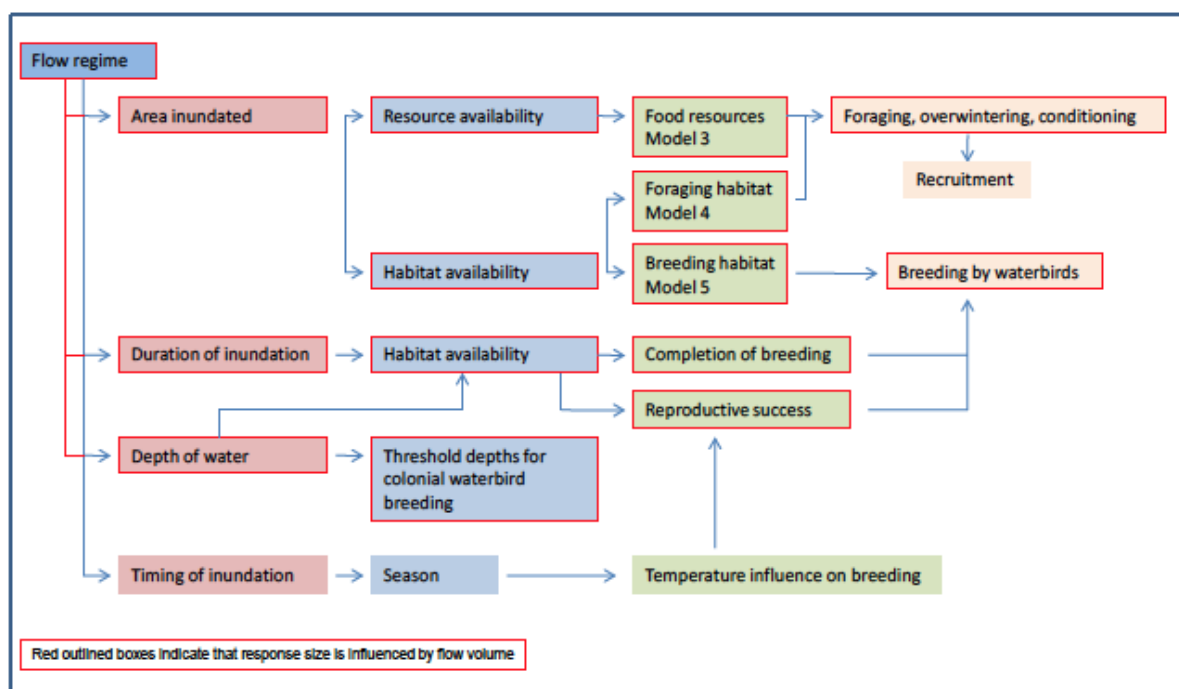
The first approach is based on a conceptual model that represents our understanding of the influence of flow on the community or species. Information about the water action (e.g. timing, depth, duration) is then evaluated through the lens of the conceptual model. Among the approaches to qualitative evaluation, this approach is associated with the greatest levels of confidence.

For example, Figure 1 is a simple conceptual model for the response of waterbirds to flow and water regimes. Predicting waterbird responses to environmental water at a given wetland would require information on the water regime such as area inundated, depth and duration of inundation, as well as some indication of the habitat availability. In addition, landscape scale factors such as availability of habitat in the region and past opportunities for breeding will also influence ecological responses to environmental watering (Brandis et al. 2009). While it is not possible to collect information on all local and landscape factors, water regime (e.g. timing, extent and duration of inundation) is the key driver of ecological response in aquatic ecosystems for wetland dependent species (Mitsch and Gosselink 2007, Poff and Zimmerman 2010, Roberts and Marston 2011). Information on the water regime at a given wetland is essential for making robust predictions of ecological responses and identifying species and communities that may have benefited from a watering action.

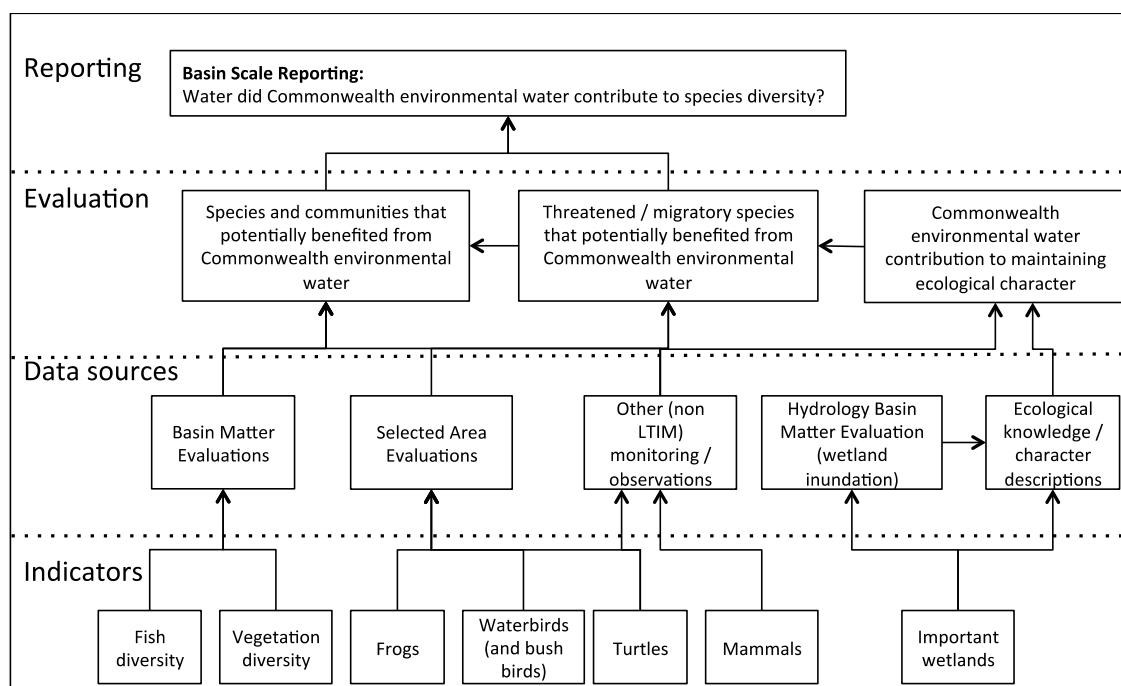
The second approach is to take a multiple lines and levels of evidence approach that uses information from different sources to identify species that potentially benefited from Commonwealth environmental water. The sources of information include (Figure 2):

- evaluations from other Basin Matters (vegetation, fish, ecosystem diversity)
- monitoring at Selected Areas
- monitoring/observations at sites watered but not monitored
- a case study approach for wetlands that are nationally or internationally recognised as important (i.e. listed on the Directory of Important Wetlands in Australia (DIWA) or under the Ramsar Convention).

Rather than using a conceptual model or specific hydraulic outcomes, this approach uses general information about a species life history or habitat requirements and broad assumptions about the hydraulic outcomes to infer benefit. Because the information is quite general, there is a much lower level of confidence associated with the evaluation.



**Figure 1.** Waterbird response to water regime (Brandis et al. 2009)



**Figure 2.** Basin evaluation of generic diversity.

The third approach is only used in situations where there is not enough information for someone with no knowledge of the system to infer anything about the outcomes of the water action. In these situations, expert opinion is the only approach possible but this is associated with very high levels of uncertainty and cannot be undertaken by the Basin evaluation. Where experts have expressed opinions in the Selected Area reports, these are included in the evaluation.

In this first year of the LTIM, the emphasis is on the second method, using multiple lines and levels of evidence to identify those species and communities that benefited from the use of Commonwealth environmental water. It is anticipated that in future years there will be a greater focus on the use of

conceptual models as the data generated by the LTIM program and other research, monitoring and assessment programs improve our understanding of community and species' water requirements.

## 2.2 Other Basin Matters

The effects of Commonwealth environmental water on vegetation, fish and ecosystem diversity have been evaluated as other Basin Matters (Brooks, 2016; Capon and Campbell 2016; Stoffels et al. 2016). These evaluations adopted different approaches and methods for assessing the effect of Commonwealth environmental water, which are documented in each report. Species and communities that were identified in each of these evaluations as benefitting (or potentially benefitting) from Commonwealth environmental water have been extracted and input to the aggregated list of species in Appendix B.

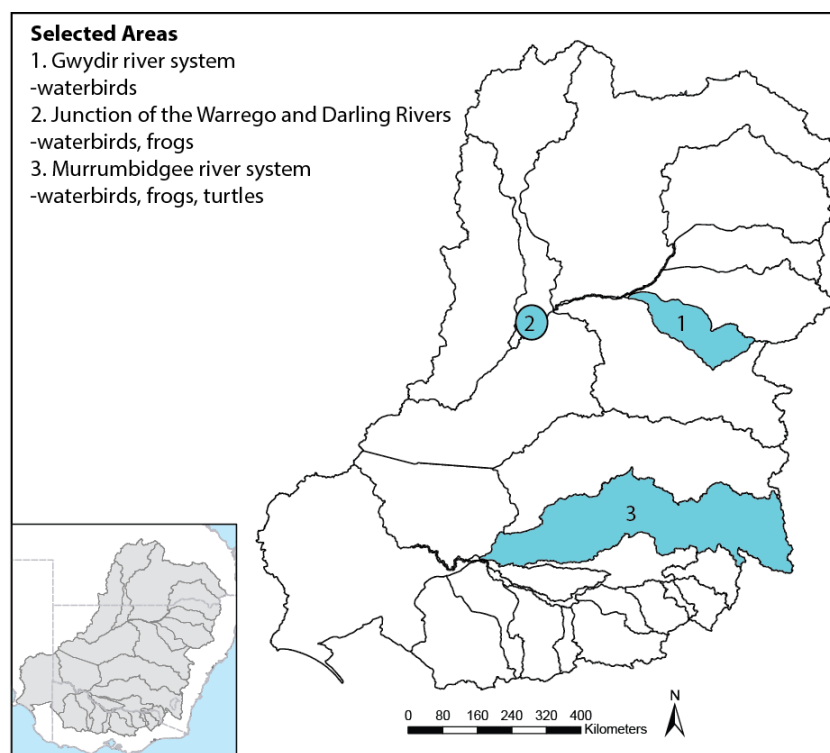
## 2.3 Waterbirds, frogs, turtles and mammals

### 2.3.1 Selected Area outcomes

In the 2014-15 watering year, several Selected Areas were monitored for waterbirds, frogs and / or turtles (noting that aquatic ecosystem dependent mammals were not included in any LTIM monitoring) Figure 2:

- Gwydir – waterbirds
- Murrumbidgee – waterbirds, frogs and turtles
- Junction of the Warrego and Darling Rivers – waterbirds and frogs

Information collected from Selected Area monitoring has been reviewed and summarised to identify species that potentially benefited from Commonwealth environmental water in 2014-15.



**Figure 3.** Locations of Selected Area monitoring for waterbirds, frogs and turtles 2014-15.

### **2.3.2 Unmonitored sites**

In this report “unmonitored” refers to sites that received Commonwealth environmental water, but were not measured as part of LTIM. These sites had varying degrees of information available relevant to ecological responses to watering. There are sites that were monitored under State or Darling Basin Authority (MDBA) programs (e.g. The Living Murray (TLM) program); sites at which there are observations documented in the CEWO Acquittal Reports and sites at which there may be general information available on the species likely to be present, but at which no direct information related to the ecological outcomes of environmental watering could be sourced.

Where information on the effects of environmental watering in the 2014-15 watering year was available, this has been extracted and aggregated into a list of species and communities for each aquatic ecosystem.

In addition, several case studies have been explored for internationally recognised Ramsar wetland sites, and nationally recognised wetlands listed in DIWA. These sites are identified as being significant at national or international scales because of the species and communities they support. They are some of the most diverse and species-rich wetlands in the Murray–Darling Basin. As case studies, they provide examples of the benefits of environmental watering and contributions to meeting Basin Plan objectives for both diversity and for maintaining the ecological character of Ramsar wetlands.

DIWA and Ramsar sites that were the target of Commonwealth environmental watering actions and had Expected Outcomes related to diversity were selected as case studies. Information related to the watering action, known species and habitats at the site and any complementary monitoring data were used to evaluate the effects of the watering action through the following questions:

- What was the expected outcome?
- What information is available about the watering action?
- What evidence is available to evaluate the outcome?
- What species and communities potentially benefited from Commonwealth environmental water?

## **3 Synthesis of Area outcomes (waterbirds, frogs and turtles)**

### **3.1 Highlights**

- Commonwealth environmental water accounted for a significant proportion of water within the Gwydir river system, which would otherwise have been largely dry. The 51 species of aquatic ecosystem–dependent birds, including 11 species that bred almost certainly benefited from the increase in available habitat. Three international migratory bird species listed under treaties and two species of waterbird listed as threatened at the State level were also recorded at sites that received Commonwealth environmental water.
- Some evidence was provided that Commonwealth environmental water benefited bird, frog and turtle species in the Murrumbidgee river system.
- At the Junction of the Warrego and Darling rivers, a small portion of the Western Floodplain received water as a result of CEWO decisions, and the short-term, small-scale inundation event benefited a small number of bird and frog species, including brolga, listed as vulnerable in NSW.



## 3.2 Effects of Commonwealth environmental water on waterbird, frog and turtle species diversity at Selected Areas

Information on waterbirds, frogs and turtles from monitoring within the Selected Areas is summarised in Table 1.

### 3.2.1 Gwydir river system

Thirteen wetlands that received Commonwealth environmental water in the Gwydir Selected Area were surveyed for waterbirds, with 51 species recorded (Table 2). This includes three international migratory waders listed under international migratory agreements (common greenshank, Latham's snipe and sharp-tailed sandpiper) and two species listed as vulnerable under state legislation (magpie goose and brolga). There were also a further three species that, while listed under international migratory agreements, are residents within Australia (cattle egret, eastern great egret and white-bellied sea eagle). There was evidence of 11 species breeding in response to Commonwealth environmental water, but breeding success and recruitment are not known. Given that almost all of the water in the wetlands surveyed was attributed to Commonwealth environmental water deliveries, there is a strong argument to suggest that these species benefited in terms of feeding and/or nesting habitat availability.

**Table 2.** Aquatic ecosystem dependent waterbirds recorded at sites in the Gwydir Selected Area that received Commonwealth environmental water.

Functional guild	Common name	Species name	Significance
Australian breeding shorebird	Black-fronted dotterel	<i>Elseyornis melanops</i>	
	Black-winged stilt	<i>Himantopus himantopus</i>	
	Masked lapwing	<i>Vanellus miles</i>	
	Red-kneed dotterel	<i>Erythronyx cinctus</i>	
Migratory shorebird	Common greenshank	<i>Tringa nebularia</i>	JAMBA, CAMBA, ROKAMBA
	Latham's snipe	<i>Gallinago hardwickii</i>	JAMBA, CAMBA, ROKAMBA
	Sharp-tailed sandpiper	<i>Calidris acuminata</i>	JAMBA, CAMBA, ROKAMBA
Ducks swans and grebes	Australasian grebe	<i>Tachybaptus novaehollandiae</i>	
	Australasian shoveler	<i>Anas rhynchos</i>	
	Australian wood duck	<i>Chenonetta jubata</i>	
	Black Swan	<i>Cygnus atratus</i>	
	Grey teal	<i>Anas gracilis</i>	
	Hardhead	<i>Aythya australis</i>	
	Hoary-headed grebe	<i>Poliiocephalus poliocephalus</i>	
	Magpie goose	<i>Anseranas semipalmata</i>	Vulnerable (NSW)
	Pacific black duck	<i>Anas superciliosa</i>	
	Pink-eared duck	<i>Malacorhynchus membranaceus</i>	
	Plumed whistling-duck	<i>Dendrocygna eytoni</i>	
	Wandering whistling-duck	<i>Dendrocygna arcuata</i>	

Functional guild	Common name	Species name	Significance
Cranes, crakes and rails	Black-tailed native-hen	<i>Tribonyx ventralis</i>	
	Brolga	<i>Grus rubicunda</i>	Vulnerable (NSW)
	Dusky moorhen	<i>Gallinula tenebrosa</i>	
	<b>Eurasian coot</b>	<b><i>Fulica atra</i></b>	
	Purple swampphen	<i>Porphyrio porphyrio</i>	
Large wading birds	Australian little bittern	<i>Ixobrychus dubius</i>	
	<b>Australian white ibis</b>	<b><i>Threskiornis molucca</i></b>	
	Cattle egret	<i>Ardea ibis</i>	JAMBA, CAMBA (Australian resident)
	Eastern great egret	<i>Ardea modesta</i>	JAMBA, CAMBA (Australian resident)
	Glossy ibis	<i>Plegadis falcinellus</i>	
	Intermediate egret	<i>Ardea intermedia</i>	
	Little egret	<i>Egretta garzetta</i>	
	Royal spoonbill	<i>Platalea regia</i>	
	Straw-necked ibis	<i>Threskiornis spinicollis</i>	
	White-faced heron	<i>Egretta novaehollandiae</i>	
	White-necked heron	<i>Ardea pacifica</i>	
	Yellow-billed spoonbill	<i>Platalea flavipes</i>	
Fish eating birds	<b>Australasian darter</b>	<b><i>Anhinga novaehollandiae</i></b>	
	Australian pelican	<i>Pelecanus conspicillatus</i>	
	Great cormorant	<i>Phalacrocorax carbo</i>	
	Little black cormorant	<i>Phalacrocorax sulcirostris</i>	
	Little egret	<i>Egretta garzetta</i>	
	<b>Little pied cormorant</b>	<b><i>Microcarbo melanoleucos</i></b>	
	Pied cormorant	<i>Phalacrocorax varius</i>	
	Whiskered tern	<i>Chlidonias hybrida</i>	
Raptors	Swamp harrier	<i>Circus approximans</i>	
	<b>White-bellied sea eagle</b>	<b><i>Haliaeetus leucogaster</i></b>	CAMBA (Australian resident)
Other wetland dependent species	<b>Australian reed-warbler</b>	<b><i>Acrocephalus australis</i></b>	
	Golden-headed cisticola	<i>Cisticola exilis</i>	
	Little grassbird	<i>Megalurus gramineus</i>	
	<b>Sacred kingfisher</b>	<b><i>Todiramphus sanctus</i></b>	
	Tawny grassbird	<i>Megalurus timoriensis</i>	

<sup>1</sup> Bold indicates evidence of breeding.

<sup>2</sup> CAMBA = China–Australia Migratory Bird Agreement; JAMBA = Japan–Australia Migratory Bird Agreement; ROKAMBA = Republic of Korea – Australia Migratory Bird Agreement.

### 3.2.2 Murrumbidgee river system

Surveys were conducted at 12 wetlands in the Murrumbidgee river system Selected Area for waterbirds and frogs. Only five of these, however, received Commonwealth environmental water

and are considered here: Mercedes Swamp, Two Bridges Swamp, Waugorah Lagoon and Piggery Lake in Yanga National Park (Lowbidgee; DIWA listed) and Yarradda Lagoon in the mid-Murrumbidgee wetlands (Wassens et al. 2015).

Twenty-seven species of waterbird were recorded in low to moderate abundances (Table 3). Two species are listed under international migratory agreements (eastern great egret and white-bellied sea eagle), but in Australia these are resident species that do not migrate out of the country. There was no evidence of breeding recorded in the ground surveys, but the Selected Area report indicates small-scale cormorant and heron breeding was observed by Office of Environment and Heritage aerial surveys (Wassens et al. 2015).

**Table 3.** Aquatic ecosystem dependent waterbirds recorded at sites in the Murrumbidgee river system Selected Area that received Commonwealth environmental water.

Functional guild	Common name	Species name	Significance
Australian breeding shorebird	Masked lapwing	<i>Vanellus miles</i>	
Ducks swans and grebes	Australasian grebe	<i>Tachybaptus novaehollandiae</i>	
	Australasian shoveler	<i>Anas rhynchos</i>	
	Australian shelduck	<i>Tadorna tadornoides</i>	
	Australian wood duck	<i>Chenonetta jubata</i>	
	Black Swan	<i>Cygnus atratus</i>	
	Grey teal	<i>Anas gracilis</i>	
	Hardhead	<i>Aythya australis</i>	
	Hoary-headed grebe	<i>Poliiocephalus poliocephalus</i>	
	Pacific black duck	<i>Anas superciliosa</i>	
	Pink-eared duck	<i>Malacorhynchus membranaceus</i>	
Cranes, crakes and rails	Eurasian coot	<i>Fulica atra</i>	
Large wading birds	Australian white ibis	<i>Threskiornis molucca</i>	
	Eastern great egret	<i>Ardea modesta</i>	JAMBA, CAMBA (Australian resident)
	Intermediate egret	<i>Ardea intermedia</i>	
	Nankeen night-heron	<i>Nycticorax caledonicus</i>	
	Straw-necked ibis	<i>Threskiornis spinicollis</i>	
	White-faced heron	<i>Egretta novaehollandiae</i>	
	White-necked heron	<i>Ardea pacifica</i>	
	Yellow-billed spoonbill	<i>Platalea flavipes</i>	
Fish eating birds	Australasian darter	<i>Anhinga novaehollandiae</i>	
	Australian pelican	<i>Pelecanus conspicillatus</i>	
	Great cormorant	<i>Phalacrocorax carbo</i>	
	Little black cormorant	<i>Phalacrocorax sulcirostris</i>	
	Little pied cormorant	<i>Microcarbo melanoleucos</i>	
Raptors	White-bellied sea eagle	<i>Haliaeetus leucogaster</i>	CAMBA (Australian resident)

Functional guild	Common name	Species name	Significance
Other wetland dependent species	Sacred kingfisher	<i>Todiramphus sanctus</i>	

<sup>1</sup> CAMBA = China–Australia Migratory Bird Agreement; JAMBA = Japan–Australia Migratory Bird Agreement.

Five species of frog and two species of turtle were also recorded at Murrumbidgee wetland sites that received Commonwealth environmental water in 2014-15:

- barking marsh frog (*Limnodynastes fletcheri*)
- spotted marsh frog (*Limnodynastes tasmaniensis*)
- plains froglet (*Crinia parinsignifera*)
- Peron's tree frog (*Litoria peronii*)
- inland banjo frog (*Limnodynastes interioris*)
- eastern long-necked tortoise (*Chelodina longicollis*)
- broad shell tortoise (*Chelodina expansa*)

### 3.2.3 Junction of the Warrego and Darling rivers

Management decisions made by the CEWO resulted in water flowing down the Western Floodplain during February–March 2015 inundating around 40 hectares of the floodplain (CEWO 2015b). Waterbird and frog surveys were conducted during and after the water delivery. Sixteen species of waterbird including the State listed vulnerable brolga were recorded (Table 4). Abundance, was however, low with a maximum count of just over 100 birds.

**Table 4.** Aquatic ecosystem dependent waterbirds recorded at sites in the Western Floodplain in 2014-15.

Functional guild	Common name	Species name	Significance
Australian breeding shorebird	Black-fronted dotterel	<i>Euseyornis melanops</i>	
	Masked lapwing	<i>Vanellus miles</i>	
Ducks swans and grebes	Australasian grebe	<i>Tachybaptus novaehollandiae</i>	
	Australian wood duck	<i>Chenonetta jubata</i>	
	Grey teal	<i>Anas gracilis</i>	
	Hoary-headed grebe	<i>Poliiocephalus poliocephalus</i>	
	Pink-eared duck	<i>Malacorhynchus membranaceus</i>	
Cranes, crakes and rails	Brolga	<i>Grus rubicunda</i>	Vulnerable (NSW)
	Eurasian coot	<i>Fulica atra</i>	
Large wading birds	Australian white ibis	<i>Threskiornis molucca</i>	
	Eastern great egret	<i>Ardea modesta</i>	JAMBA, CAMBA (Australian resident)
	White-faced heron	<i>Egretta novaehollandiae</i>	
	White-necked heron	<i>Ardea pacifica</i>	
Fish eating birds	Little black cormorant	<i>Phalacrocorax sulcirostris</i>	
Other wetland dependent species	Little grassbird	<i>Megalurus grammurus</i>	
	Sacred kingfisher	<i>Todiramphus sanctus</i>	

<sup>1</sup> CAMBA = China–Australia Migratory Bird Agreement; JAMBA = Japan–Australia Migratory Bird Agreement.

Six frog species were recorded on the Western Floodplain following inundation:

- barking frog (*Limnodynastes fletcheri*)
- desert froglet (*Crinia deserticola*)
- desert tree frog (*Litoria rubella*)
- green tree frog (*Litoria caerulea*)
- Peron's tree frog (*Litoria peronii*)
- spotted marsh frog (*Limnodynastes tasmaniensis*)

Abundance of all species was low. Diversity, however, was higher than on the permanent waterbodies sampled within the Selected Area. The Selected Area report concluded that this suggested that providing water to the Western Floodplain was important for maintaining regional scale frog diversity.

## 4 Unmonitored area outcomes

In this report, 'unmonitored' refers to sites that received Commonwealth environmental water, but were not measured as part of the LTIM project.

### 4.1 Highlights

- Monitoring of the fish species Murray hardyhead (*Craterocephalus fluviatilis*), listed as endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), indicated a strong positive response to Commonwealth environmental water in South Australia, although there was a potential negative effect at Cardross Lakes in Victoria.
- Multiple sites in South Australia recorded the presence of the EPBC-listed vulnerable southern bell frog (*Litoria raniformis*) coincident with Commonwealth environmental water.
- Potential breeding of the state-listed waterbird brolga (*Grus rubicunda*) was noted and some evidence (from calls) of breeding of the EPBC-listed endangered waterbird species Australasian bittern (*Botaurus poiciloptilus*) at Moodies swamp in the Goulburn River catchment in Victoria.
- Monitoring at Hattah–Kulkyne Lakes indicated benefits to a range of species and communities, including river red gum and black box woodlands, bush birds (including the threatened regent parrot, *Polytelis anthopeplus*), waterbirds (breeding of great cormorant (*Phalacrocorax carbo*), Australasian darter (*Anhinga novaehollandiae*) and pied cormorant (*Phalacrocorax varius*)) and provision of nursery grounds for native fish (including the threatened silver perch, *Bidyanus bidyanus*).
- There were small-scale temporary benefits to species and communities at the Macquarie Marshes, particularly in acting as a drought refuge in a dry landscape.

### 4.2 Aggregation of data from other sources

#### 4.2.1 Effects of CEW on waterbird, frog, turtle and mammal species diversity at unmonitored sites

Information on the ecological responses of waterbirds, frogs, turtles and mammals is summarised in Table 5. This table does not include important wetland sites such as Hattah-Kulkyne Lakes and Macquarie Marshes, which are considered in more detail in Section 4.3. The majority of the information collated is qualitative and includes very little additional evidence about the site that

received Commonwealth environmental water or how species or communities responded to water regime.

There were multiple observations of the EPBC listed vulnerable southern bell frog from South Australian wetlands (Overland Corner, Weilai, Markaranka, Akuna and Johnson's Waterhole). This frog species requires long periods of inundation (five to seven months) and breeds in spring to summer (Wassens et al. 2010). While the information available provides an indication of the length of the watering action, it does not provide any information on the period of inundation. All sites received water in spring and/or summer, and some for periods of over 5 months, however the potential benefits to the threatened species, including breeding and recruitment, remain uncertain without more detailed hydraulic information (see Methods section).

Other species of frog were only recorded by name at Johnson's Waterhole in South Australia, where a small number of species were observed; eastern banjo frog (*Limnodynastes dumerilii*), spotted marsh frog (*Limnodynastes tasmaniensis*), Peron's tree frog (*Litoria peronii*). Attempts or success at breeding and recruitment are unknown.

Breeding was observed (or considered likely due to behavioural observations) in a number of species. This includes brolga, Australasian bittern, swans, egrets and herons at Moodies Swamp in the Goulburn and grey teal (*Anas gracilis*) and Australasian darters (*Anhinga novaehollandiae*) at Mulcra Island. There were observations of waterbird breeding from Johnson's Waterhole, but species that bred were not provided.

Commonwealth environmental water was delivered to the Berri Saline Water Disposal Basin in South Australia for the EPBC listed endangered Murray hardyhead. This species was reintroduced to the site in 2012, following a captive breeding and translocation program and has been maintained by Commonwealth environmental water since that time (Ellis and Kavanagh 2014). High abundances of the species were recorded at the site in February 2015 (MDBA 2015). Murray hardyhead spawn from September to March, with peak spawning in late October to early November. They reach maturity within four or five months of spawning. They are largely an annual species (populations dominated by individuals aged less than one year) and therefore heavily reliant on yearly recruitment (Ellis and Kavanagh 2014). The high abundance of individuals in February suggests spawning and recruitment in response to Commonwealth environmental water.

**Table 5.** Summary of observations and other information from unmonitored watering actions related to waterbird, frog, turtle and mammal diversity in 2014-15. Note that many of these actions involved multiple water sources (in addition to Commonwealth environmental water). Additional information on the portfolio of environmental water can be found in the Basin Matter Hydrology Report (Stewardson and Guarino 2016).

Surface water region/asset (Watering Action Reference) <sup>1</sup>	Water delivery dates (start – end) <sup>1</sup>	Flow component type <sup>1</sup>	Commonwealth environmental water volume delivered (GL) <sup>1</sup>	Expected ecological outcome <sup>1</sup>	Observed ecological outcomes	Source of information
Goulburn – Moodies Swamp (10014-01)	06/10/14 – 02/12/14	Wetland inundation	0.25	Maintain wetland vegetation, especially southern cane grass, which provides nesting habitat for brolga  Provide opportunity for waterbird breeding, especially brolga	One hundred hectares inundated for 4 months  Brolga observed in courtship behaviour  Australasian bittern heard calling  Swans, egrets and herons observed	CEWO unpublished, Victorian Environmental Water Holder (VEWH) (2016)
Vic Murray – Mulcra Island (10009-02)	12/08/14 – 22/12/14	Wetland inundation	3.76	Secondary: Support suitable habitat conditions and food resources for water bird growth and survival, maintenance of population condition and diversity	Three threatened bird species observed: musk duck, eastern great egret and white-bellied sea eagle  Breeding of grey teal and Australasian darters	VEWH Operational Report of 24/11/2015
South Australia (SA) Murray – Berri Basin (10009-03)	01/09/14 – 30/06/15	Wetland inundation	1.241	Primary: Maintain water quality to levels in which a healthy Murray hardyhead population can be sustained, including breeding events (electrical conductivity (EC) 10 000–31 000 $\mu\text{S}/\text{cm}$ )  Secondary: Provide habitat for waterbird species, including threatened and migratory species	High abundances of Murray hardyhead recorded, linked to environmental watering at the site	<a href="http://www.mdfrc.org.au/projects/featured/MHHtranslocation.asp">http://www.mdfrc.org.au/projects/featured/MHHtranslocation.asp</a>
SA Murray – Overland Corner (10009-05)	17/12/14 – 15/05/15	Wetland inundation	0.842	Provide habitat for frogs, including the southern bell frog	Southern bell frog recorded	SA Murray–Darling Basin Annual Report 2014–15 (2015)

Surface water region/asset (Watering Action Reference) <sup>1</sup>	Water delivery dates (start – end) <sup>1</sup>	Flow component type <sup>1</sup>	Commonwealth environmental water volume delivered (GL) <sup>1</sup>	Expected ecological outcome <sup>1</sup>	Observed ecological outcomes	Source of information
SA Murray – Wella (10009-05)	12/11/14 – 21/02/15	Wetland inundation	0.255	Provide habitat for frogs, including the southern bell frog	Southern bell frog recorded	SA Murray–Darling Basin Annual Report 2014–15 (2015)
SA Murray – Markaranka South (10009-06)	01/12/14 – 07/06/15	Wetland inundation	1.652	Provide habitat for waterbird species, including threatened and migratory species Provide habitat for the regent parrot	Waterbird breeding event (no species provided) Southern bell frog and regent parrot recorded	Riverland West Landcare Annual Report (2015)
SA Murray – Markaranka East (10009-06)	06/01/15 – 24/02/15	Wetland inundation	0.6	Provide habitat for frogs, including the southern bell frog	Southern bell frog recorded	Riverland West Landcare Annual Report (2015)
SA Murray – Akuna (10009-06)	26/11/14 – 04/12/15	Wetland inundation	0.125	Provide habitat for frogs, including the southern bell frog	Southern bell frog recorded	SA Murray–Darling Basin Annual Report 2014–15 (2015)
SA Murray – Johnson’s Waterhole (00137-01)	02/09/14 – 15/06/15	Wetland inundation	0.162	Primary: Extend temporary feeding habitat for waterbirds and therefore increase the abundance and diversity of waterbirds  Secondary: Provide habitat for frog and aquatic invertebrate condition, abundance and diversity	Birds observed at the waterhole to date include pink-eared duck, black swan, black duck, chestnut teal, white-eyed duck, grey teal, Caspian tern, masked lapwing, Australian wood duck, banded lapwing, ibis, pelican, silver gull and hardhead  Many frogs have also taken advantage of the temporary habitat, including eastern banjo frog, spotted marsh frog, Peron’s tree frog and southern bell frog	Water for nature factsheet <a href="http://www.waterfornature.org.au">www.waterfornature.org.au</a>

<sup>1</sup> As reported by the Commonwealth Environmental Water Office (CEWO unpublished).

Note: sites for which no information could be sourced have been excluded.



### 4.3 Important wetland case studies

Five DIWA / Ramsar sites were the target of Commonwealth environmental water in 2014-15 and had expected outcomes related to diversity. Two sites (Gingham and Lower Gwydir (Big Leather) Watercourses and Lowbidgee wetlands, which includes Yanga Lake) are within Selected Areas and considered under the Selected Area monitoring in Section 3 above. This leaves three sites selected as case studies for the evaluation of unmonitored sites:

- Cardross Lakes – DIWA
- Hattah-Kulkyne Lakes – DIWA and Ramsar
- Macquarie Marshes – DIWA and Ramsar

It should be noted that at least two DIWA / Ramsar sites received Commonwealth environmental water as a result of water delivery from Queensland (Narran Lakes and The Lower Balonne Floodplain). Similarly, the Coorong and Lakes Alexandrina and Albert Ramsar Site received inflows from the Murray River that contained a component of Commonwealth environmental water. However, inundation of these sites was not quantified during 2014–15 and, in the absence of information on the watering actions, could not be evaluated with respect to potential ecological responses and generic diversity. These areas will be included in future evaluation when observational information or modelling of inundation is sufficient to support the evaluation.

#### 4.3.1 Cardross Lakes

##### What was the Expected Outcome?

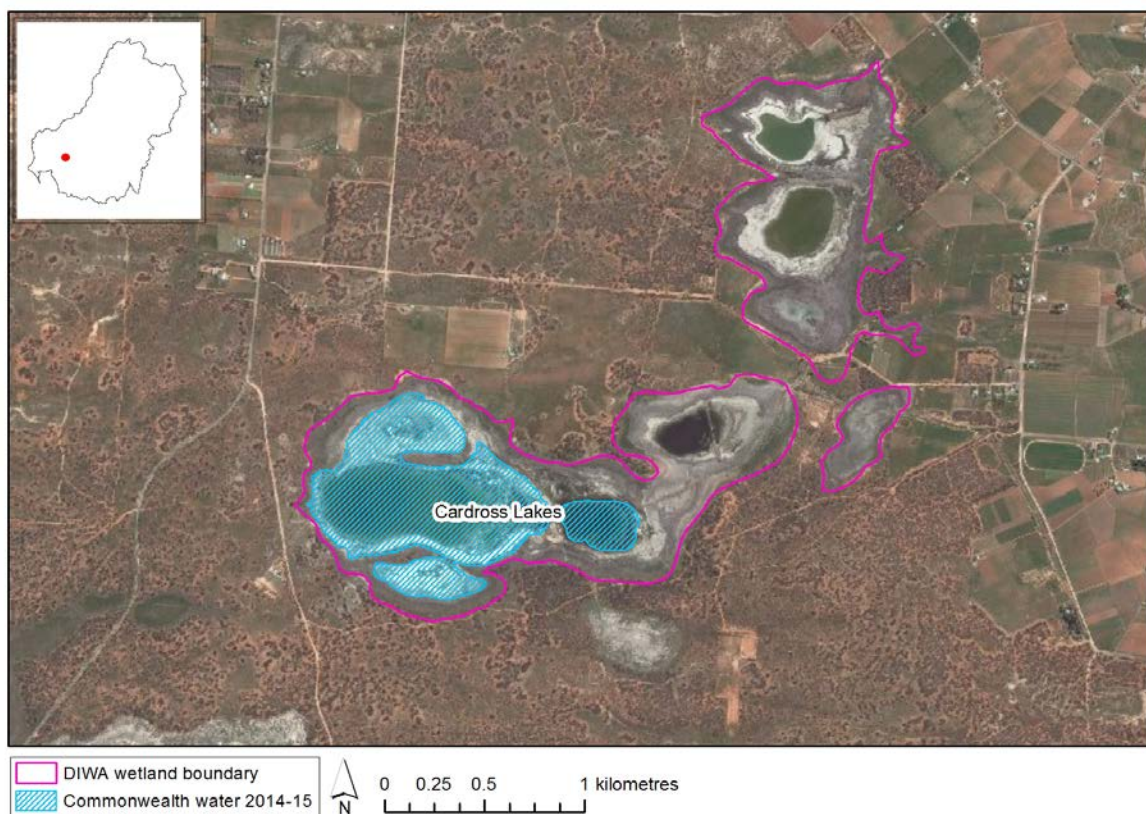
The expected outcome is not clear in the acquittal report for the Mallee Wetlands Victoria (CEWO unpublished), but is assumed to be *“Increase the abundance and distribution of Murray hardyhead by providing suitable habitat.”*

##### What information is available about the watering action?

A total of 576.6 megalitres (ML) of environmental water was delivered to Cardross Lakes, 288.3 ML of which was Commonwealth environmental water. The water extended across the lower basin (Basin 1) which is also called Cardross Lake (Figure 4) covering approximately 80 hectares of predominantly open water habitat (ANAE wetland type: temporary saline lakes). The effect of Commonwealth environmental water on duration or depth of inundation is not known.

##### What evidence is available to evaluate the outcome?

The Cardross Lakes DIWA site comprises a chain of wetlands that when fully inundated are interconnected. Basin 1 (Cardross Lakes) is the southernmost wetland and was the target of the environmental watering action. The site was identified as a nationally important wetland largely on the basis of supporting threatened fish populations; in particular, EPBC-listed endangered Murray hardyhead (*Craterocephalus fluviatilis*) (Directory of Important Wetlands in Australia <http://www.environment.gov.au/node/25064>).



**Figure 4.** Extent of inundation at Cardross Lakes during environmental watering 2014-15.

There is a population monitoring program for Murray hardyhead (Ellis et al. 2014), which was the target of this environmental watering action. Murray hardyhead are recorded most often in wetlands with brackish salinity ( $> 4000 \mu\text{S}/\text{cm}$ ), although they have a wide salinity tolerance (Ellis et al. 2014). Monitoring indicates that there was low abundance of Murray hardyhead in 2014-15 in Cardross Lakes following environmental watering. It was suggested that high freshwater inflows lowered salinity and may have negatively impacted Murray hardyhead through: increased abundance of competing small-bodied fish species; and a decline in the saline submerged plant *Ruppia* spp. which provides spawning habitat (Huntley in prep.). The abundance of Murray hardyhead at Cardross Lakes has declined from peaks of  $> 100$  catch per net in 2011 to isolated records in 2015 (Huntley in prep.).

#### What species/communities potentially benefited?

The endangered Murray hardyhead has undoubtedly benefited from environmental water over the past two decades. It seems likely, however, that there was little benefit, and possibly a negative impact in the 2014-15 watering year. A good adaptive management program is in place at the site, with lessons learned from 2014-15 environmental watering resulting in a revised watering regime for future years (Huntley in prep.).

#### 4.3.2 Hattah - Kulkyn Lakes

##### What was the Expected Outcome?

The Expected Outcomes were to:

- Increase the diversity, extent and abundance of wetland and floodplain vegetation communities, particularly river red gum and black box woodlands; and

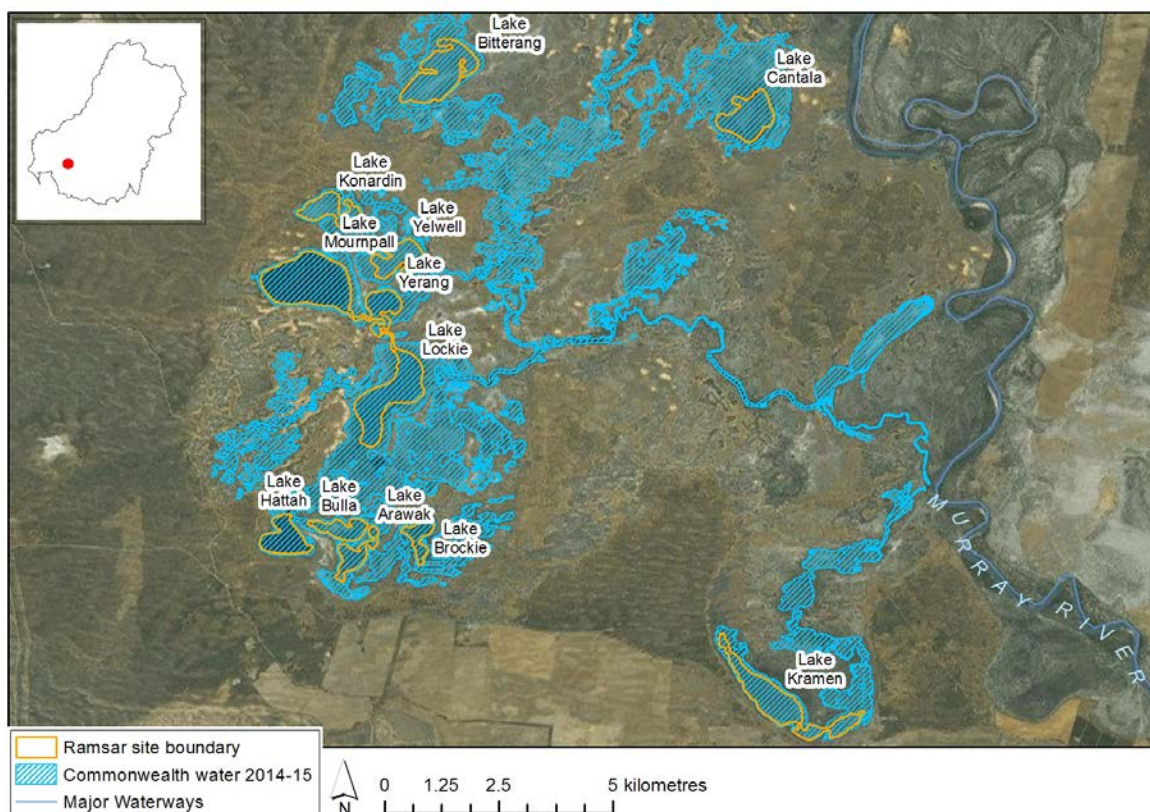
- *Restore and maintain wetlands and floodplain habitat to support fish communities and waterbird breeding.*

### What information is available about the watering action?

A total of 106,178 ML of environmental water was delivered to Hattah-Kulkyne Lakes, 1505 ML of which was Commonwealth environmental water. Water was delivered to the site via pumping from the Murray River commencing in May 2014 and was completed in January 2015. All 12 lakes that comprise the Hattah-Kulkyne Lakes Ramsar site were inundated as well as wetlands outside the Ramsar boundary and areas of surrounding floodplain (Figure 5).

The Ramsar site boundary follows the wetland boundaries and excludes much of the surrounding floodplain. So while the inundation data presented in Table 6 indicates that the majority of inundation was of open lakes (temporary floodplain lakes) there would have been extensive areas of river red gum woodland and black box woodland inundated as well.

There is a good record of inundation in the Hattah-Kulkyne Lakes. The lakes filled from natural floods in 2010-11 and were dry in 2011-12 and 2012-13. In 2013, environmental works were completed which included the construction of a permanent pump station, regulators and environmental levees to allow for more effective environmental watering at the site. The lakes were inundated in 2013-14 and the 2014-15 represented a second large scale watering action at the site (Henderson et al. 2014).



**Figure 5.** Extent of inundation at Hattah-Kulkyne Lakes during environmental watering 2014-15. Note that the orange line indicates the Ramsar boundary, which includes only the lake beds of the wetlands.



**Table 6.** ANAE wetland and floodplain types inundated from environmental watering in 2014-15 at Hattah-Kulkyne Lakes Ramsar Site.

Australian National Aquatic Ecosystem (ANAE) wetland type	Area inundated (hectares)
Lt1.1: Temporary lakes	4
Lt2.1: Temporary floodplain lakes	1236
Pt1.1: Temporary swamp	201
Pt4: Temporary wetland	20
Pt1.1.1: Intermittent River red gum floodplain swamp	44
Pt1.2.1: Intermittent Black box floodplain swamp	< 1
Pt1.6.1: Temporary woodland floodplain swamp	< 1
<b>Total</b>	<b>1505</b>

### What evidence is available to evaluate the outcome?

Hattah-Kulkyne Lakes were listed as a Ramsar site in 1982 for a high diversity of wetland dependent plant species, breeding of waterbirds and fish and supporting threatened species: Australasian bittern (*Botaurus poiciloptilus*), Australian painted snipe (*Rostratula australis*), regent parrot (*Polytelis anthopeplus*), silver perch (*Bidyanus bidyanus*), Murray cod (*Maccullochella peelii peelii*), flat-headed galaxias (*Galaxias rostratus*), and winged peppercress (*Lepidium monoplacoides*) (Butcher and Hale 2011).

Hattah-Kulkyne Lakes is an example of a site where there is a large amount of information available, primarily through other monitoring programs conducted on behalf of the Mallee Catchment Management Authority (CMA) and MDBA. Monitoring outcomes of environmental water were available from 2014-15 for vegetation (Moxham and Kenny 2015), fish (Brown et al. 2015, Wood et al. 2015) and birds (Robertson and Hurley 2015, Loyn and Dutson 2016). In addition, responses to watering measured on the previous year provide some indication on likely responses of biota for which information for the 2014-15 watering year was not yet available (Mallee CMA 2014, Hughes et al. 2016).

Environmental watering resulted in increased canopy cover of river red gum and black box communities (Moxham and Kenny 2015, Hughes et al. 2016). While seedlings of river red gum and black box were recorded, recruitment of woody species decreased following 2014-15 watering, most likely due to seedling death from inundation (Moxham and Kenny 2015). Species composition was affected by environmental water with 27 native species and 6 exotic species associated with inundation (Moxham and Kenny 2015). Two species listed as threatened under the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act) were recorded; Darling lily (*Crinum flaccidum*) and curly flat-sedge (*Cyperus rigidellus*). These species are both associated with damp soil and periodic inundation, but whether these species benefited from environmental water is uncertain (Moxham and Kenny 2015).

The assessment of fish in the Hattah-Kulkyne Lakes concluded that environmental watering clearly allows the Hattah-Kulkyne Lakes to function as a “nursery-environment” for a range of species found within the southern Murray–Darling Basin (Brown et al. 2015). This includes silver perch, which is listed as critically endangered under the EPBC Act. Monitoring indicates that the source of some species sampled was the lakes, suggesting spawning in the lakes by golden perch (*Macquaria ambigua*), bony herring (*Nematalosa erebi*) and Australian smelt (*Retropinna semoni*). There is evidence that some species can move back into the river during a connecting flow, with golden

perch, Murray cod and bony herring detected moving out of the lake system into the main river channel. In addition, fish remaining within the wetland system can contribute to food webs by providing food for fish-eating birds.

Monitoring indicated that environmental watering benefited a number of species of bush birds, which were markedly more abundant on sites that had been inundated or were in flood recession than on sites that did not receive environmental water (Loyn and Dutson 2016). Increases in productivity and food resources benefited several species of insectivores, nectivores and seed eating species, including the EPBC listed vulnerable regent parrot.

Environmental watering over the two years (2013-2014 and 2014-15) resulted in high abundances of waterbirds, particularly fish eating species. The highest abundance of great cormorant (*Phalacrocorax carbo*) and Australasian darter (*Anhinga novaehollandiae*) were recorded at the Ramsar site since listing occurred in June 2014 (Mallee CMA 2014). This record includes a count of 1115 great cormorant, which represents more than 1% of the Australian population. This high abundance of fish eating species indicates high productivity and available food resources (fish). There were observations of breeding of Australasian darter and great cormorant at Lakes Arawak, Yelwell, Hattah and Mournpall, with Lake Yelwell also supporting the breeding of pied cormorant (*Phalacrocorax varius*) (Mallee CMA 2014). Overall 25 species from 5 guilds were recorded indicating a variety of habitats provided at the site.

Although the threatened species Australasian bittern has been previously recorded at the site, the species is known to inhabit emergent reed and sedge beds, and there was little of this habitat available at the site in 2014-15. The majority of the site was either open water with submerged plants or inundated woodland (Hughes et al. 2016) and so the watering action is unlikely to have benefited this species. Similarly, habitat for the Australian painted snipe (and other migratory wader species) would be limited to the flood recession, and number of small waders were very low (Mallee CMA 2014).

### What species / communities potentially benefited?

There is evidence to suggest that a wide range of species benefited from Commonwealth environmental water at Hattah-Kulkyne Lakes in 2014-15 (Table 7).

**Table 7.** Species and communities that potentially benefitted from Commonwealth environmental water at Hattah-Kulkyne Lakes in 2014-15.

Community / species	Evidence
River red gum woodland	Increased canopy cover; decreased recruitment
Black box woodland	Increased canopy cover, decreased recruitment
27 species of native plant (see Appendix B for full list)	Occurred only in inundated sites or in significantly greater abundance in inundated sites
Silver perch	Otolith sampling indicates spawning in the Murray River, followed by movement into the Hattah–Kulkyne Lakes, which acted as a nursery for the species
Golden perch, bony herring	Monitoring indicates potential spawning in the lakes following inundation in 2013-2014 and movement back to the river in 2014-15
Australian smelt	Monitoring indicates potential spawning in the lakes
Murray cod	Movement out of the lakes into the river, suggests habitat use in the lakes
Carp gudgeon	Monitoring indicates high abundance in lakes following inundation

Community / species	Evidence
A range of bush birds (see Appendix B for full list)	High abundance following inundation suggesting increased productivity benefits
Regent parrot	Increased seed abundance providing food resources, high abundance in receded flood sites (3.3 birds per hectare per 10 min survey)
Great cormorant, Australasian darter, pied cormorant	High abundances and breeding observed

### 4.3.3 Macquarie Marshes

#### What was the Expected Outcome?

The primary Expected Outcomes were:

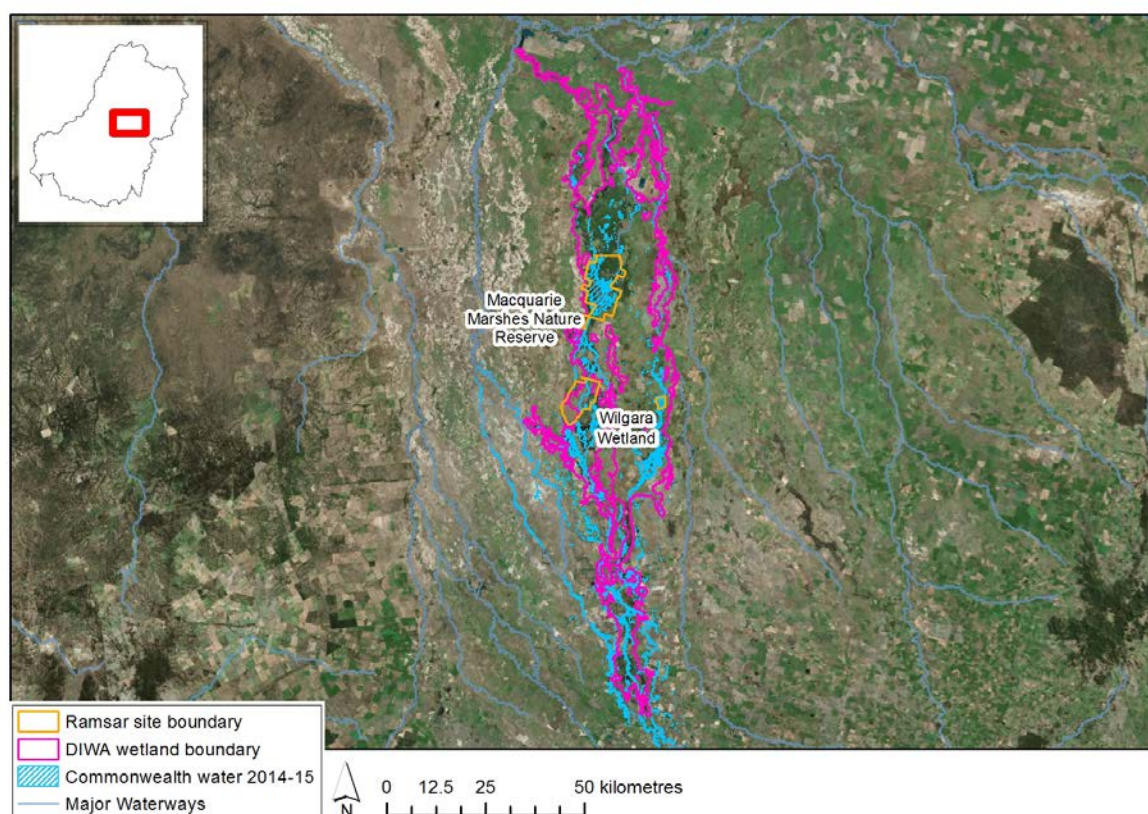
- *To inundate core wetlands in the Macquarie Marshes and contribute to annual water requirements of native marsh vegetation; and*
- *To support native fish habitat by increasing availability of and access to suitable fish habitat, promoting fish movement and providing cues and appropriate habitats for spawning, recruitment and migration of native fish.*

#### The secondary Expected Outcomes were to:

- *Maintain vegetation condition and reproduction;*
- *Provide refuge habitat for waterbirds, fish and other aquatic species*
- *Maintain ecosystem resilience by supporting individual survival and condition;*
- *Provide baseflows and freshes to increase lateral and longitudinal hydrological connectivity; and*
- *Allow for sediment transport, nutrient and carbon cycling.*

#### What information is available about the watering action?

A total of 28,494 ML of environmental water was delivered to the Macquarie Marshes, 10,000 ML of which was Commonwealth environmental water. Delivery of environmental water from Burrendong dam commenced October 5 2014, with flows reaching the entrance to the Northern Marshes on October 22 2014. By early November water was expanding out of the channel to fill some of the southern marsh areas. Water delivery continued until 12 December 2014. Although duration of inundation is not known, the Watering Action Acquittal Report for Macquarie Catchment (CEWO unpublished) indicates that conditions were hot and inundation of the wetlands and floodplains is unlikely to have persisted for long.



**Figure 6.** Total extent of inundation at Macquarie Marshes by all sources of water, including Commonwealth environmental water and NSW environmental entitlements during environmental watering 2014–15.

Water inundated approximately 4600 hectares of the 19,850 hectare Ramsar site (Table 8). The Ramsar site comprises the northern and southern sections of the Macquarie Marshes Nature Reserve as well as two additional disjunct areas “U-block” and “Wilgara”. Within the Ramsar site the inundation was predominantly of ANAE wetland type “permanent floodplain wetland”, with smaller areas of ‘Intermittent River red gum floodplain swamp’ inundated. It should be noted, however, that ANAE classifications are broad, and the ecological character description for the site indicates that the area described as “permanent floodplain wetland” in Table 8 is more accurately described as intermittent marsh with emergent vegetation such as common reed (*Phragmites australis*), cumbungi (*Typha* spp.) and water couch (*Paspalum distichum*) (Office of Environment and Heritage 2012).

The DIWA site covers the entire 200,000 hectare Macquarie Marshes floodplain and 8100 hectares of the Northern and Southern Marshes was inundated by the combined Commonwealth and New South Wales environmental watering action in 2014–15 in this broader area. This comprised large areas of ‘Sedge/forb/grassland floodplain’ and ‘River red gum forest floodplain (Table 9).

**Table 8.** ANAE wetland and floodplain types inundated from Commonwealth and NSW environmental watering in 2014-15 at the Macquarie Marshes Ramsar site.

Australian National Aquatic Ecosystem (ANAE) wetland type	Area inundated (hectares)
Lt2.1: Temporary floodplain lakes	42
Pp2.1.2: Permanent tall emergent marshes	19
Pp2.3.1: Permanent floodplain grass marshes	13
Pp2.3.2: Permanent grass marshes	7

Australian National Aquatic Ecosystem (ANAE) wetland type	Area inundated (hectares)
Pp4.1: Permanent floodplain wetland	4149
Pp4.2: Permanent wetland	13
Pt1.1.1: Intermittent River red gum floodplain swamp	321
Pt1.1.2: Intermittent River red gum swamps	1
Pt1.4.2: Intermittent River Cooba swamp	17
Pt1.6.1: Temporary woodland floodplain swamp	2
Pt2.2.1: Temporary sedge/grass/forb floodplain marsh	2
Pt2.2.2: Temporary sedge/grass/forb marsh	1
Pt2.3.1: Floodplain freshwater meadow	7
Pt3.1.1: Floodplain clay pans	1
Pt3.1.2: Clay pans	38
<b>Total</b>	<b>4633</b>

**Table 9.** Additional ANAE floodplain types inundated from Commonwealth and NSW environmental watering in 2014-15 at the Macquarie Marshes DIWA site.

Australian National Aquatic Ecosystem (ANAE) wetland type	Area inundated (hectares)
F1.1: Upland river red gum forest floodplain	1
F1.2: River red gum forest floodplain	1663
F1.4: River red gum woodland floodplain	325
F2.4: Shrubland floodplain	3
F3.2: Sedge/forb/grassland floodplain	6134
F4: Floodplain with unspecified vegetation	27
<b>Total</b>	<b>8154</b>

### What evidence is available to evaluate the outcome?

The Macquarie Marshes was listed as a Ramsar site in 1986 for its extensive wetland vegetation communities; abundance of waterbirds; supporting migratory birds listed under international treaties; supporting waterbird breeding, particularly colonial nesting species; the native fish community and supporting threatened species: Australasian bittern (*Botaurus poiciloptilus*), Australian painted snipe (*Rostratula australis*), superb parrot (*Polytelis swainsonii*), Murray cod (*Maccullochella peelii peelii*), and aromatic peppercreep (*Lepidium hyssopifolia*) (Office of Environment and Heritage 2012).

Ecological monitoring of environmental water deliveries in the Macquarie catchment is undertaken by NSW OEH including: inundation mapping via remote sensing; bird monitoring in October 2014, with on ground observations of bird activity; vegetation condition and community extent surveys in autumn 2015; frog surveys in early December 2014 and late January 2015. At the time of preparation, only the vegetation, waterbird and fish data was available.



The watering action inundated approximately a quarter of the Macquarie Marshes Ramsar site and less than 10 % of the more extensive DIWA site. This, together with the short duration of inundation, would limit the benefits to species and communities. Observations detailed in the CEWO acquittal report indicate:

- a short, positive response in vegetation condition in core wetland areas
- low abundance, but moderate diversity of waterbirds (species not identified)
- presence of four species listed under international migratory agreements — sharp-tailed sandpiper (*Calidris acuminata*), marsh sandpiper (*Tringa stagnatilis*), common greenshank (*Tringa nebularia*) and Latham's snipe (*Gallinago hardwickii*)
- no waterbird breeding observed
- low abundance and diversity of frogs (some evidence of breeding and recruitment).

The migratory shorebirds recorded at the site all have foraging habitat preferences for shallow water at the edge of wetland, often among vegetation (Higgins and Davies 1996). The Ramsar site would have provided good feeding habitat for these species, especially on the flood recession.

Monitoring of fish in response to the 2014-15 watering action included sites within the Macquarie Marshes Ramsar site. There was limited evidence of recruitment, within the Macquarie Marshes with the exception of bony bream (*Nematalosa erebi*). Six native species of fish were recorded in the Macquarie Marshes channels during the environmental watering action: carp gudgeon (*Hypseleotris* spp.), spangled perch (*Leiopotherapon unicolor*), golden perch (*Macquaria ambigua*), Murray cod, Murray-Darling rainbowfish (*Melanotaenia fluviatilis*) and bony bream. Number of exotic species such as common carp (*Cyprinus carpio*), however, comprised 30-60 % of the total abundance (Stocks et al. 2015).

### What species / communities potentially benefited?

There is evidence to suggest that a number of species and communities potentially benefited from Commonwealth environmental water at the Macquarie Marshes in 2014-15 (Table 10).

**Table 10.** Species and communities that potentially benefitted from Commonwealth environmental water in the Macquarie Marshes in 2014-15.

Community / species	Evidence
River red gum forest and woodland	No direct evidence, but inundation of over 2000 hectares of this community is likely to have had some benefit, even if short-lived.
Emergent marsh vegetation	Observations of a short term increase in condition.
Bony herring	Potential spawning within the Ramsar site
Carp gudgeon, spangled perch, golden perch, Murray cod, Murray-Darling rainbow fish	Short term habitat availability
Sharp-tailed sandpiper, marsh sandpiper, common greenshank and Latham's snipe	Short term foraging habitat

#### **4.4 Effect of Commonwealth environmental water on species diversity**

Commonwealth environmental water contributed to the inundation of approximately 48% of the wetland types in the Basin (as determined by the interim ANAE classification of wetlands and floodplains in the Basin; Brooks 2016; Appendix B). This has contributed to maintaining (or restoring) ecosystem diversity and the species and communities upon which those ecosystems depend.

Lists of species that potentially benefited from Commonwealth environmental water in 2014–15 are provided in Appendix B and comprise:

- 47 species of plants
- 11 species of fish
- 48 species of bush birds
- 59 species of waterbird
- 10 species of frog
- 2 species of turtle.

## **5 Basin-scale outcomes**

### **5.1 Highlights**

- Strong evidence was provided to suggest that Commonwealth environmental water contributed significantly to maintaining the ecological character of the Hattah–Kulkyne Lakes Ramsar site.
- Some evidence suggested that Commonwealth environmental water contributed to maintaining the ecological character of the Macquarie Marshes Ramsar site, especially in the context of a regionally dry period.
- Eighteen species of conservation significance were recorded at sites that received Commonwealth environmental water.
- Large-scale environmental watering occurred in the Gwydir catchment, resulting in benefits to a large range of species and communities.

### **5.2 Synthesis**

In this first year of data collection and evaluation, assessing the significance of Commonwealth environmental water at the Basin scale has a high degree of uncertainty. As the portfolio of watering actions increases over time and we have results from multiple years at a larger number of locations, confidence will increase in our evaluation of Basin scale outcomes. Therefore, this first assessment of Basin scale outcomes is focused on three more certain pathways:

1. Contributions to maintaining the ecological character of Ramsar sites is of international significance and so can be considered significant at the Basin scale.
2. Benefits to threatened species and communities which, by definition, are also considered significant at the Basin scale.
3. The effects of large-scale environmental watering actions that inundated a significant proportion of a catchment that would otherwise have remained dry could be considered significant at the Basin scale.

#### **5.2.1 Maintaining the ecological character of Ramsar sites**

Two case studies have been selected for an assessment of the effects of Commonwealth environmental water on maintaining the ecological character of Ramsar sites in the Basin: Hattah-Kulkyne Lakes and Macquarie Marshes. In each case, consideration has been given to the

relationship of Commonwealth environmental water to the identified critical components, processes and services.

The ecological character description for the Hattah-Kulkyne Lakes Ramsar site identifies four components / process and five services as critical to ecological character (Butcher and Hale 2011). The potential contribution of Commonwealth environmental water to maintaining each of these identified critical components, processes and services is provided in Table 11.

**Table 11.** Contribution of Commonwealth environmental water in 2014-15 to maintaining the ecological character of the Hattah-Kulkyne Lakes Ramsar site.

<b>Critical components, processes and services</b>	<b>Description</b>	<b>Contribution of Commonwealth environmental water</b>
Hydrology	Lakes are filled via Chalka Creek (now via modified infrastructure). While the majority of the lakes dry within 12 months after inflows cease, Lakes Mournpall and Hattah can retain water for several years post flooding.	Environmental water delivered through the new infrastructure is designed to meet the hydrological needs at the site. This critical process is directly maintained by environmental water.
Lake bed herbland vegetation	Dominant vegetation across all lakes is lake bed herbland. It shifts from being dominated with aquatic and amphibious species with some terrestrial species on the edges in the wet phase, to being dominated by terrestrial species in the dry phase.	Evidence of aquatic specie dominance during the wet phase of environmental watering, with expectations of increased diversity of amphibious and terrestrial damp species on flood recession.
Fish	Fish fauna is dominated by small bodied native species. Site regularly supports: Australian smelt, bony herring, carp gudgeon and flyspecked hardyhead.	Evidence that Commonwealth environmental water benefited a range of fish species including Australian smelt, bony herring and carp gudgeon
Waterbirds	Supports 70 species of waterbirds, 12 of which are covered by international migratory bird treaties. Thirty-four species have been recorded breeding at the site.	Twenty-five species of waterbird recorded at the site following environmental watering. High abundances of fish eating species and >1% of the population of great cormorant.
Supports near-natural wetland ecosystems	The site represents the largest series of floodplain lakes along the Murray River and is in relatively good condition.	Strong evidence to suggest the environmental water contributed to maintaining the site in good condition.
Provides physical habitat (for breeding waterbirds)	Hattah-Kulkyne Lakes provide habitat that supports waterbird breeding and feeding.	Habitat suitable for breeding of at least three species of fish eating birds.
Supports threatened wetland species	Australasian bittern, Australian painted snipe, regent parrot, silver perch, Murray cod, flat-headed galaxias and winged peppercress.	Good evidence that environmental water in 2014-15 supported silver perch, Murray cod and regent parrot
Biodiversity	The site supports regionally significant range and number of species comparable to other sites within the Murray Darling Basin. This includes supporting a large number and variety	Large number of species and communities potentially benefited from Commonwealth environmental water in 2014-15 (see Table 7).

Critical components, processes and services	Description	Contribution of Commonwealth environmental water
	of waterbirds, including breeding habitat for many waterbird species and a rich and diverse flora and seed bank.	
Ecological connectivity	Hattah-Kulkyne Lakes are hydrologically and ecologically connected and provide semipermanent surface water in a semi arid environment thus ensuring ecological persistence of aquatic habitats.	Evidence of connectivity (hydrological and biological) through the delivery of environmental water and return flows in 2014-15.

The ecological character description for the Macquarie Marshes Ramsar site identifies four components / process and five services as critical to ecological character (Office of Environment and Heritage 2012). Potential contribution of Commonwealth environmental water to maintaining each of these identified critical components, processes and services is provided in Table 12. While the watering action was over only a portion of the Ramsar site and for a relatively short duration, there is some evidence of contributions to maintaining ecological character, especially in terms of drought refuge in a dry landscape.

**Table 12.** Contribution of Commonwealth environmental water in 2014-15 to maintaining the ecological character of the Macquarie Marshes Ramsar site.

Critical components, processes and services	Description	Contribution of Commonwealth environmental water
Wetland types and vegetation	River red gum woodland and forests (6500 hectares) Common reed beds (3350 hectares) Cumbungi rushland (280 hectares) Water couch marsh (1100 hectares) Mixed marsh grasslands (50 hectares) Lagoons (90 hectares) Coolibah woodland and black box woodland (720 hectares) Lignum (200 hectares)	Environmental water inundated a range of vegetation communities and although for only a relatively short duration, would have contributed to maintaining condition during a regionally dry period.
Aquatic invertebrates	High densities of microinvertebrates, which are an important food source for fish. Also supports a diversity of macroinvertebrate species.	Possible that the inundation of the wetland and floodplain systems resulted in increased productivity and abundance of microinvertebrates for a short period.
Fish species diversity	Eleven species of native fish recorded. Provides rich productive feeding habitats, and spawning habitat for several species.	Some evidence of spawning of bony bream, and potential increase in productivity from inundation of the Ramsar site. However, very high abundance of exotic fish species.
Waterbird abundance and diversity	Supports over 70 species of waterbirds, with between 10,000 and 30,000 adult waterbirds reliant on the site each season.	Limited benefits for waterbirds, given the small nature of the inundation.

Critical components, processes and services	Description	Contribution of Commonwealth environmental water
Waterbird breeding	Sixteen species of colonial nesting waterbirds, with colonies of more than 500 nests on average in nine in every 15 years.	No evidence of colonial nesting breeding for this watering action.
Migratory birds and waders	Seventeen species listed under international migratory agreements have been recorded at the site.	Four international migratory waders recorded at the site, albeit in small numbers.
Supports threatened wetland species	Australasian bittern, Australian painted snipe, superb parrot, Murray cod and aromatic peppergrass.	No evidence that this watering action benefited threatened species at the site.

### 5.2.2 Threatened species

Eighteen significant species were recorded at sites that received environmental water in 2014-15 (Table 13). This includes three international migratory waterbird species, eight nationally listed threatened species and seven listed under state legislation. It is anticipated that as LTIM progresses and more data become available, this list will not only grow, our understanding of how Commonwealth environmental water is benefiting these species across the Basin will also increase.

**Table 13.** Listed species that were recorded at sites that received Commonwealth environmental water in 2014-15.

Group	Common name	Species name	Significance <sup>1</sup>
Birds	Common greenshank	<i>Tringa nebularia</i>	JAMBA, CAMBA, ROKAMBA
	Latham's snipe	<i>Gallinago hardwickii</i>	JAMBA, CAMBA, ROKAMBA
	Sharp-tailed sandpiper	<i>Calidris acuminata</i>	JAMBA, CAMBA, ROKAMBA
	Magpie goose	<i>Anseranas semipalmata</i>	Vulnerable (NSW)
	Brolga	<i>Grus rubicunda</i>	Vulnerable (NSW, VIC)
	Australasian bittern	<i>Botaurus poiciloptilus</i>	Endangered (EPBC)
	Regent parrot	<i>Polytelis anthopeplus</i>	Vulnerable (EPBC)
	White-bellied sea eagle	<i>Haliaeetus leucogaster</i>	Vulnerable (VIC)
	Eastern great egret	<i>Ardea modesta</i>	Vulnerable (VIC)
	Musk duck	<i>Biziura lobata</i>	Vulnerable (VIC)
Fish	Eel-tailed catfish	<i>Tandanus tandanus</i>	Endangered (NSW, VIC)
	Murray hardyhead	<i>Craterocephalus fluviatilis</i>	Endangered (EPBC)
	Silver perch	<i>Bidyanus bidyanus</i>	Endangered (EPBC)
	Trout cod	<i>Maccullochella macquariensis</i>	Endangered (EPBC)
	Murray cod	<i>Maccullochella peelii</i>	Vulnerable (EPBC)
Frogs	Southern bell frog	<i>Litoria raniformis</i>	Vulnerable (EPBC)
Plants	Basalt peppergrass	<i>Lepidium hyssopifolium</i>	Endangered (EPBC)
	Rigid water milfoil	<i>Myriophyllum porcatum</i>	Vulnerable (EPBC)

<sup>1</sup> CAMBA = China–Australia Migratory Bird Agreement; JAMBA = Japan–Australia Migratory Bird Agreement;  
 ROKAMBA = Republic of Korea – Australia Migratory Bird Agreement;  
 EPBC = Environment Protection and Biodiversity Conservation (Act)

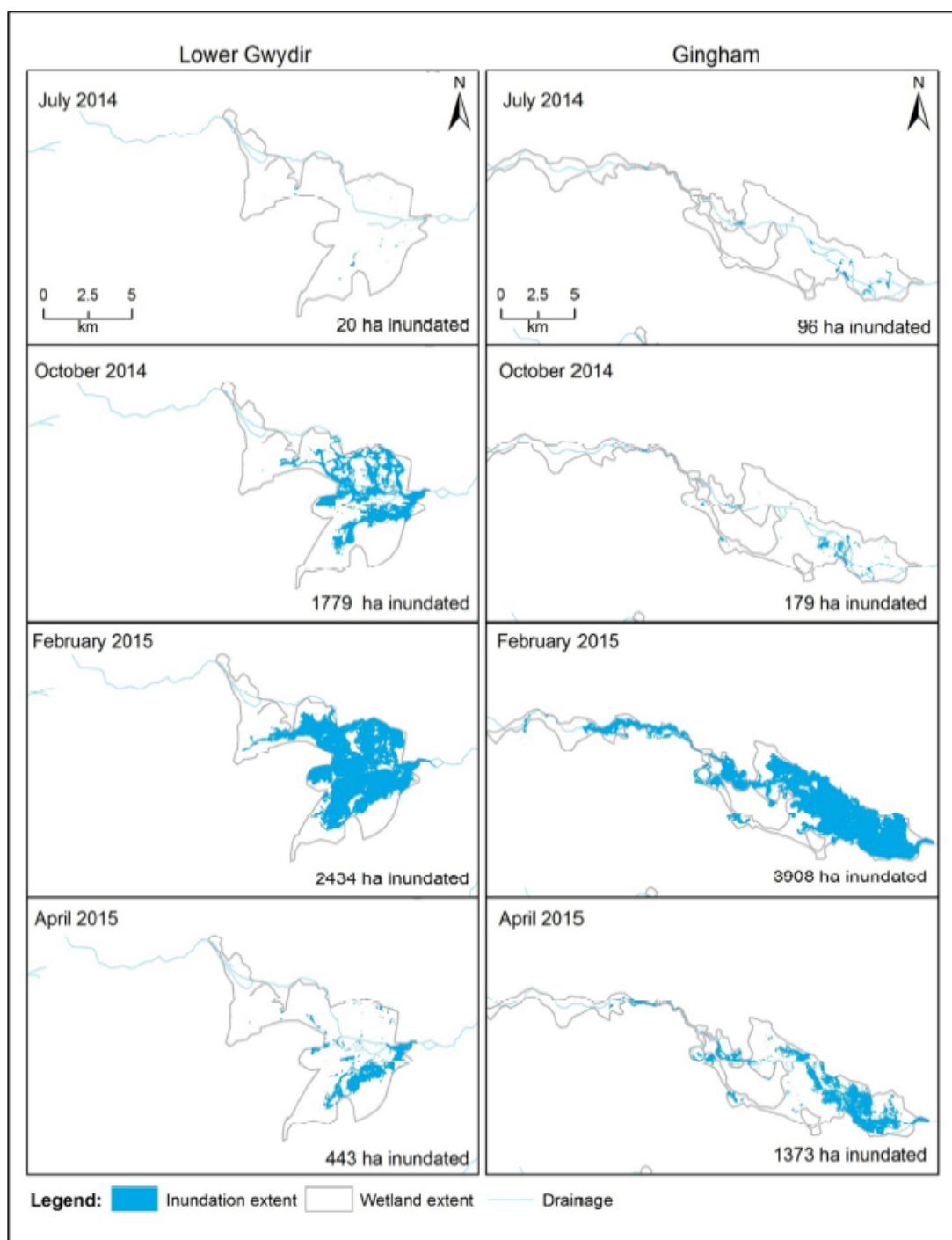
### 5.2.3 Large scale inundation

Environmental water delivery to the Gwydir wetlands followed a prolonged dry period. Environmental water inundated approximately 6700 hectares of wetlands across the Gingham and Lower Gwydir wetlands (Ramsar listed site) with peak inundation in late summer (Figure 5). Habitats inundated included large areas of sedge / forb / grassland as well as woodland floodplain (Table 14).

**Table 14.** ANAE floodplain types inundated from environmental watering in 2014-15 at the Gingham and Lower Gwydir Ramsar site.

Australian National Aquatic Ecosystem (ANAE) floodplain type	Area inundated (hectares)
F1.10: Coolibah woodland and forest floodplain	44
F1.11: River cooba woodland floodplain	470
F1.4: River red gum woodland floodplain	1660
F3.2: Sedge/forb/grassland floodplain	4556
F4: Floodplain with unspecified vegetation	10
<b>Total</b>	<b>6741</b>

Commonwealth environmental water contributed approximately 50 % of the total water volume in the wetlands of the Selected Area (the remainder being provided from state environmental water reserves). In the absence of environmental water the wetlands would have been largely dry. This large-scale water event that persisted over many months would have benefited a large number of aquatic ecosystem dependent species and communities. The size of the watering actions, and the high biodiversity values of the Gingham and Lower Gwydir Ramsar site support the premise that these outcomes were of Basin scale significance.



**Figure 7: Inundation extents mapped in the Gingham and Lower Gwydir wetlands in the 2014-15 water year (CEWO 2015a).**

## 6 Contribution to achievement of Basin Plan objectives

The environmental water outcomes framework is a hierarchy of Expected Outcomes based around the Basin environmental watering objectives. Expected Outcomes are matters that best available science indicates can be achieved from environmental watering (CEWH 2013):

- within a 1-year time frame (1-year expected outcomes)
- within a 1–5-year time frame (5-year expected outcomes).

Despite the limitation of the data available in year 1, the outcomes framework provides a template for synthesising outcomes of environmental water and progress towards meeting Basin Plan objectives. There is evidence across the Basin that Commonwealth environmental water is contributing to Basin Plan objectives for ecosystem and species diversity (Table 15).

**Table 15.** Contribution of CEWO watering in 2014-2105 to Basin Plan objectives associated with Generic Diversity.

Basin Plan objectives	Basin Outcomes		Five-year Expected Outcomes	One-year Expected Outcomes	Measured and predicted one-year outcomes 2014-15
Biodiversity (Basin Plan S. 8.05)	Ecosystem diversity		None identified	None identified	Total of 79,000 hectares of mapped wetland inundated. 48% of the different wetland types and 79% of the different floodplain types
	Species diversity	Vegetation	Vegetation diversity	Reproduction	Mostly, but not consistently increased diversity and cover of vegetation communities
				Condition	
			Growth and survival	Germination Dispersal	
		Macro-invertebrates	Macroinvertebrate diversity		
		Fish	Fish diversity	Condition	Comparatively high level of nativeness in fish assemblages.
				Larval abundance Reproduction	Spawning by golden perch, bony bream
			Larval and juvenile recruitment		Evidence of Murray hardyhead recruitment
		Waterbirds	Waterbird diversity		Foraging habitat provided at a number of locations, most notably the Gwydir and Hattah–Kulkyne Lakes
			Waterbird diversity and population condition (abundance and population structure)	Survival and condition	
				Chicks	Some evidence of breeding of waterbird species
				Fledglings	
		Other vertebrate diversity		Young	Evidence of breeding of frogs
			Adult abundance		



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**Appendix A. Watering actions contributed to by Commonwealth environmental water in 2014-15 with expected outcomes for fish, vegetation, waterbirds, frogs or other vertebrates**

Surface water region/asset	Watering Action Reference (WAR)	Commonwealth environmental water volume (GL)	Dates	Flow component	Expected Outcomes (P = primary; S = secondary; X = unassigned)								
					Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Campaspe – Reaches 2 and 4	10003-01	5.7914	09/10/14 – 22/10/14	Fresh	X	X			X		X		X
Goulburn – Reaches 4 and 5	10002-01	12.986	25/08/14 – 25/09/14	Base	P				P	P	S		P
Goulburn – Reaches 4 and 5	10002-01	1.315	10/11/14 – 17/11/14	Base	P				P	P	S		P
Goulburn – Reaches 4 and 5	10002-01	67.46	14/10/14 – 11/11/14	Fresh	S	P					S		
Goulburn – Reaches 4 and 5	10002-01	14.472	20/11/14 – 30/11/14	Fresh	P	S					S		
Goulburn – Reaches 4 and 5	10002-01	18.291	01/12/14 – 28/02/15	Base	P				P	P	S		P
Goulburn – Reaches 4 and 5	10002-01	21.103	01/03/15 – 15/03/15 13/04/15 – 12/06/15	Base	P				P	P	S		P
Goulburn – Reaches 4 and 5	10002-01	13.321	16/03/15 – 12/04/15	Fresh		P					S		
Goulburn – Reaches 4 and 5	10002-01	65.444	13/06/15 – 30/06/15	Fresh		P					S		
Goulburn – Lower Broken Creek	10020-01	13.592	03/10/14 – 30/12/14	Base	P	S							P
Goulburn – Lower Broken Creek	10020-01	13.13	01/01/15 – 20/04/15	Base	S	P				P			P
Goulburn – Lower Broken Creek	10020-01	2.644	21/04/15 – 15/05/15	Base	P	S							P

Surface water region/asset	Watering Action Reference (WAR)	Commonwealth environmental water volume (GL)	Dates	Flow component	Expected Outcomes (P = primary; S = secondary; X = unassigned)								
					Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Goulburn – Moodies Swamp	10014-01	0.25	06/10/14 – 02/12/14	Wetland		P	P					S	S
Gwydir – Gwydir wetlands	00016-01	30	17/09/14 – 07/03/15		X	X	X		X	X	X	X	X
Gwydir – Mallowa wetlands	00016-02	9.667	17/09/14 – 07/03/15		X	X	X		X	X			
Gwydir – Carole Creek	00016-03	3.656	03/10/14 – 29/10/15								X		X
Gwydir – Mehi River	00016-04	13.316	02/10/14 – 27/10/14								X		X
Lachlan – Lower Lachlan	10013-01	5	03/10/14 – 29/10/14	Fresh	X	X				X			
Loddon – Reaches 3 and 4 and fringing wetlands	10001-01	2.8695	21/09/14 – 07/10/15	Fresh	X	X			X	X			X
Macquarie–Castlereagh – Macquarie Marshes	10015-01	10	13/10/14 – 12/12/14	Base Fresh Wetland	P	P	S		S	S	S	S	
Murrumbidgee – Mid North Redbank	10023-01	40	12/08/14 – 20/01/15	Wetland	P	P	P	P	P	P	P		
Murrumbidgee – Yanga National Park	10023-02	74.512	23/10/14 – 10/04/15	Wetland	P	P	P	P	P	S	S		
Murrumbidgee – Upper North Redbank	10023-03	20	01/10/14 – 25/03/15	Wetland	P	P	P	P	P		S		
Murrumbidgee – Yarradda Lagoon	10023-04	1.15	04/12/14 – 22/01/15	Wetland		P	S	S					
Murrumbidgee – Sandy Creek	10023-05	0.25	22/03/15 – 01/04/15	Wetland		P	S	S					
Murrumbidgee – Juanbung	10023-06	5.688	04/05/15 – 29/06/15	Wetland		P	S	S					

Surface water region/asset	Watering Action Reference (WAR)	Commonwealth environmental water volume (GL)	Dates	Flow component	Expected Outcomes (P = primary; S = secondary; X = unassigned)								
					Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Murrumbidgee – Paika Lake	10023-06	8.498	25/05/15 – 27/06/15	Wetland	S	S	P	S					
Murrumbidgee – Yanco Creek	10005-02	2.46	23/06/15 – 30/06/15	Wetland	P	P	P	P	P	S			
NSW Murray – Edward–Wakool: Yallakool Creek and Wakool River	10008-01	34.563	12/08/14 – 09/01/15	Base	P	S				S			
NSW Murray – Edward–Wakool: Tuppall Creek	10008-03	2	15/09/14 – 23/11/14	Base / Fresh	P					P			P
NSW Murray – Edward–Wakool: Tuppall Creek	10008-05	0.05	15/09/14 – 23/11/14	Base / Fresh	P					P			P
NSW Murray – Edward–Wakool: Colligen–Niemur System	10008-04	2.949	12/01/15 – 28/01/15	Base	P								
NSW / Vic Murray – River Murray Hume Dam to Coroong	10031-01	23.5	22/06/15 – 30/06/15	Fresh	P	P	S			S			P
Vic Murray – Mulcra Island	10009-02	3.7609	12/08/14 – 22/12/14	Wetland	S	P	S			P			
Vic Murray – Hattah Lakes	NA	34.2389	26/05/14 – 17/01/15	Wetland	X	X	X			X	X		
Ovens – Ovens River	10004-01	0.05 0.02	04/04/15 – 05/04/15 30/04/15 – 30/04/15	Base	X				X	X	X		
SA Murray – Murray River from Wentworth to Lower Lakes	10009-01	191.833	04/09/14 – 31/12/14	Base	X	X				X		X	X
SA Murray – Murray River from Wentworth to Lower Lakes	10026-01	389.205	01/01/15 – 30/06/15	Base	X					X			X
SA Murray – Berri Creek	10009-03	1.241	01/09/14 – 30/06/15	Wetland	P		S						

Surface water region/asset	Watering Action Reference (WAR)	Commonwealth environmental water volume (GL)	Dates	Flow component	Expected Outcomes (P = primary; S = secondary; X = unassigned)								
					Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
SA Murray – Overland Corner	10009-05	0.842	17/12/14 – 15/05/15	Wetland		P		P					
SA Murray – Piggy Creek	10009-05	0.201	11/11/14 – 21/11/14	Wetland		P	P						
SA Murray – Wella	10009-05	0.255	12/11/14 – 21/02/15	Wetland		P		P					
SA Murray – Whirlpool	10009-05	0.09	02/12/14 – 24/03/15	Wetland		P		P					
SA Murray – Markaranka South	10009-06	1.652	01/12/14 – 07/06/15	Wetland		P	P						
SA Murray – Markaranka East	10009-06	0.6	06/01/15 – 24/02/15	Wetland		P		P					
SA Murray – Nikalapko	10009-06	0.8	10/11/14 – 28/11/14	Wetland		P	P	P					
SA Murray – Molo Flats	10009-06	0.703	03/12/14 – 02/04/15	Wetland		P		P					
SA Murray – Wigley	10009-06	0.31	13/11/14 – 23/01/15	Wetland		P		P					
SA Murray – Akuna	10009-06	0.125	26/11/14 – 04/12/15	Wetland		P		P					
SA Murray – Johnson’s Waterhole	00137-01	0.162	02/09/14 – 15/06/15	Wetland		P	P		S				
SA Murray – Clark’s Floodplain	00148-04	0.201	27/10/14 – 15/06/15	Wetland		P	P						
SA Murray – Loxton Riverfront Reserve	00148-05	0.039	25/09/14 – 15/06/15	Wetland		P	P						
SA Murray – Thiele’s Flat	00148-06	0.033	02/09/14 – 30/04/15	Wetland		P	P						

Surface water region/asset	Watering Action Reference (WAR)	Commonwealth environmental water volume (GL)	Dates	Flow component	Expected Outcomes (P = primary; S = secondary; X = unassigned)								
					Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
SA Murray – Ramco River Terrace	00150-03	0.008	06/11/14 – 30/04/15	Wetland		P	P						
SA Murray – Rilli Reach	00150-04	0.025	19/11/14 – 30/04/15	Wetland		P	P						
SA Murray – Cobdogla	00150-04	0.002	04/03/15 – 10/03/15	Wetland		P							
SA Murray – Calperum Station	10024-01	0.276	05/11/14 – 15/06/15	Wetland		P	P						
SA Murray – Duck Hole	10024-03	0.220	13/11/14 – 07/12/14	Wetland		P							
SA Murray – South Teringie	10024-03	0.136	25/11/14 – 30/05/14	Wetland		P	S		S				
Wimmera–Mallee – Brickworks Billabong	10011-02	0.0999	x	Wetland	P	P							P
Wimmera–Mallee – Bridge Creek	10011-02	0.233	x	Wetland		P							
Wimmera–Mallee – Bullock Swamp	10011-02	0.2995	x	Wetland	P	P							P
Wimmera–Mallee – Burra Creek South	10011-02	0.3151	x	Wetland		P							
Wimmera–Mallee – Cardross Lakes	10011-02	0.2883	x	Wetland	P								P
Wimmera–Mallee – Psyche Bend	10011-02	0.4176	x	Wetland	P								P
Wimmera–Mallee – Woorlong Wetlands	10011-02	0.3341	x	Wetland	P								P
QLD Border Rivers – Severn River	00111-17	0.3179	11/12/14 – 16/12/14	Bankfull	P	S				P			
QLD Border Rivers – Severn River	00111-17	0.931	27/12/14 – 30/01/15	Bankfull	P	S				P			
QLD Border Rivers – Dumaresq–Macintyre River and fringing wetlands	00111-18	0.332 0.231	29/01/15 – 05/02/15 06/04/2015	Fresh	P						S		



Surface water region/asset	Watering Action Reference (WAR)	Commonwealth environmental water volume (GL)	Dates	Flow component	Expected Outcomes (P = primary; S = secondary; X = unassigned)								
					Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
QLD Moonie – Lower Moonie River and fringing wetlands	00111-19	0.1968 0.324 0.2856 0.6086	30/12/14 – 05/01/15 27/01/15 – 01/02/15 27/02/15 – 05/03/15 04/04/15 – 11/04/15	Fresh	P					P		S	
QLD Condamine-Balonne	0011-21	17.244 0.145	Late Jan – Early Feb May 2015	Fresh	S					P		S	
QLD Warrego – Upper Warrego and fringing wetlands	00111-22	0.3728	17/12/14 – 04/01/15	Fresh	P					P		S	
QLD Warrego – Upper Warrego and fringing wetlands	00111-23	0.2816 1.8873	27/12/14 – 28/12/14 09/01/15 – 15/01/15	Fresh	P					P			
NSW Barwon-Darling	00111-24	1.2564 0.108 0.39636	11-17 Jan 2015 30-31 May 2015 Late Feb & May 2015	Fresh							S	P	S

## Appendix B. Species and communities that potentially benefited from Commonwealth environmental water in 2014-15.

**Table B 1** ANAE ecosystem types likely to have been influenced by Commonwealth environmental water in 2014–15 (Brooks 2016).

Australian National Aquatic Ecosystem (ANAE) wetland type	Total area (ha)	Inundated		Influenced	
		Area (ha)	% of total	Area (ha)	% of total
Pp4.1: Permanent floodplain wetland	41 993	4685	11.2	18 645	44.4
Pt2.2.1: Temporary sedge/grass/forb floodplain marsh	51 081	70	0.1	18 200†	35.6†
Pt1.1.1: Intermittent River red gum floodplain swamp	63 394	4130	6.5	10 043	15.8
Rp1.4: Permanent lowland streams	74 529	2135	2.9	3906	5.2
Pp2.1.1: Permanent floodplain tall emergent marshes	7809	471	6.0	3557	45.6
Rt1.4: Temporary lowland streams	222 996	624	0.3	2100	0.9
Pt3.1.2: Clay pans	51 071	1047	2.1	2098	4.1
Lt1.1: Temporary lakes	302 882	171	0.1	1593	0.5
Pt3.1.1: Floodplain clay pans	49 329	1354	2.7	1578	3.2
Pt4.1: Temporary floodplain wetland	122 815	463	0.4	1557	1.3
Lst2.1: Temporary saline floodplain lakes	10 636	1334	12.5	1383	13.0
Pt1.2.1: Intermittent Black box floodplain swamp	33 916	322	0.9	1188	3.5
Lp2.1: Permanent floodplain lakes	137 406	627	0.5	634	0.5
Pst1.1: Temporary saline swamp	17 020	411	2.4	551	3.2
Lt2.1: Temporary floodplain lakes	198 419	148	0.1	517	0.3
Pt2.3.1: Floodplain freshwater meadow	11 138	229	2.1	327	2.9
Pt1.7.2: Intermittent Lignum swamps	17 565	141	0.8	321	1.8
Pt1: Temporary swamps	3766	264	7.0	280	7.4
Pp2.3.1: Permanent floodplain grass marshes	431	23	5.3	217	50.3
Pt1.7.1: Intermittent Lignum floodplain swamp	26 521	120	0.5	205	0.8
Psp4: Permanent saline wetland	3965	157	4.0	158	4.0
Lp1.1: Permanent lakes	44 110	9	<0.1	150	0.3
Pst4: Temporary saline wetlands	11 294	101	0.9	102	0.9
Pt1.4.2: Intermittent River Cooba swamp	104	17	16.3	101	97.1
Pt2.2.2: Temporary sedge/grass/forb marsh	30 524	2	<0.1	92	0.3
Pt1.1.2: Intermittent River red gum swamps	8480	28	0.3	91	1.1
Pt1.6.1: Temporary woodland floodplain swamp	179 791	5	<0.1	87	<0.1
Pp4.2: Permanent wetland	22 354	16	0.1	51	0.2
Pt2.1.1: Temporary tall emergent floodplain marsh	50 687	42	0.1	42	0.1
Pp2.1.2: Permanent tall emergent marshes	134	25	18.7	31	23.1
Rp1.3: Permanent low energy upland streams	286	23	8.0	24	8.4
Pt1.6.2: Temporary woodland swamp	44 280	1	<0.1	15	<0.1

Australian National Aquatic Ecosystem (ANAE) wetland type	Total area (ha)	Inundated		Influenced	
		Area (ha)	% of total	Area (ha)	% of total
Pt1.3.2: Intermittent Coolibah swamp	1019	3	0.3	9	0.9
Pp2.3.2: Permanent grass marshes	183	7	3.8	7	3.8
Rt1: Temporary streams	294	3	1.0	5	1.7
Pp2.2.2: Permanent sedge/grass/forb marshes	2564	<0.1	<0.1	4	0.2
Lst1.1: Temporary saline lakes	12 634	4	<0.1	4	<0.1
Pt1.3.1: Intermittent Coolibah floodplain swamp	5173	<0.1	<0.1	3	0.1
Pt1.2.2: Intermittent Black box swamp	16 470	<0.1	<0.1	1	<0.1

**Table B 2** Plant species that potentially benefited from Commonwealth environmental water (restricted to wet plots) in 2014–15 (Capon & Campbell 2016).

Species name	Species name	Species name
<i>Atriplex</i> spp.	<i>Glyceria</i> spp.	<i>Oxalis</i> spp.
<i>Carex appressa</i>	<i>Gnaphalium</i> spp.	<i>Paspalum dilatatum</i> *
<i>Carthamus lanatus</i> *	<i>Goodenia heteromera</i>	<i>Persicaria hydropiper</i>
Characeae	<i>Hibiscus trionum</i>	<i>Persicaria</i> spp.
Chenopodiaceae	<i>Landoltia punctata</i>	<i>Physalis minima</i> *
<i>Cotula australis</i>	<i>Lemna disperma</i>	<i>Potamogeton tricarlinatus</i>
<i>Cycnogeton dubium</i>	<i>Lemna</i> spp.	<i>Ricciocarpos</i> spp.
<i>Cycnogeton procerum</i>	<i>Limosella australis</i>	<i>Senecio</i> spp.
<i>Cyperus bifax</i>	<i>Lycium australe</i>	<i>Soliva anthemifolia</i> *
<i>Cyperus concinnus</i>	<i>Maireana</i> spp.	<i>Spirodela polyrhiza</i>
<i>Cyperus</i> spp.	<i>Marsilea costulifera</i>	<i>Trifolium</i> spp. *
<i>Dysphania ambrosioides</i> *	<i>Medicago lupulina</i> *	<i>Typha</i> spp.
<i>Echinochloa inundata</i>	<i>Myoporum acuminatum</i>	<i>Vallisneria australis</i>
<i>Eichhornia crassipes</i> *	<i>Nymphoides crenata</i>	<i>Vittadinia hispidula</i>
<i>Eragrostis leptostachya</i>	<i>Osteocarpum acropterum</i>	<i>Wahlenbergia communis</i>
<i>Eriochloa pseudoacrotricha</i>	<i>Ottelia ovalifolia</i> subsp. <i>ovalifolia</i>	

Note: asterisks (\*) indicate exotic species.

**Table B 3** Fish species that potentially benefited from Commonwealth environmental water in 2014–15 (extracted from Stoffels *et al.* 2016).

Common name	Species name	Listing
Australian smelt	<i>Retropinna semoni</i>	
Bony bream	<i>Nematalosa erebi</i>	
Carp gudgeon	<i>Hypseleotris</i> spp.	
Eel-tailed catfish	<i>Tandanus tandanus</i>	Endangered (NSW, Vic)
Golden perch	<i>Macquaria ambigua</i>	
Murray cod	<i>Maccullochella peelii</i>	Vulnerable (EPBC)
Murray–Darling rainbowfish	<i>Melanotaenia fluviatilis</i>	
Murray hardyhead	<i>Craterocephalus fluviatilis</i>	Endangered (EPBC)
Silver perch	<i>Bidyanus bidyanus</i>	Endangered (EPBC)
Spangled perch	<i>Leiopotherapon unicolor</i>	
Trout cod	<i>Maccullochella macquariensis</i>	Endangered (EPBC)

Note: EPBC = Environment Protection and Biodiversity Conservation (Act)

**Table B 4** Frog species that potentially benefited from Commonwealth environmental water in 2014–15.

Common name	Species name	Listing
Barking marsh frog	<i>Limnodynastes fletcheri</i>	
Desert froglet	<i>Crinia deserticola</i>	
Desert tree frog	<i>Litoria rubella</i>	
Eastern banjo frog	<i>Limnodynastes dumerilii</i>	
Green tree frog	<i>Litoria caerulea</i>	
Inland banjo frog	<i>Limnodynastes interioris</i>	
Peron's tree frog	<i>Litoria peronii</i>	
Plains froglet	<i>Crinia parinsignifera</i>	
Southern bell frog	<i>Litoria raniformis</i>	Vulnerable (EPBC)
Spotted marsh frog	<i>Limnodynastes tasmaniensis</i>	

Note: EPBC = Environment Protection and Biodiversity Conservation (Act)

**Table B 5** Turtle species that potentially benefited from Commonwealth environmental water in 2014–15.

Common name	Species name	Listing
Eastern long-necked tortoise	<i>Chelodina longicollis</i>	
Broad shell tortoise	<i>Chelodina expansa</i>	

**Table B 6** Bush bird species that potentially benefited from Commonwealth environmental water in 2014–15 at Hattah Lakes (extracted from Loyn and Dutson 2016 as species whose abundance increased during or after environmental watering).

Common name	Species name	Listing
Apostlebird	<i>Struthidea cinerea</i>	
Australian raven	<i>Corvus coronoides</i>	
Australian ringneck	<i>Barnardius zonarius</i>	
Black-faced cuckoo-shrike	<i>Coracina novaehollandiae</i>	
Blue bonnet	<i>Northiella haematogaster</i>	
Blue-faced honeyeater	<i>Entomyzon cyanotis</i>	
Brown falcon	<i>Falco berigora</i>	
Brown treecreeper	<i>Climacteris picumnus</i>	
Chestnut-rumped thornbill	<i>Acanthiza uropygialis</i>	
Common bronzewing	<i>Phaps chalcoptera</i>	
Eastern rosella	<i>Platycercus eximius</i>	
Galah	<i>Eolophus roseicapilla</i>	
Grey fantail	<i>Rhipidura albiscapa</i>	
Grey shrike-thrush	<i>Colluricincla harmonica</i>	
Laughing kookaburra	<i>Dacelo novaeguineae</i>	
Little corella	<i>Cacatua sanguinea</i>	
Little eagle	<i>Hieraaetus morphnoides</i>	
Little friarbird	<i>Philemon citreogularis</i>	
Magpie-lark	<i>Grallina cyanoleuca</i>	
Major Mitchell's cockatoo	<i>Lophochroa leadbeateri</i>	
Noisy miner	<i>Manorina melanocephala</i>	
Rainbow bee-eater	<i>Merops ornatus</i>	
Red-capped robin	<i>Petroica goodenovii</i>	
Regent parrot	<i>Polytelis anthoepus</i>	Vulnerable (EPBC)
Restless flycatcher	<i>Myiagra inquieta</i>	
Rufous whistler	<i>Pachycephala rufiventris</i>	
Sacred kingfisher	<i>Todiramphus sanctus</i>	
Singing honeyeater	<i>Lichenostomus virescens</i>	
Spiny-cheeked honeyeater	<i>Acanthagenys rufogularis</i>	
Spotted pardalote	<i>Pardalotus punctatus</i>	
Striated pardalote	<i>Pardalotus striatus</i>	
Striped honeyeater	<i>Plectorhyncha lanceolata</i>	
Tree martin	<i>Petrochelidon nigricans</i>	
Varied sittella	<i>Daphoenositta chrysoptera</i>	
Weebill	<i>Smicrornis brevirostris</i>	
Welcome swallow	<i>Hirundo neoxena</i>	
Whistling kite	<i>Haliastur sphenurus</i>	
White-backed swallow	<i>Cheramoeca leucosterna</i>	
White-bellied sea eagle	<i>Haliaeetus leucogaster</i>	FFG listed (Victoria)
White-browed woodswallow	<i>Artamus superciliosus</i>	
White-plumed honeyeater	<i>Lichenostomus penicillatus</i>	

Common name	Species name	Listing
White-winged cough	<i>Corcorax melanorhamphos</i>	
White-winged triller	<i>Lalage tricolor</i>	
Willie wagtail	<i>Rhipidura leucophrys</i>	
Yellow rosella	<i>Platycercus elegans flaveolus</i>	
Yellow thornbill	<i>Acanthiza nana</i>	
Yellow-rumped thornbill	<i>Acanthiza chrysorrhoa</i>	
Yellow-throated miner	<i>Manorina flavigula</i>	

Note: EPBC = Environment Protection and Biodiversity Conservation (Act); FFG = Flora and Fauna Guarantee (Act)

**Table B 7.** Waterbird species that potentially benefited from Commonwealth environmental water in 2014–15 (bold indicates breeding observed).

Functional guild	Common name	Species name	Significance
Australian breeding shorebirds	Banded lapwing	<i>Vanellus tricolor</i>	
	Black-fronted dotterel	<i>Elseya melanops</i>	
	Black-winged stilt	<i>Himantopus himantopus</i>	
	Masked lapwing	<i>Vanellus miles</i>	
	Red-kneed dotterel	<i>Erythronyx cinctus</i>	
Migratory shorebirds	Common greenshank	<i>Tringa nebularia</i>	JAMBA, CAMBA, ROKAMBA
	Latham's snipe	<i>Gallinago hardwickii</i>	JAMBA, CAMBA, ROKAMBA
	Marsh sandpiper	<i>Tringa stagnatilis</i>	JAMBA, CAMBA, ROKAMBA
	Sharp-tailed sandpiper	<i>Calidris acuminata</i>	JAMBA, CAMBA, ROKAMBA
Ducks, swans and grebes	Australasian grebe	<i>Tachybaptus novaehollandiae</i>	
	Australasian shoveler	<i>Anas rhynchos</i>	
	Australian shelduck	<i>Tadorna tadornoides</i>	
	Australian wood duck	<i>Chenonetta jubata</i>	
	Black swan	<i>Cygnus atratus</i>	
	Chestnut teal	<i>Anas castanea</i>	
	Grey teal	<i>Anas gracilis</i>	
	Hardhead	<i>Aythya australis</i>	
	<b>Hoary-headed grebe</b>	<b><i>Poliocephalus poliocephalus</i></b>	
	<b>Magpie goose</b>	<b><i>Anseranas semipalmata</i></b>	Vulnerable (NSW)
	Musk duck	<i>Biziura lobata</i>	Vulnerable (VIC)
	Pacific black duck	<i>Anas superciliosa</i>	
	Pink-eared duck	<i>Malacorhynchus membranaceus</i>	
	<b>Plumed whistling-duck</b>	<b><i>Dendrocygna eytoni</i></b>	
	<b>Wandering whistling-duck</b>	<b><i>Dendrocygna arcuata</i></b>	
	Black-tailed native-hen	<i>Tribonyx ventralis</i>	

Functional guild	Common name	Species name	Significance
Cranes, crakes and rails	<b>Brolga</b>	<i>Grus rubicunda</i>	Vulnerable (NSW)
	Dusky moorhen	<i>Gallinula tenebrosa</i>	
	<b>Eurasian coot</b>	<i>Fulica atra</i>	
	Purple swampphen	<i>Porphyrio porphyrio</i>	
Large wading birds	Australasian bittern	<i>Botaurus poiciloptilus</i>	Endangered (EPBC)
	Australian little bittern	<i>Ixobrychus dubius</i>	
	<b>Australian white ibis</b>	<i>Threskiornis molucca</i>	
	Cattle egret	<i>Ardea ibis</i>	JAMBA, CAMBA (Australian resident)
	Eastern great egret	<i>Ardea modesta</i>	JAMBA, CAMBA (Australian resident)
	Glossy ibis	<i>Plegadis falcinellus</i>	
	Intermediate egret	<i>Ardea intermedia</i>	
	Little egret	<i>Egretta garzetta</i>	
	Nankeen night-heron	<i>Nycticorax caledonicus</i>	
	Royal spoonbill	<i>Platalea regia</i>	
	Straw-necked ibis	<i>Threskiornis spinicollis</i>	
	White-faced heron	<i>Egretta novaehollandiae</i>	
	White-necked heron	<i>Ardea pacifica</i>	
	Yellow-billed spoonbill	<i>Platalea flavipes</i>	
Fish-eating birds	<b>Australasian darter</b>	<i>Anhinga novaehollandiae</i>	
	Australian pelican	<i>Pelecanus conspicillatus</i>	
	Caspian tern	<i>Hydroprogne caspia</i>	JAMBA, CAMBA (Australian resident)
	Great cormorant	<i>Phalacrocorax carbo</i>	
	Little black cormorant	<i>Phalacrocorax sulcirostris</i>	
	Little egret	<i>Egretta garzetta</i>	
	<b>Little pied cormorant</b>	<i>Microcarbo melanoleucos</i>	
	Pied cormorant	<i>Phalacrocorax varius</i>	
	Whiskered tern	<i>Chlidonias hybrida</i>	
Raptors	Swamp harrier	<i>Circus approximans</i>	
	<b>White-bellied sea eagle</b>	<i>Haliaeetus leucogaster</i>	CAMBA (Australian resident)
Other wetland-dependent species	<b>Australian reed-warbler</b>	<i>Acrocephalus australis</i>	
	Golden-headed cisticola	<i>Cisticola exilis</i>	
	Little grassbird	<i>Megalurus gramineus</i>	
	<b>Sacred kingfisher</b>	<i>Todiramphus sanctus</i>	
	Tawny grassbird	<i>Megalurus timoriensis</i>	

Note: JAMBA = Japan–Australia Migratory Bird Agreement; CAMBA = China–Australia Migratory Bird Agreement; ROKAMBA = Republic of Korea – Australia Migratory Bird Agreement; EPBC = Environment Protection and Biodiversity Conservation (Act).