

# 2017–18 Basin-scale evaluation of Commonwealth environmental water – Biodiversity

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Report prepared for the Commonwealth Environmental Water Office by La Trobe University

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The La Trobe University 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 23 000 square kilometres of lakes and wetlands, 50 000 square kilometres of floodplain and 600 000 kilometres of mapped river channel (Brooks 2017). Sixteen wetlands of international importance, listed under the Ramsar Convention, are located 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).

An 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 water regimes for all or parts of their life -cycle. Most of the aquatic ecosystem-dependent 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 & Casanova 1997; Young *et al.* 2001; Roberts & 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 Biodiversity component of the Commonwealth Environmental Water Office's (CEWO's) Long Term Intervention Monitoring (LTIM) Project aims to evaluate the contribution of Commonwealth environmental water to achieving diversity-related objectives of the Basin Plan (section 8.05(3)). 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, bird, 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<sup>1</sup>) benefited from Commonwealth environmental water?

## 1.1 Summary of water actions in 2017–18 with expected outcomes for biota

Commonwealth environmental water contributed to 115 watering actions in the 2017–18 water year with expected outcomes directly related to aquatic ecosystem dependent plant and vertebrate species (Annex A). Of these, 72 watering actions had expected outcomes for fish; 60 for plant species or vegetation communities; 43 for waterbirds, 26 for frogs, 9 for reptiles and 1 for mammals (platypus). This is consistent with previous LTIM years, where the largest number of waterbirds, with a smaller number of actions targeting frogs, turtles and occasionally mammals (Figure 1).

<sup>&</sup>lt;sup>1</sup> JAMBA (Japan–Australia Migratory Bird Agreement); CAMBA (China–Australia Migratory Bird Agreement); ROKAMBA (Republic of Korea– Australia Migratory Bird Agreement).

<sup>2017–18</sup> Basin-scale evaluation of Commonwealth environmental water – Biodiversity



**Figure 1.** Summary of the number of watering actions with expected outcomes related to biodiversity across the first four years of LTIM.

## 2 Methods

## 2.1 General approach

The main output of the Biodiversity 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, and other monitoring programs (external to LTIM).

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 benefited. The Biodiversity Basin Matter (formerly termed "generic diversity") undertakes a qualitative evaluation of expected outcomes of watering actions undertaken by CEWO. The approach 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 as part of LTIM
- 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).





General information about a species life-history or habitat requirements and broad assumptions about the hydraulic outcomes are used to infer benefit. Increased confidence in the assessment that a species or community benefited from environmental water is assigned as a result of repeated observations over space and time. That is, as a species or community is observed at sites that receive Commonwealth environmental water at different locations in the Basin and in multiple years, confidence that the species benefited from environmental water is increased. It was initially envisioned that we would be able to take information from the Ecosystem Diversity Basin Matter about the types and extent of wetlands that received environmental water toge ther with hydrological outputs about timing, extent and duration of inundation to predict outcomes at a variety of aquatic ecosystems that received Commonwealth environmental water but were not monitored. This has proven to be difficult due to very little available information about the hydrological regimes and ecology at unmonitored sites. At this stage, therefore, this analysis is limited to a smaller number of locations, where we have better information about the number of plants and animal species that are likely to occur and therefore potential benefit arising from Commonwealth environmental water. These important wetland sites (DIWA and Ramsar Sites) were listed for their high biodiversity values and the effects of Commonwealth environmental water on diversity at these locations provides a good representation of the effects Basin wide.

## 2.2 Other Basin Matters

The effects of Commonwealth environmental water on vegetation, fish and ecosystem diversity have been evaluated as other Basin Matters. 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 benefiting (or potentially benefiting) from Commonwealth environmental water have been extracted and included in the aggregated list of species in Annex B.

## 2.3 Waterbirds, frogs, turtles and mammals

## 2.3.1 Selected Area outcomes

In the 2017–18 watering year, three Selected Areas were monitored for waterbirds, frogs and/or turtles (Figure 3); noting that aquatic ecosystem–dependent mammals were not included in any LTIM monitoring:

- Gwydir river system waterbird diversity
- Murrumbidgee river system waterbird diversity, frogs and turtles
- Junction of the Warrego and Darling rivers waterbird diversity and frogs.

Information collected from Selected Area monitoring has been collated and summarised to identify species that potentially benefited from Commonwealth environmental water in 2017–18.

## 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 regarding ecological responses to watering. There are sites that were monitored under state or Murray–Darling Basin Authority (MDBA) programs (e.g. The Living Murray program); sites at which there are observations documented in CEWO acquittal reports (unpublished); 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 2017–18 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 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. For case study sites, 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?



Figure 3. Locations of Selected Area monitoring for waterbirds, frogs and turtles 2017–18.

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

#### 3.1 Highlights

- Commonwealth environmental water was delivered to maintain refuge habitats in a drying landscape in 2017–18. This resulted in sustained records for waterbird and frog diversity across Selected Areas.
- A total of 75 species of wetland dependent birds have been recorded at sites that received Commonwealth environmental water in Selected Areas over the first four years of the LTIM project.
- The nationally listed endangered Australian painted snipe (*Rostratula australis*) was recorded in the Gwydir river systems at wetlands that received Commonwealth environmental water in 2017–18.
- The nationally listed vulnerable southern bell frog (*Litoria raniformis*) was recorded in wetlands in the Murrumbidgee system at sites that received Commonwealth environmental water, with limited evidence of breeding in the drier conditions of 2017–18.

The outcomes of monitoring of waterbirds, frogs and/or turtles in 2017–18 in the Murrumbidgee river system, Gwydir river system and the Junction of the Warrego and Darling rivers are summarised in Table 1.

Selected Area (watering action reference)	Dates <sup>1</sup>	Commonwealth environmental water volume (ML) <sup>1</sup>	Flow component <sup>1</sup>	Expected ecological outcome <sup>1</sup>	Monitored site(s) <sup>2</sup>	Observed ecological outcome <sup>2</sup>	Influences <sup>2</sup>
Gwydir (10069- 01)	19/12/17 - 17/01/18	4000	Wetland	Provide refuge habitat for waterbirds, fish and other aquatic species	Lower Gwydir River and Gingham watercourse – 21 locations	54 species of waterbird recorded including the endangered Australian painted snipe; eight waterbird species with evidence of breeding activity	Availability and timing of inundated habitat; productivity (vegetation and food sources) responses to watering.
Murrumbidgee (10062-01)	24/07/17 - 01/09/17	159 283	Fresh, Wetland	Support reproduction and improved condition of vegetation, waterbirds, native fish and other biota.	Mid- Murrumbidgee wetlands (Sunshower,	32 species of waterbird recorded including Latham's snipe which is listed under the international migratory agreements JAMBA and BOKAMBA Small number of	Direct link with environmental water, with repeat watering over multiple years
Murrumbidgee (10062-02)	04/07/17 - 24/07/17	326	Wetland	Support the habitat requirements of waterbirds, native fish and other aquatic animals.	Gooragool, Yarradda and McKennas)	colonial nesting species observed breeding.	habitat for waterbirds, frogs and turtles.
Murrumbidgee (10062-03)	18/07/17 - 11/08/17	1426	Wetland			Six species offrog and three turtle species supported, including small	Impacts of carp on tadpoles and foxes on
Murrumbidgee (10068-06)	20/11/17 - 25/11/17	178	Wetland			numbers of the vulnerable southern bell frog. Tadpoles recorded in all mid-Murrumbidgee monitoring sites.	turtle hatchings uccess. The importance of permanent water for turtle species.
Warrego: Lower Warrego River (152-10)	Dec 2017	0	Fresh	Provide opportunities for native fish (e.g. fish s pawning, recruitment and movement) (Warrego River)	Boera Dam, Booka Dam, Ross Billabong	22 species of waterbird, in relatively low numbers. Twelve species of frog induding first record for the water holding frog at this location.	Dry conditions and limited water / inundation resulted in reduced numbers and diversity of waterbirds and frogs.

**Table 1.** Summary of monitored watering actions related to waterbird, frog and turtle diversity at Selected Areas in 2017–18.

<sup>1</sup> As reported by the Commonwealth Environmental Water Office (CEWO) see Stewardson & Guarino (2019) for definitions of flow components.

<sup>2</sup> As reported by the Monitoring and Evaluation (M&E) team for each Selected Area in Selected Area reports for 2017–18.

#### 3.1.1 Waterbirds

#### Waterbird diversity

A total of 75 wetland-dependent species were recorded at aquatic ecosystems in the Gwydir, Murrumbidgee and Warrego-Darling Selected Areas that received Commonwealth environmental water across the four years (Appendix B). This included several species that are listed as threatened. Two nationally listed endangered species have been recorded at wetlands that received Commonwealth environmental water; the Australasian bittern (*Botaurus poiciloptilus*) in the Murrumbidgee in both 2015–16 and 2016–17 and in the Gwydir in 2016–17; and Australian painted snipe in the Gwydir in 2017–18. Seven additional species listed as vulnerable in New South Wales (NSW) were also recorded at least once across the four years: comb-crested jacana (*Irediparra gallinacea*), black-necked stork (*Ephippiorhynchus asiaticus*), brolga (*Grus rubicunda*), freckled duck (*Stictonetta naevosa*), magpie goose (*Anseranas semipalmata*) and white-bellied sea eagle (*Haliaeetus leucogaster*). In addition, a number of species listed under international migratory bird agreements were present at sites that received Commonwealth environmental water, including seven species that are part of the East Asian–Australasian Flyway.

Six of the 75 species were recorded in sites that received Commonwealth environmental water in all three Selected Areas across all years, comprising four species of duck, Australian pelican (*Pelecanus conspicillatus*), and white-faced heron (*Egretta novaehollandiae*). By contrast, 13 species were recorded at only one Selected Area and in one year. This includes three species of international migratory shorebirds, the spotless crake (*Porzana tabuensis*) and several fish-eating species (see Appendix B).

Species richness varied across the Selected Areas and the four years but was greatest in the Gwydir river system (Figure 4). The number of aquatic ecosystem dependent bird species increased in each of the Selected Areas from 2014–15 to 2016–17 and then declined in 2017–18 noting that locations within a Selected Area that received Commonwealth environmental water have changed between the four periods. In terms of species richness, fish-eating species (piscivores) were the dominant functional group in all locations and years (Figure 3).



**Figure 4.** Species richness of functional groups in the three Selected Areas monitored for waterbirds as part of the LTIM project in 2014–15 (Yr1), 2015–16 (Yr2) 2016–17 (Yr 3) and 2017–18 (Yr4). See Appendix 2 for waterbird functional group descriptions.

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Abundance (as indicated by the maximum count at a single location within a Selected Area) was highest in 2016–17 in the Gwydir and Murrumbidgee, reflecting the increased inundation in this wetter year. In the Warrego-Darling, abundance of waterbirds was comparatively low across all four LTIM years, reflecting that much of the northern Basin continued to experience dry conditions (Figure 5). In terms of abundance ducks dominated waterbird assemblages in three of the four years shifting to large bodied waders in 2016-17. This reflects inundation of breeding habitat for colonial nesting species and the high abundance of ibis and egrets in the 2016–17 water year.



**Figure 5.** Abundance of functional groups (as indicated by maximum count for each species in a Selected Area) in 2014–15 (Yr1), 2015–16 (Yr2) 2016–17 (Yr 3) and 2017–18 (Yr4). See Appendix 2 for waterbird functional group descriptions.

#### Waterbird breeding

Evidence of breeding has been recorded in sites that received Commonwealth environmental water for a total of 45 species across the three Selected Areas in the first four years of LTIM. This comprised a mix of both colonial nesting species and other waterbirds (Figure 6). The greatest number of species observed breeding was during 2016–17. While modest numbers of birds were recorded breeding in years 1, 2 and 4, there were large scale waterbird breeding events recorded for colonial nesting species in 2016–17. Close to 70 000 nests of ibis, herons, cormorants, egrets and pelicans were recorded in targeted monitoring in the Murrumbidgee and Lachlan Selected Areas in 2016–17, highlighting the importance of widescale floodplain inundation for these species.



Figure 6. Total number of species observed breeding across the three Selected Areas in each watering year.

#### 3.1.2 Frogs

Frogs were monitored in two Selected Areas in all four LTIM years including 2017–18: the Murrumbidgee river system and the Junction of the Warrego and Darling rivers. Frogs were also monitored for a single year (2015–16) in the Gwydir and Lachlan river systems under the LTIM project, with additional data for 2017–18 in the Gwydir provided by NSW OEH (Ocock *et al.* 2017). A total of 16 species of frog have been recorded at sites that received Commonwealth environmental water, including the nationally listed vulnerable southern bell frog.

Common name	Species name	Lachlan	Murrumbidgee				Gwydir		Warrego–Darling			
		Yr2	Yr1	Yr2	Yr3	Yr4	Yr2	Yr3	Yr1	Yr2	Yr3	Yr4
Desert froglet	Crinia deserticola	-							Х		х	Х
Plains froglet	Crinia parinsignifera	Х	Х	Х	Х	Х	Х	Х		Х	Х	
Stripedburrowingfrog	Cyclorana alboguttata							Х				
Water-holding frog	Cyclorana platycephala											Х
Barking marsh frog	Limnodynastes fletcheri		Х	Х	Х	Х	Х	Х	Х		Х	Х
Inland banjo frog	Limnodynastes interioris	Х		Х	Х	Х						
Salmon striped frog	Limnodynastes salmini							Х			х	
Spotted marsh frog	Limnodynastes tasmaniensis	Х	Х	Х	Х	Х	Х	Х	Х	Х		Х
Green tree frog	Litoria caerulea							Х	Х		Х	Х
Broad-palmed rocket frog	Litoria latopalmata						Х	Х				
Peron's tree frog	Litoria peronii	Х	Х	Х	Х	Х	Х	Х	Х	Х	Х	Х
Southern bellfrog <sup>1</sup>	Litoria raniformis		Х	Х	Х	Х						
Desert tree frog	Litoria rubella								Х			Х
Sudell's frog	Neobatrachus sudallae										Х	
Ornate burrowing frog	Platyplectrum ornatum							Х				
Small-headed toadlet	Uperoleia capitulata											Х

Table 2. Frog species recorded at sites in Selected Areas that received Commonwealth environmental water.

<sup>1</sup> Listed as vulnerable nationally under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Monitoring methods varied between Selected Areas and so a comparison of breeding and recruitment success is not possible. The frogs recorded in Table 4, largely represent calls and could be considered to represent attempts at breeding.

In the Murrumbidgee, there is clear evidence that the southern bell frog has benefited from environmental water management over the LTIM project to date. A dry period in 2015 followed by extended inundation in 2016–17 resulted in substantial numbers, with a CPUE of more than 400

adults at Nap Nap Swamp (Wassens *et al.* 2017). The drier conditions in 2017–18 lead to a reduction in abundance and limited evidence of breeding in the Selected Area.

#### 3.1.3 Turtles

Turtles were monitored in the Murrumbidgee river system in all four of the LTIM years to date, with three species recorded at sites that received Commonwealth environmental water:

- eastern long-necked turtle (*Chelodina longicollis*)
- broad shelled turtle (*Chelodina expansa*)
- Macquarie river turtle (*Emydura macquarii*).

## 4 Unmonitored area outcomes

In this report, 'unmonitored' refers to sites that received Commonwealth environmental water but were not measured as part of LTIM. It includes information from other monitoring programs as well as observations.

#### 4.1 Highlights

- Watering of wetlands along the Lower Murray resulted in a network of inundated habitats supporting habitat for frogs and a high diversity of waterbird species, including over 50 species at Calperum Station.
- Commonwealth environmental water contributed to maintaining the ecological character of nine Ramsar listed wetlands in 2017–18.
- Large inundation events at the Hattah-Kulkyne Lakes and Macquarie Marshes Ramsar sites improved vegetation condition and provided habitat for a high diversity of waterbirds across all functional feeding groups.
- Commonwealth environmental water contributed to improvement in populations of Murray cod and other native fish in Gunbower Creek.

#### 4.2 Aggregation of data from other sources

## 4.2.1 Effects of Commonwealth environmental water 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 3. This table does not include important wetland sites such as Barmah Forest 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 the water regime. **Table 3.** Summary of observations and other information from unmonitored watering actions related to waterbirds, frogs, turtles and mammals in 2017–18. 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 & Guarino 2019). Ramsar wetlands are considered in section 4.3.

Surface water region/asset	Commonwealth environmental water volume (ML) <sup>1</sup>	Dates <sup>1</sup>	Flow component <sup>1</sup>	Expected ecological outcome <sup>1</sup>	Observed ecological outcome	Source of information
Upper Broken Creek and Moodie Swamp	498	18/04/18 - 07/06/18	Fresh, Wetland	Provide a more natural flooding regime to ensure the success of bird breeding events (incl Brolga) and to provide growth conditions for water dependant vegetation.	Moodie Swamp: Autumn watering event triggered a response in frogs and macroinvertebrates priming the site for spring e cological outcomes. Platypus recorded in the Upper Broken Creek.	CEWO a cquittal report (unpublished)
Lower Murray - Calperum Station	3894	Oct 2017 - Apr 2018	Wetland	Provide seasonal waterbird habitat to support food sources and maintain species diversity and abundances. Provide seasonal wetland habitat to support frog breeding.	Supported variety of waterbirds with 51 species recorded over three wetland sites. This induded four migratory shorebirds: common greenshank ( <i>Tringa nebularia</i> ); red-necked stint ( <i>Calidris</i> <i>ruficollis</i> ); sharp-tailed sandpiper ( <i>Calidris</i> <i>acuminata</i> ) and wood sandpiper ( <i>Tringa glareola</i> ) as well as two species listed under South Australian threatened species legislation: freckled duck and white-bellied sea e agle. Six species of frog recorded: Peron's tree frog, plains froglet, barking marsh frog and spotted marsh frog. While there was evidence of breeding for all species, a bundance was low due to low temperatures.	Cale (2018)
Lower Murray: Wingillie Station	1459	28/09/17 - 20/04/18	Wetland	Support suitable habitat condition for waterbirds.	Watering provided a range of habitats that supported for aging and breeding of different	CEWO acquittal report (unpublished)
Lower Murray: Lucerne Day	82	28/09/17 - 28/09/17	Wetland	Support and maintain vegetation condition and habitat for the nationally endangered southern bell frog.	tunctional groups of waterbirds as well as frogs. This included large-bodied waders, Australian shorebirds, dabbling ducks and fish-eating species. Species of conservation significance recorded included: southern bell frog, regent parrot, freckled duck and white-bellied sea eagle.	

Surface water region/asset	Commonwealth environmental water volume (ML) <sup>1</sup>	Dates <sup>1</sup>	Flow component <sup>1</sup>	Expected ecological outcome <sup>1</sup>	Observed ecological outcome	Source of information
					Breeding recorded for several species of duck as well as eastern great egret ( <i>Ardea modesta</i> ) and yellow-billed spoonbill ( <i>Platalea flavipes</i> ).	
Lower Murray: Renmark Wetlands Site 8	158	09/04/18 - 31/05/18	Wetland	Increase diversity and a bundance of waterbirds through a quatic habitat improvements.	An increase in waterbird usage a cross 19.2 ha of inundated floodplain. There were hundreds of ducks induding the South Australian threatened species freckled duck	CEWO a cquittal report (unpublished)
Lower Murray: Renmark Wetlands Site 15	22	01/07/17 - 10/10/17	Wetland	Increase diversity and a bundance of frogs through a quatic habitat improvements.	9.9 ha of floodplain inundation and an increase in frog activity observed over the course of watering.	
Lower Murray: Bookmark Creek	448	11/08/17 - 30/06/18	Wetland	Provide waterbird habitat.	A total of 22 s pecies of waterbirds recorded using the site following watering representing s everal functional groups including large bodied waders, ducks and piscivores.	CEWO a cquittal report (unpublished)
Lower Murray: Riversleigh Lagoon	650	Oct 2017 - Feb 2018	Wetland	Provide seasonal waterbird habitat to support food sources and maintain species diversity and abundances. Provide seasonal wetland habitat to support frog	Large numbers of duck as the lagoon filled including 2000 grey teal ( <i>Anas gracilis</i> ) and breeding of black swans ( <i>Cygnus atratus</i> ). Numbers of Australian waders such as red-necked a vocets ( <i>Recurvirostra novaehollandiae</i> ) and stilts also recorded.	CEWO a cquittal report (unpublished)
Lower Murray: Pike River	19	01/04/18 - 27/04/18	Wetland	breeding.	Several species of waterbird recorded including royal spoonbill, black-winged stilt, chestnut r=teal and red-necked avocet. Four species of frog including popplebonk ( <i>Limnodynastes dumerilii</i> ).	

<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; EPBC = endangered or vulnerable under the national *Environment Protection and Biodiversity Conservation Act* 1999; NFSA = Nature Foundation SA; NRM = Natural Resource Management; SA = South Australia.

#### 4.3 Important wetland case studies

Eleven DIWA/Ramsar sites were the target of Commonwealth environmental water in 2017–18 and had expected outcomes related to diversity (See Appendix A). These included several sites within Selected Areas (e.g. Gingham and Lower Gwydir (Big Leather) watercourses) as well as several sites for which little information on the effects of environmental water could be sourced (e.g. Pike–Mundic wetland system, Tuckerbil Swamp, Lower Balonne Floodplain). Five Ramsar sites were selected as case studies to assess the effects of Commonwealth environmental water on important wetlands:

- Banrock Station
- Barmah Forest
- Gunbower Forest
- Hattah-Kulkyne Lakes
- Macquarie Marshes.

#### 4.3.1 Banrock Station

#### What was the expected outcome?

The expected outcomes were:

- Protect the extent and condition of native riparian vegetation communities and provide reproduction and recruitment opportunities.
- Improve cover and condition of understorey vegetation including lignum.
- Enhance survival of seedlings arising from 2011 flood event.
- Improve the condition of the associated red gum woodland vegetation communities that are hosting one of the few colonies of regent parrot in South Australia.
- Establish more diverse and healthy habitat for both wetland and migratory bird species found in the surrounding Ramsar area.

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

A total of 2005 megalitres (ML) of environmental water was delivered to Banrock Station, all of which was Commonwealth environmental water. Water was delivered to five locations within the Ramsar site via pumping from December 2017 to June 2018: Herons Bend, Banrock Bend, Wigley Reach, Eastern Lagoon and Herons and Banrock Bend flats. Inundation of approximately 200 hectares (ha) of aquatic ecosystems occurred within the Ramsar site boundary (Figure 7 and Table 4). Environmental water in 2017–18 was part of a multi-year strategy to restore the ecological character of the Ramsar site. Commonwealth environmental water was first delivered via pumping to the site in 2015–16 and there was broader inundation during 2016–17 due to natural flooding.

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

Banrock Station was listed as a Ramsar site in 2002, primarily for its role in supporting threatened species – the endangered regent parrot (*Polytelis anthopeplus monarchoides*) and the vulnerable southern bell frog – as well as supporting a variety of waterbirds during critical life stages of migration, breeding and moulting (Butcher *et al.* 2009).

Information on the effects of the environmental water delivery are largely limited to observations contained within the CEWO acquittal report (unpublished). There are also a number of records during and immediately after environmental water delivery on the Atlas of Living Australia for waterbirds observed at the site. These provide qualitative evidence and the confidence in attributing benefits from environmental water to species must be considered in this context.



DIWA Loch Luna Wetland Complex Commonwealth environmental water 2017-18

Figure 7. Extent of inundation at Banrock Station during environmental watering in 2017–18.

Table 4. ANAE wetland and floodplain types inundated from environmental watering in 2017–18 at Banrock Station Ramsar site.

Australian National Aquatic Ecosystem (ANAE) wetland type	Area inundated (hectares)
F1.2: River red gum forest riparian zone or floodplain	5
F1.4: River red gum woodland riparian zone or floodplain	5
F1.8: Black box woodland riparian zone or floodplain	1
F2.2: Lignum shrubland riparian zone or floodplain	5
Pp4.2: Permanent wetland	160
Pt1: Temporary swamp	5
Pt2.1.2: Temporary tall emergent marsh	3
Pt2.3.2: Freshwater meadow	1
Pt3.1.2: Clay pan	11
Pt4.1: Floodplain or riparian wetland	10
Total	206

#### What species/communities potentially benefited?

There is some observational evidence to suggest that a range of species benefited from Commonwealth environmental water at Banrock Station in 2017–18 (Table 7). Monitoring over subsequent years would improve confidence in these assessments.

 Table 5. Species and communities that potentially benefited from Commonwealth environmental water at Banrock Station in 2017–18 (CEWO unpublished).

Community/species	Evidence
Wetland and riparian vegetation	Positive response including increased growth and / or condition observed in several species including nardoo ( <i>Marsilea drummondii</i> ), river red gum ( <i>Eucalyptus camaldulensis</i> ), black box ( <i>Eucalyptus largiflorens</i> ) and lignum ( <i>Duma florulenta</i> ).
Frogs	Six species of frog recorded including the nationally listed vulnerable southern bell frog heard calling and tadpoles observed from Eastern Lagoon. Monitoring indicates stable population of southern bell frog at the site since 2008.
Waterbirds	49 species of waterbird recorded. Breeding of cormorants, ibis, spoonbills, musk ducks ( <i>Biziura lobata</i> ), blue-billed ducks ( <i>Oxyura australis</i> ) and Australian spotted crake ( <i>Porzana fluminea</i> ). Provision of habitat for moulting Australian shelduck ( <i>Tadorna tadornoides</i> ).
Regent parrot	Consistent sightings of the regent parrot at all sites that received water. Improved condition (canopy cover) of river red gum trees, suggesting that Commonwealth environmental water is helping to support the nesting habitat of this species.

#### 4.3.2 Barmah–Millewa Forest

#### What was the expected outcome?

The expected outcomes for this watering action were described in terms of the broader objectives of environmental water across the entire River Murray system (CEWO, unpublished). Specific objectives for environmental water in 2017–18 for the Barmah–Millewa Forest are provided in the intervention monitoring report (Borrell 2018a):

- Promote floodplain connectivity to support large bodied native fish movement such as Murray cod (Maccullochella peelii peelii) and trout cod (Maccullochella macquariensis).
- Sustain colonial waterbird nesting sites with adequate water levels to enable fledging of young.
- Provide suitable habitat and resources for water birds.

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

The delivery of water to the Barmah–Millewa Forest is complex and was part of a broader watering action designed to affect the River Murray and associated floodplains and wetlands from Hume Dam to the Murray Mouth. For the first time, regulators in the Barmah–Millewa Forest were opened early in winter whilst flows in the main-stem Murray were still in-channel to allow a more natural inflow of water into the creeks as the river level downstream Yarrawonga rose and fell. A total of 439 GL of environmental water passed throughout the floodplain from July 2017 to March 2018 (Borrell 2018a), this included contributions from Commonwealth environmental water as well as TLM (Living Murray) water.

Inundation mapping indicates around 11780 ha of ANAE wetland types within the Ramsar sites were inundated (Figure 8 and Table 4). This is less than the maximum extent of inundation reported by Borrell (2018a) of 17 600 ha of inundation, which is likely due to inundation outside the Ramsar boundaries.



DIWA wetland boundary Commonwealth environmental water 2017-18 0 5 10 20 km

 $\sum_{\mathbf{N}}$ 

Figure 8. Extent of inundation at Barmah–Millewa Forest during environmental watering in 2017–18.

**Table 6.** ANAE wetland and floodplain types inundated from environmental watering in 2017–18 at Barmah–Millewa Forest (note that inundation of types < 1 hectare shown collectively as "other").</td>

Australian National Aquatic Ecosystem (ANAE) wetland type	Area inundated (hectares)
F1.12 Woodland riparian zone or floodplain	53
F1.2: River red gum forest floodplain	3388
F1.4: River red gum woodland floodplain	134
Lp1.1: Permanent lake	392
Lt1.1: Temporary lake	64
Pp4.2: Permanent wetland	303
Pt4.2: Temporary wetland	163
Pt1.1.2: Temporary river red gum swamp	5958
Pt1.2.2: Temporary black box swamp	9
Pt1.6.2: Temporary woodland swamp	314
Pt2.1.2: Temporary tall emergent marsh	307
Pt2.2.2: Temporary sedge/grass/forb marsh	305
Pt2.3.2: Freshwater meadow	92
Pt3.1.2: Clay pan	5
Other	296
Total	11 783

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

Barmah–Millewa Forest is listed as a single DIWA site but is part of two separate Ramsar sites: Barmah Forest, which lies in Victoria, and Millewa Forest, which is part of the NSW Ramsar site 'Central Murray Forests'. Barmah Forest was listed as a Ramsar site in 1982 and Central Murray Forests in 2003. The reasons for designation of the two sites are largely the same, in that together they form the largest intact floodplain forest in the bioregion; they support several threatened species, including Australasian bittern, superb parrot (*Polytelis swainsonii*), Murray cod, silver perch (*Bidyanus bidyanus*) and trout cod; and are important for breeding waterbirds, particularly colonial nesting species.

Aspects of biodiversity were monitored as part of the long-term icon site monitoring of the Barmah– Millewa Forest and included vegetation (Borrell 2018a), fish (Raymond *et al.* 2018; Sharpe 2018) and waterbirds (Borrell 2018b). The 2017–18 watering year was dry and the responses of biota to environmental watering across the Barmah–Millewa Forest need to be considered in this context.

#### Vegetation

Monitoring of moira grass (*Pseudoraphis spinescens*) indicated that the species was not present at Porter's Plain in Millewa Forest in 2017–18, despite the site supporting extensive areas of the community in the past (Hale and Butcher 2011). Porter's Plain did however support a diverse community of other wetland plants. Moira grass was present at Moira Lake and although the extent at this location had not increased, the condition in areas where it persisted was considered good (Borrell 2018a). Moira grass at Barmah–Millewa Forest has been declining in extent and condition for several years, due to a combination of factors including encroachment by river red gum (*Eucalyptus camaldulensis*) seedlings and giant rush (*Juncus ingens*), grazing (particularly by feral horses) and altered water regimes (Colloff *et al.* 2014). Recent studies have suggested that without appropriate grazing management, environmental watering is unlikely to result in improvements in the extent of moira grass in Barmah Forest (Nicol *et al.* 2018). The species is improving in places where fencing has been installed to exclude feral grazers (Goulburn Broken CMA, personal communication).

#### Fish

The overall condition of fish in the Barmah–Millewa Forest improved in 2018 compared to previous years (Raymond *et al.* 2018). Ten native and four alien fish species were recorded in 2017–18, including all three threatened species: Murray cod, silver perch and trout cod. The authors suggested that the improvement in fish indices of condition was related to improved floodplain – riverine habitat connectivity in the previous two years, contributed to by Commonwealth environmental water.

Native fish spawning in river habitats was high with in excess of 300 silver perch and golden perch eggs along with 380 Murray cod and 18 trout cod larvae collected during the 2017–18 sampling. There was some evidence that in-channel pulses as a result of environmental water increased golden perch (*Macquaria ambigua*) spawning intensity and may have benefited silver perch spawning (Raymond *et al.* 2018).

#### Waterbirds

Monitoring in Millewa Forest indicated a range of waterbird species utilising the wetlands benefiting from environmental water delivery. Forty-two species of waterbird were recorded with a maximum total abundance of 3800 individuals in autumn 2018 (Borrell 2018b) and 3900 from an aerial survey in October 2017 (data provided by MDBA). This included records of four threatened species:

- Australasian bittern targeted surveys indicating 62 males, representing more than 10% of the population of this species<sup>2</sup>.
- Australian little bittern (*Ixobrychus dubious*) in spring and summer surveys in both Barmah Forest and Millewa Forest
- eastern great egret (Ardea modesta) maximum count of over 100 birds at Barmah Lake
- intermediate egret (*Ardea intermedia*) in summer on Barmah Lake.

The inundation of wetlands by environmental water provided feeding and suspected breeding habitat for the endangered Australasian bittern. The number of males represents over 10% of the total population of this species (estimated at 500 individuals – Wetlands International 2012). Given that males are suspected to be polygamous (breeding with more than one female) it is possible that the site supported more than a third of the total population during environmental watering.

In addition, data provided by the MDBA for aerial surveys conducted in October 2017, indicate that 362 yellow-billed spoonbills were within the wetlands of the Barmah-Millewa Forest, which represents greater than 1% of the population for this species (estimated at 25 000 individuals – Wetlands International 2012).

A total of eight species of waterbird were recorded nesting in Millewa Forest in 2017–18 (Borrell 2018b):

- Australian white ibis (*T. moluccal*) 148 pairs
- little pied cormorant (*Microcarbo melanoleucos*)-125 pairs
- little black cormorant (*Phalacrocorax sulcirostris*) 17 pairs
- eastern great egret 65 pairs
- intermediate egret 3 pairs
- Nankeen night heron (*Nycticorax caledonicus*) 67 pairs
- royal spoonbill (*Platalea regia*) 102 pairs
- Australasian darter (Anhinga novahollandiae) 14 pairs

#### What species/communities potentially benefited?

Environmental water significantly extended the duration and extent of inundation across the site. In the absence of Commonwealth environmental water, many aquatic habitats would not have been inundated and duration would have likely been insufficient to complete cycles of breeding. There is good evidence to suggest that a number of species benefited from Commonwealth environmental water at Barmah–Millewa Forest in 2017–18 (Table 7).

<sup>&</sup>lt;sup>2</sup> Wetlands International 5<sup>th</sup> Waterbird Population Estimates (2012).

<sup>2017–18</sup> Basin-scale evaluation of Commonwealth environmental water – Biodiversity

**Table 7.** Species and communities that potentially benefitted from Commonwealth environmental water atBarmah-Millewa Forestin 2017–18.

Community/species	Evidence			
River red gum forest and woodland	No empirical evidence, but it is likely that inundation of around 9500 hectares of river red gum forest and woodland would have helped maintain or improve tree condition.			
Moira grass	Evidence of improved condition as a result of multiple management actions, including environmental water.			
Murray cod, trout cod, silver perch and golden perch	Spawning recorded for all four threatened species.			
Australasian bittern, yellow-billed spoonbill	Greater than 10% and 1% respectively of their populations recorded within the inundated wetland habitats.			
Waterbirds	Forty-two species with a maximum abundance of almost 400 individuals supported by inundated wetland habitats.			
Australian white ibis, little pied cormorant, little black cormorant, eastern great egret, intermediate egret, royal spoonbill Nankeen night heron and Australasian darter	Breeding supported by Commonwealth environmental water.			

#### 4.3.3 Gunbower Forest<sup>3</sup>

#### What was the expected outcome?

The expected outcomes were:

- Maintain the diversity and condition of small and large-bodied native fish populations in Gunbower Creek through the provision of habitat and opportunities for breeding and recruitment.
- Improve water quality and hydrological connectivity between Gunbower Forest and Gunbower Creek to support native fish, aquatic invertebrates and nutrient and carbon movement.

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

A total of 20 656 ML of Commonwealth environmental water was delivered over the full year (July 2017 to June 2018) as baseflows, to provide the following water regime: winter low flows, spring rise and stable flows. This is part of a long-term (three year) Environmental Water Agreement with the Commonwealth Environmental Water Office (CEWO) to provide the fish hydrograph from 2015–2018 in Gunbower Creek. Similar watering actions were implemented in 2015-16 and 2016–17.

Prior to the implementation of environmental water in Gunbower Creek, the system dried to a series of residual pools in the off-irrigation system. This was recognised as having a deleterious effect on fish recruitment and survival. Large bodied native fish such as Murray cod were found to have a fractured population structure, with no individuals in size classes that represent fish less than three years of age (Sharpe *et al.* 2014). Environmental water aimed to maintain baseflows, flow variability and connectivity in the Creek over the year.

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

The fish community of Gunbower Forest has been monitored under the MDBA TLM program since 2006. Native fish abundance in 2017 was the highest since monitoring began in 2006. In terms of size

<sup>&</sup>lt;sup>3</sup> Note that Common wealth environmental water was delivered to Gunbower Creek, a portion of which lies within the Gunbower Forest Ramsar Site.

<sup>2017–18</sup> Basin-scale evaluation of Commonwealth environmental water – Biodiversity

classes, the population structure of Murray cod was more robust, with the expected age classes increasing to 47 %. Although three invasive fish species were recorded in the Creek, the relative abundance of natives was high, with around two-thirds of fish captured representing native species (CPS Enviro 2018).

Contributions to the recovery of threatened native fish species varied across habitats. Only three of the expected seven expected threatened species were collected in the River (Murray cod, Murray-Darling rainbowfish and unspecked hardyhead<sup>4</sup>). In Gunbower Creek, however, there was a stable trend for threatened species and freshwater catfish (*Tandanus tandanus*) were recorded for the first time since monitoring began in 2006 (CPS Enviro 2018).

The authors concluded that environmental water delivery was instrumental in the recovery of Murray cod populations and made recommendations for future water deliveries to aid recovery of other native fish species.

#### What species/communities potentially benefited?

There is clear evidence that Murray cod have benefited from the restored hydrology in Gunbower Creek. There is some evidence that other threatened species in Gunbower Creek may have benefited from Commonwealth environmental water with the return of freshwater catfish to the system.

#### 4.3.4 Hattah-Kulkyne Lakes

#### What was the Expected Outcome?

The Expected Outcomes related to Ramsar values were:

- *Provide hydrological connectivity with the River Murray to promote:* 
  - exchange and cycling of nutrients and carbon between the River and the Lakes
     exchange and dispersal of biota, including seeds and fish eggs/larvae.
- Provide improved habitat and food resources for fish and waterbirds
- Maintain deeper water to support potential breeding of piscivorous waterbirds, leading to localised increases in cormorant and darter populations.
- Maintain potential breeding habitat for fish, including small bodied natives and golden perch.
- Support the ongoing reestablishment of water dependant vegetation in wetlands and waterways.

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

A total of 111 933 ML of environmental water was delivered to Hattah-Kulkyne Lakes, 32 145 ML of which was Commonwealth environmental water. Water was delivered to the site via pumping from the Murray River from July to October 2017. Eleven of the 12 lakes that comprise the Hattah-Kulkyne Lakes Ramsar site were inundated, with the episodic Lake Kramen remaining dry. Inundation of the Ramsar site comprised 1140 hectares of lake and wetland (Table 8). Although the Ramsar site encompasses wetland beds only, watering in 2017–18 contributed to inundation of an extensive area of floodplain outside the Ramsar site boundary (**Error! Reference source not found.**).

<sup>&</sup>lt;sup>4</sup> Murray cod are listed as Vulnerable under the EPBC Act, Murray-Darling rainbowfish and un-specked hardyhead are listed under the Victorian Flora and Fauna Guarantee Act.



**Figure 9.** Extent of inundation at Hattah-Kulkyne Lakes during environmental watering 2017–18. Note that the orange line indicates the Ramsar boundary, which includes only the lake beds of the wetlands.

**Table 8.** ANAE wetland and floodplain types inundated from environmental watering in 2017–18 within theHattah-Kulkyne Lakes Ramsar Site.

Australian National Aquatic Ecosystem (ANAE) wetland type	Area inundated (hectares)
F1.4: River red gum woodland riparian zone or floodplain	42
Lp1.1: Permanent lake	418
Lt1.1: Temporary lake	351
Pt2.3.2: Freshwater meadow	31
Total	842

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 extensively in 2013–14 and 2014–15 (Henderson *et al.* 2014) and in 2015–16 planned drying cycles were implemented at several of the lakes. The 2017–18 environmental watering action was the first artificial flooding of the floodplain following on from the natural flooding in 2016–17 (Wood *et al.* 2018).

#### 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, Australian painted snipe, regent parrot, silver perch, Murray cod, flat-headed galaxias (*Galaxias rostratus*), and winged peppercress (*Lepidium monoplocoides*) (Butcher & Hale 2011).

Hattah-Kulkyne Lakes is an example of a site where there is a large amount of information available, primarily through monitoring programs conducted on behalf of the Mallee Catchment Management Authority (CMA) and MDBA TLM Program. Monitoring outcomes of environmental water were available from 2015-16 for vegetation, fish and birds (Wood *et al.* 2018).

The Hattah Lakes Icon Site supports a diverse floodplain vegetation community, nothing that these areas are outside the Ramsar boundary. Monitoring in 2017 indicates that river red gum, black box and lignum communities have continued to improve as a result of natural flooding as well as environmental water. Canopy condition and population structure of floodplain trees was assessed largely as being good with progress towards ecological objectives for these communities.

Wetland vegetation in 2017 was dominated by amphibious and wetland plants with expected levels of diversity. There was no encroachment of terrestrial species into the majority of the lakes as a result of inundation with environmental water The patterns of wet and dry across the site provided a mosaic of habitats and supported a variety of wetland vegetation communities (Wood *et al.* 2018).

Ten species of native fish were recorded in 2017–18 with abundance of native fish being the highest since monitoring began in 2006. Two threatened species of native fish were recorded using habitats at the site: Murray cod and silver perch. Hattah Lakes act as nursery grounds for a number of native fish and there was evidence from 2017–18 that golden perch were able to move back to the river system from the wetlands (Wood & Brown 2018). The number of small-bodied native fish recorded was indicative of good recruitment over the past 12 months (Wood *et al.* 2018).

Thirty-four species of waterbird were recorded (32 in ground surveys, with an additional two species added from MDBA aerial surveys). This included the EPBC listed Australian painted snipe as well as several species listed under Victorian threatened species legislation: Australasian shoveller, eastern great egret, freckled duck, hardhead, little egret, and white-bellied sea eagle. The latter of which was observed to be breeding at the site (Wood *et al.* 2018). Aerial surveys recorded a small number of great cormorant nests (MDBA unpublished) and there was evidence from ground surveys of over 10 species breeding at the site in 2017–18.

#### 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 2017–18 (Table 9).

Community / species	Evidence
Piver red gum woodland	Good canopy condition and evidence of growth and increased population
River red guill woodialid	
	Good canopy condition and evidence of growth and increased population
Black box woodland	structure
Wetland vegetation	
communities	Variability in water regime supports a diversity of wetland plant species.
	High diversity and abundance of native fish. Supporting breeding of both
	small and large bodied native fish and successful movement of golden
Native fish	perch back to the river system.
	Supported 34 species of waterbird across a range of functional groups.
	Breeding of several species including the Victorian listed vulnerable white-
Waterbirds	bellied sea eagle.

**Table 9.** Species and communities that potentially benefitted from Commonwealth environmental water atHattah-Kulkyne Lakes in 2017–18.

#### 4.3.5 Macquarie Marshes

#### What was the expected outcome?

The expected outcomes were:

- Maintain and improve the condition of semi-permanent and permanent wetland vegetation in the Macquarie Marshes by providing a minimum of 90 days inundation of approximately 20 000 hectares of semi-permanent wetland vegetation (reedbeds, water couch, mixed marsh and river red gum forests).
- Maintain and provide access to feeding, foraging and breeding habitat for waterbirds, fish, frogs and other aquatic species.
- Contribute to movement, breeding, recruitment and dispersal opportunities for flow generalists and in-channel specialist native fish species such as Murray cod in the mid-Macquarie River, Marshes and lower Macquarie.

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

Water was delivered across two watering actions:

- A winter priming flow delivered between 19 July and 14 August 2017 of a total of 5939 ML, of which 2239 ML was Commonwealth environmental water.
- A winter / spring flow delivered between 15 August and 12 November 2017 of a total of 128 438 ML of which 48 421 ML was Commonwealth environmental water.

Commonwealth environmental water contributed to the inundation of a pproximately 23 000 hectares of the Macquarie Marshes in the 2017–18 water year (CEWO unpublished). This included just over 7500 hectares within the Ramsar boundary (Figure 10 and Table 10).



Figure 10. Extent of inundation at the Macquarie Marshes by Commonwealth environmental in 2017–18.

2017–18 Basin-scale evaluation of Commonwealth environmental water – Biodiversity

**Table 10.** ANAE wetland and floodplain types inundated from Commonwealth environmental watering in2017–18 at the Macquarie Marshes Ramsar site.

Australian National Aquatic Ecosystem (ANAE) wetland type	Area inundated (hectares)
Pp4.2: Permanent wetland	6791
F1.4: River red gum woodland riparian zone or floodplain	233
Pt2.2.2: Temporary sedge/grass/forb marsh	171
Pt1.8.2: Temporary shrub swamp	90
F1.10: Coolibah woodland and forest riparian zone or floodplain	79
Pt1.2.2: Temporary black box swamp	45
Pt2.1.2: Temporary tall emergent marsh	43
F1.2: River red gum forest riparian zone or floodplain	41
Rp1.4: Permanent lowland stream	40
F1.11: River cooba woodland riparian zone or floodplain	19
F2.2: Lignum shrubland riparian zone or floodplain	10
Lt1.1: Temporary lake	9
F1.8: Black box woodland riparian zone or floodplain	2

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 wetland'. 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 wetland' in Table 10 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).

#### 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, Australian painted snipe, superb parrot, Murray cod and basalt peppercress (*Lepidium hyssopifolium*) (Office of Environment and Heritage 2012).

Available data comprise summary reports on waterbirds (Spencer & Ocock 2018) and frogs (Ocock & Spencer 2017) as well as preliminary observations as detailed in the CEWO acquittal report (unpublished) and an aerial survey of waterbirds conducted by the MDBA.

While there was no data available, there is evidence that wetland vegetation benefited from Commonwealth environmental water in 2017–18 with increases in growth and diversity of vegetation and improved canopy condition of trees (CEWO unpublished).

The site supported a diversity of waterbirds with 50 species recorded in ground surveys including several threatened species (Australasian bittern, Australian painted snipe) as well as international migratory waders (marsh sandpipers and sharp-tailed sandpipers). Aerial surveys recorded over 16 000 waterbirds in the Macquarie Marshes, with 1000s of ducks and large bodied wading birds (MDBA unpublished). The inundation provided a variety of feeding and foraging habitats, which supported the diversity of birds. Although breeding activity was low in 2017–18, seven species were confirmed breeding at the site including black swan, red-kneed dotterel (*Erythrogonys cinctus*),

Australasian grebe (*Tachybaptus novaehollandiae*), Australian white ibis, little pied cormorant, Australasian darter and royal spoonbill (Spencer & Ocock 2018).

The three most common flow-responsive frog species (barking marsh frog, spotted marsh frog and eastern sign-bearing froglet) were very active in September in the Macquarie Marshes in response to the delivery of environmental water. In total six species were recorded, with evidence of not only breeding stimulated by inundation, but recruitment of frogs into the adult population (Ocock & Spencer 2017).

#### 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 2017–18 (Table 11).

**Table 11.** Species and communities that potentially benefitted from Commonwealth environmental water inthe Macquarie Marshes in 2017–18.

Community/species	Evidence
Emergent marsh vegetation	Growth of emergent marsh vegetation in response to watering.
Waterbirds	50 species recorded spanning the full range of functional groups. Includes records of Australasian bittern and Australian painted snipe.
Frogs	Six species recorded, breeding and recruitment.

## 5 Basin-scale outcomes 2014–18

## 5.1 Highlights

- Commonwealth environmental water has contributed to maintaining the ecological character of 10 of the 16 Ramsar sites in the Basin over the first four years of the LTIM project.
- Forty-nine species of conservation significance were recorded at sites that received Commonwealth environmental water in the period 2014–18.
- Over the past four years 101 waterbird species have been recorded at sites that received Commonwealth environmental water, with more than one percent of the population supported for over 20 species.

## 5.2 Effect of Commonwealth environmental water on species diversity

## 5.2.1 Number of species

Commonwealth environmental watering actions over the first four years of the LTIM Project contributed to the inundation of a wide range of ecosystem types within the Basin that included approximately 60 % of wetland, lake and floodplain and ecosystem types.

Lists of ecosystems, species and communities that potentially benefited from Commonwealth environmental water in the first four years of LTIM (2014–18) are provided in Annex B and comprise:

- 71 species of native plants
- 16 species of native fish
- 48 species of bush bird
- 101 species of wetland dependent bird<sup>5</sup>
- 20 species of frog
- 3 species of turtle.

## 5.2.2 Waterbird abundance and diversity

Aerial surveys from the MDBA Aerial Waterbird Survey provides data across a number of wetlands in the Basin. A total of 888 000 individual waterbirds have been recorded at sites that received Commonwealth environmental water over the past four years (data from MDBA) (Figure 11). Of note is that the Coorong and Lower Lakes generally represents the largest number of waterbirds of the sites that receive Commonwealth environmental water. In 2014–15; 2015–16 and 2017–18, the Coorong supported between 80 and 90 % of the total waterbird abundance at sites included in aerial surveys that received Commonwealth environmental water. In 2016–17, however, when there was widescale inundation of inland landscapes (augmented by environmental water) the Coorong and Lower Lakes Site represented just 14% of the total abundance. This highlights the continental scale distributions of many waterbirds and their ability to respond to climatic conditions, moving opportunistically to areas of highest productivity (Kingsford *et al.* 2010; Wen *et al.* 2016).

Wetlands International (2012) provides population estimates for waterbirds across the globe and in Australia. Supporting greater than one percent of the population of any species of waterbird is considered to be significant with respect to maintaining that species and is one of the criteria for listing a wetland of international importance under the Ramsar Convention. Cumulative totals (within a single year but across sites) indicate that Commonwealth environmental water is likely to have supported greater than one percent of the population of over 20 waterbird species (Table 12).

<sup>&</sup>lt;sup>5</sup> Note that this is the first report that has included data collected from the Coorong and Lower Lakes, which has added additional (typically coastal) species to this list.

<sup>2017–18</sup> Basin-scale evaluation of Commonwealth environmental water – Biodiversity



**Figure 11.** Total abundance of waterbirds from sites that received Commonwealth environmental water (source MDBA Aerial Waterbird Survey; data provided by MDBA). Note that shorebirds cannot be distinguished to species in aerial surveys and so Australian shorebirds and migratory shorebirds are combined into a single group.

**Table 12.** Waterbird species for which greater than one percent of the population have been recorded in a single year at sites that received Commonwealth environmental water (data provided by MDBA, with data from several ground surveys added). CLL = Coorong and Lower Lakes, Inland = all other sites.

Species	1% of the	Total abundance from multiple sites							
	population*	2014–15		2015–16		2016–17		2017–18	
		Inland	CLL	Inland	CLL	Inland	CLL	Inland	CLL
Aus tra lasian bittern	5			48				50+	
Australian fairy tern	15		165		108				
Australian pelican	1400		10 735	4051	9232	13 191	5492		7953
Australian shelduck	10 000		13 926		12 953				
Australian wood duck	10 000					17 658			
Bandedlapwing	1000					1984			
Black-winged stilt	1750					5043			
Black swan	10 000				10 129				
Eastern great egret	1000					2295			
Great cormorant	1000		17 383		14 593		8925		13 706
Great crested grebe	250				556				
Greyteal	20 000		41 954		40 431	138 795			46 890
Little black cormorant	10 000								11 002
Pied cormorant	1000		9044		5568		3294		4392
Red-necked avocet	1100		3980		3830				1795
Red-necked stint	3200				16 430				
Sharp-tailed sandpiper	1600		4066				9242		
Straw-necked ibis	10 000					74 725			
White-faced heron	1000					2338			
White-necked heron	250			302		792		1035	
Yellow-billed spoonbill	250	436		2480				1753	

\* Population estimates from Wetlands International (2012).

#### Providing a diversity of habitat for a diversity of waterbirds

Over the first four years of the LTIM Project 101 waterbird species have been recorded at sites that received Commonwealth environmental water. In addition to providing habitat for foraging, there is a growing body of evidence of environmental water supporting a broad range of functions for waterbirds including critical life stages of breeding, migration, moulting and drought refuge. The high diversity of waterbirds and the range of functions supported is a product of providing a diversity of habitats across the Basin.

#### Large open water bodies in spring and early summer for moulting waterfowl

Waterfowl undergo an annual moult of their primary flight feathers, during which individuals are flightless for a period of two to five weeks, which makes them more vulnerable to predators. The Australian shelduck is the only species of waterfowl in Australia known to form large moulting congregations. The species will migrate to permanent wetlands with expanses of open water which provide a refuge during this vulnerable stage (Firth 1982). Commonwealth environmental water was used to maintain permanent open water habitat at Banrock Station supporting 160 moulting Australian shelduck in 2017–18.

#### Suitable habitat and high productivity to support waterbird breeding

Although breeding of waterbirds has occurred in all four years of the LTIM project, the most notable example was during the 2016–17 watering year. Large scale breeding occurred at a number of locations, with 1000s of nests of colonial breeding birds in the Lachlan, Murrumbidgee and Macquarie catchments supported by Commonwealth environmental water. Most of these waterbirds required vegetated habitat (generally shrubs and trees) to be inundated for the duration of breeding from nest building to fledging of young. Reproductive success was improved through the use of water by maintaining water depths under nesting colonies (Brandis 2017), and by providing adequate foraging habitats in adjacent wetland areas.

#### Supporting international migratory species

A number of locations across the Basin that received Commonwealth environmental water supported migratory shorebirds from the East Asian-Australasian Flyway. The majority of these birds migrate from breeding grounds in North-east Asia and Alaska to non-breeding grounds in Australia and New Zealand, covering the journey of 10,000 kilometres twice in a single year. The lifecycle of most international migratory shorebirds involves (Bamford et al. 2008):

- breeding in May to August (northern hemisphere);
- southward migration to the southern hemisphere (August to November);
- feeding and foraging in the southern hemisphere (August to April); and
- northward migration to breeding grounds (March to May).

These species typically require shallow wetland or mudflat habitat of high productivity in order to build up sufficient reserves to complete the return journey to the northern hemisphere. While the Coorong has supported the largest number and highest diversity of these species (of sites that received Commonwealth environmental water) they have also been recorded at several inland sites.

#### Maintaining drought refuges in dry times

With the exception of 2016–17 in the southern basin, the first four years of the LTIM project have been characterised by dry climatic conditions. Commonwealth environmental water has contributed significantly to maintaining wet habitat for waterbirds and other biota across much of the Basin. This includes providing large artificial floods in Hattah-Kulkyne Lakes and Macquarie Marches during 2017–18 as well as keeping areas of the Gwydir wetlands inundated each year. Waterbirds benefit both directly by the immediate provision of for aging habitat and indirectly through maintaining important habitats for critical life stages over longer periods.



White ibis chicks at Barmah (Keith Ward).

Text box 1. Commonwealth environmental water contributions to supporting waterbirds.

#### 5.3 Maintaining the ecological character of Ramsar sites

There are 16 Ramsar sites in the Basin and over the first four years of the LTIM Project, Commonwealth environmental water has been delivered to 10 of these sites (**Error! Reference** ource not found.).

**Table 13.** Ramsar sites that have been the target of Commonwealth environmental watering actions in the firstfour years of the LTIM Project.

Ramsar site	Commonwealth environmental water				
	2014–15	2015–16	2016–17	2017–18	
Banrock Station		х		Х	
Barmah Forest		х		Х	
Central Murray Forests		х		Х	
Coorong, Lakes Alexandrina and Albert	Х	х	Х	Х	
Fivebough and Tuckerbil Swamps				Х	
Gunbower Forest		х	Х	Х	
Gwydir Wetlands	Х	х	Х	Х	
Hattah-Kulkyne Lakes	х	х		Х	
Macquarie Marshes	х	х	Х	Х	
Narran Lakes			Х		

In the first four years of the LTIM project, Commonwealth environmental water contributed to multi-year strategic inundation of Ramsar Sites designed specifically to maintain ecological character. Environmental water is delivered differently in response to the state of critical components, processes and services and the climatic conditions. At Hattah Lakes and the Macquarie Marshes, for example environmental water has been used to both augment natural floods as well as to inundate wetlands and floodplains at times when they otherwise would have remained dry (see Text Box 2).

At Gunbower Forest water was delivered each year between 2015–18 as part of a three year Environmental Water Agreement with the Commonwealth Environmental Water Office (CEWO) to provide the fish hydrograph in Gunbower Creek. Prior to the implementation of environmental water in Gunbower Creek, the system dried to a series of residual pools in the off-irrigation system. This was recognised as having a deleterious effect on fish recruitment and survival with no Murray cod in size classes that represent fish less than three years of age (Sharpe *et al.* 2014). Following the implementation of Commonwealth environmental watering there was evidence of recruitment in five native species: Australian smelt, carp gudgeon, Murray cod, Murray-Darling rainbow fish and unspecked hardy-head (Bloink & Robinson 2016). There has been a marked improvement in the population structure of Murray cod in the system and the first instances of freshwater catfish recorded in over 15 years (CPS Enviro 2018). While this action was aimed at only a small number of critical components, processes and services (native fish, threatened fish species) there is good evidence to suggest that Commonwealth environmental water is contributing to maintaining both these aspects of the ecological character of the site.

Barmah–Millewa Forest is listed as two separate Ramsar sites – Barmah Forest and Central Murray Forests. However, the ecological character descriptions for both sites identify largely the same critical components, processes and services for the site (Hale & Butcher 2011; Harrington & Hale 2011). The potential contribution of Commonwealth environmental water to maintaining each of these identified critical components, processes and services and services is provided in Table 14.

**Table 14.** Contribution of Commonwealth environmental water in 2014–18 to maintaining the ecologicalcharacter of the Barmah Forest and Central Murray Forests Ramsar sites.

Critical components, processes and services	Description	Contribution of Commonwealth environmental water
Hydrology	In undation of the site is driven largely by flows within the River Murray. Large-scale floods that in undate the forest are generally the result of catchment-scale rainfall events. Moderate-and small-scale in undation is managed through regulators and environmental water.	There is evidence to suggest that Commonwealth environmental water contributed to small/moderate-scale in undation of the site in 2015–16 and 2017– 18.
Vegetation	The 2 critical wetland vegetation categories a re river red gum forests and floodplain marshes. Approximately 85–90% of the 2 sites a re covered by inundation-dependent forest and woodland. Floodplain marshes include moira grass plains which are regionally significant.	It is likely that environmental water contributed to maintaining river red gum health. Despite a slight improvement in the condition of moira grass in 2017–18, there has been no increase in extent. This is largely a result of grazing and the presence of feral horses.
Fish	17 native species of fish have been recorded from within the site.	11 native species recorded within the site over the two watering events with evidence that environmental water was maintaining habitat for theses pecies.
Waterbirds	67 species of wetland bird have been recorded from the site. This includes 11 species listed under international migratory agree ments. The site is significant for supporting breeding of colonial nesting waterbirds and contains a significant breeding population of superb parrot.	Over 45 species of waterbirds recorded in the two years that Commonwealth environmental water contributed to the inundation of the site. Small scale breeding of colonial nesting species recorded on both occasions.
Supports diversity of wetland types	The site supports part of the largest remaining river red gum forest and provides a mosaic of vegetated wetland habitats.	Some evidence that the short-term watering maintained the diversity of wetland types in what would otherwise have been dry conditions.
Provides physical habitat (for waterbirds)	The site provides habitat that supports waterbird breeding and feeding.	Small-scale waterbird breeding supported, and evidence of foraging habitat provided. Aerial surveys recorded several thousand waterbirds in November 2015 and October 2017.
Supports threatened wetland species	Austra lasian bittern, Australian painted s ni pe, superb parrot, silver perch, Murray cod, trout cod.	Very large numbers of Australasian bittern recorded in inundated vegetated marshes. Superb parrot recorded feeding and nesting in river red gums. All three threatened fish species recorded at the site with evidence of breeding and recruitment for each.
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 of waterbirds, including breeding habitat for many waterbird species and a rich and diverse flora and seed bank.	The small-scale, short-term environmental watering of the Barmah–Millewa Forest is likely to have helped maintain the diversity of plants and animals at the sites in what would otherwise have been a dry period.
Ecological connectivity	The site provides important migratory routes between riverine, we tland and floodplain habitats for fish spawning and recruitment.	There is evidence that fish moved in and out of the sites in response to environmental watering; maintaining ecological connectivity.

#### Large scale inundation at high value sites

In 2017–18, Commonwealth environmental water contributed to large scale floodplain inundation at two Ramsar sites. At Hattah-Kulkyne Lakes 111 933 ML of environmental water (32 145 ML of which was Commonwealth environmental water) was delivered to inundate 11 lakes within the Ramsar site and a moderate amount of surrounding floodplain comprising of river red gum and black box woodland. At the Macquarie Marshes, 23 000 hectares of wetland was inundated by environmental water, including over 7000 hectares of the Ramsar site. In both of these instances, large areas of floodplain and wetland that would otherwise have remained dry was inundated for several months. The magnitude of these events is highlighted by comparing inundation in 2016–17 with 2017–18 at the Macquarie Marshes (see map below). While the extent of Commonwealth environmental water was similar in both years, in 2016–17 environmental water was used to augment a large natural flood, while in 2017–18 environmental water represented the only significant surface water in an otherwise dry landscape.

The short-term effects of the wide scale artificial inundation in 2017–18 included high diversity and moderate abundance of waterbirds, with over 50 species of waterbirds recorded and the nationally endangered Australian painted snipe observed at both locations. There were also positive responses from frogs, turtles and other wetland dependent fauna as well as an improvement in vegetation condition.

The effects on ecological character, however, are likely to be longer lasting, with expected increases in resilience of wetland ecosystems as a result of multi-year inundation.



**Text box 2.** Commonwealth environmental water contributions to maintaining the ecological character of Hattah-Kulkyne Lakes and Macquarie Marshes Ramsar sites.

## 5.4 Supporting threatened species

Forty-nine significant species were recorded at sites that received environmental water in 2014–18 (Table 15). This includes 18 international migratory waterbird species, 18 nationally listed threatened species and 17 species listed under state legislation. It is anticipated that as LTIM progresses and more data become available, this list will not only grow, but our understanding of how Commonwealth environmental water is benefiting these species across the Basin will also increase.

Two iconic and nationally listed threatened bird species were recorded at inland sites that received Commonwealth environmental water. The Australasian bittern was recorded in all four years and the Australian painted snipe in 2015–16 and 2017–18. There is very good evidence that Commonwealth environmental water is contributing to maintaining populations of Australasian bittern with over 10% of the estimated population of the species recorded at the Barmah-Millewa Forest sites. The species prefers shallow wetlands with emergent vegetation (Menkhorst 2012), which has been the target of environmental water at this Ramsar site in two of the past four years.

In addition, several national listed species are regularly supported at the Coorong and Lower Lakes sites including the Australian fairy tern (*Sternula nereis nereis*) and four international migratory waders that are also listed as vulnerable or critically endangered under EPBC Act: bar-tailed godwit (*Limosa lapponica*), curlew sandpiper (*Calidris ferruginea*), eastern curlew (*Numenius madagascariensis*) and red knot (*Calidris canutus*).

Two species of parrot that are listed nationally as vulnerable (regent parrot and superb parrot) are often considered 'wetland dependent' for their reliance on river red gum as nesting trees. These two species were recorded in sites that received Commonwealth environmental water in all years and watering actions aimed at maintaining tree health would be sustaining nesting habitat.

There are indications of benefits to Murray cod, in Gunbower Creek with a restoration of age structure in the population following the implementation of the "fish hydrograph" with Commonwealth environmental water (CPS Enviro 2018); and to freshwater catfish from a number of locations around the Basin including the Border Rivers (CEWO unpublished).

There are a relatively large number of records for southern bell frog from several locations around the Basin that received Commonwealth environmental water including the Murrumbidgee wetlands, Banrock Station and wetlands along the Lower Murray (CEWO unpublished). This species of frog is considered "flow dependent" and has been shown to move in response to artificial watering, rather than rainfall (Wassens *et al.* 2010) indicating that it can benefit from environmental watering at key habitats.

Group	Common name	Species name	Significance <sup>1</sup>
Birds	Australian fairy tern	Sternula nereis neries	V (EPBC)
	Bar-tailed godwit	Limosa lapponica	V (EPBC), JAMBA, CAMBA, ROKAMBA
	Black-tailed godwit	Limosa limosa	JAMBA, CAMBA, ROKAMBA, V (NSW)
	Common greenshank	Tringa nebularia	JAMBA, CAMBA, ROKAMBA
	Common sandpiper	Actitis hypoleucos	JAMBA, CAMBA, ROKAMBA
	Curlew sandpiper	Calidris ferruginea	CE (EPBC), JAMBA, CAMBA, ROKAMBA
	Eastern curlew	Numenius madagascariensis	СЕ (ЕРВС), ЈАМВА, САМВА, ROKAMBA
	La tha m's s nipe	Gallinago hardwickii	JAMBA, CAMBA, ROKAMBA
	Marsh sandpiper	Tringa stagnatilis	JAMBA, CAMBA, ROKAMBA
	Oriental pratincole	Glareola maldivarum	JAMBA, CAMBA, ROKAMBA

**Table 15.** Listed species that were recorded at sites that received Commonwealth environmental water in2014–18.

Group	Common name	Species name	Significance <sup>1</sup>
	Pacific golden plove r	Pluvialis fulva	ЈАМВА, САМВА, КОКАМВА
	Redknot	Calidris canutus	V (EPBC), JAMBA, CAMBA, ROKAMBA
	Red-necked stint	Calidris ruficollis	JAMBA, CAMBA, ROKAMBA
	Ruddyturnstone	Arenaria interpres	JAMBA, CAMBA, ROKAMBA
	Ruff	Philomachus pugnax	JAMBA, CAMBA, ROKAMBA
	Sanderling	Calidris alba	ЈАМВА, САМВА, КОКАМВА
	Sharp-tailed sandpiper	Calidris acuminata	JAMBA, CAMBA, ROKAMBA
	Whimbrel	Numenius phaeopus	ЈАМВА, САМВА, КОКАМВА
	Wood sandpiper	Tringa glareola	JAMBA, CAMBA, ROKAMBA
	Austra lasian bittern	Botaurus poiciloptilus	Endangered (EPBC)
	Australianlittlebittern	Ixobrychus dubius	Endangered (VIC)
	Australian painted snipe	Rostratula australis	Endangered (EPBC)
	Black-necked stork	Ephippiorhynchus asiaticus	Endangered (NSW)
	Blue-billed duck	Oxyura australis	Endangered (VIC)
	Brolga	Grus rubicunda	Vulnerable (NSW, VIC)
	Comb-crested jacana	Irediparra gallinacea	Vulnerable (NSW)
	Eastern great egret	Ardea modesta	Vulnerable (VIC)
	Freckledduck	Stictonetta naevosa	Vulnerable (SA)
	Hardhead	Aythya australis	Vulnerable (VIC)
	Intermediate egret	Ardea intermedia	Endangered (VIC)
	Little egret	Egretta garzetta	Endangered (VIC)
	Magpiegoose	Anseranas semipalmata	Vulnerable (NSW)
	Muskduck	Biziura lobata	Vulnerable (VIC)
	Regent parrot	Polytelis anthopeplus	Vulnerable (EPBC)
	Superb parrot	Polytelis swainsonii	Vulnerable (EPBC)
	White-belliedsea-eagle	Haliaeetus leucogaster	Vulnerable (NSW, VIC)
Fish	Eel-tailed catfish	Tandanus tandanus	Endangered (NSW, VIC)
	Flat-headed galaxias	Galaxias rostratus	Critically endangered (EPBC)
	Murraycod	Maccullochella peelii	Vulnerable (EPBC)
	Murrayhardyhead	Craterocephalus fluviatilis	Endangered (EPBC)
	Olive perchlet	Ambassis agassizii	Endangered population (NSW)
	Purple-spotted gudgeon	Mogurnda adspersa	Endangered (NSW)
	Silverperch	Bidyanus bidyanus	Endangered (EPBC)
	Trout cod	Maccullochella macquariensis	Endangered (EPBC)
Frogs	Southern bellfrog	Litoria raniformis	Vulnerable (EPBC)
Plants	Basalt peppercress	Lepidium hyssopifolium	Endangered (EPBC)
	Glistening dock	Rumex crystallinus	Vulnerable (VIC)
	Rigid water milfoil	Myriophyllum porcatum	Vulnerable (EPBC)
	Winged peppercress	Lepidium monoplocoides	Endangered (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 1999* (EPBC Act).

## 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 (CEWO 2013):

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

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 16).

Basin Plan objectives	Basin outcom	ies	5-year expected outcomes	1-year expected outcomes	Measured and predicted 1-year outcomes 2017–18	Measured and predicted 1–4-year outcomes 2014–18
Biodiversity	Ecosystem di	versity	None identified	None identified	Over 296 000 hectares of mapped wetland and floodplain i nundated	75% of the different a quatic ecosystem
(Basin Plan S. 8.05)					71% of the different a quatic ecosystem types represented in areas influenced by Commonwealth environmental water	environmental water.
	Species diversity	Vegetation	Vegetation diversity	Reproduction	A significant proportion of native species, including numerous aquatic forbs, grasses and sedges/rushes,	Presence of some native species likely to be dependent on in undation by
				Condition	only present in areas in undated by Commonwealth environmental water.	Common wealth e nvironmental water. De cre ase in exotic taxa.
			Growth and survival	Germination Dispersal	Greater vegetation cover in wetlands i nundated by Common wealth environmental water in the Murrumbidgee river system. Significant increases in species richness in wetlands in undated by Common wealth environmental water during draw down phase.	Enhanced diversity of vegetation communities at Basin scale in response to delivery of Common wealth environmental water.
		Waterbirds	Waterbird diversity		70 species of waterbird recorded across all functional feeding groups	101 waterbird species recorded at sites that have received Commonwealth environmental water.
			Waterbird diversity and	Survival and condition	Supporting greater than 1% of the relevant populations of nine species of waterbird.	Greater than 1% of the population of 21 species.
			population condition	Chicks	Breeding recorded for several species in low to	Smallerscalebreeding at localised sites
			(abundance and population structure)	Fledglings	moderate numbers.	ye a rs . Commonwealth environmental water in drier ye a rs . Commonwealth environmental water a ugmenting large floods in wet periods to improve reproductive success.
		Other vertebrate diversity		Young	Breeding of many frog species including some temporary we tland specialists. Some evidence of turtle breeding.	Breeding offrogs at several locations across the four years.
			Adult a bundance		Large numbers of several species recorded including the southern bell frog.	Continued foraging habitat provided.

 Table 16. Contribution of Commonwealth environmental water in 2014–18 to Basin Plan objectives associated with biodiversity.

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# Annex A. Watering actions contributed to by Commonwealth environmental water in 2017–18 with expected outcomes for fish, vegetation, waterbirds, frogs or other vertebrates

**Table A1.** Watering actions contributed to by Commonwealth environmental water in 2017–18 with expected outcomes for fish, vegetation, waterbirds, frogs or other vertebrates. Expected outcomes have been translated into the categories of the Outcomes Framework for simplicity (Con. = connectivity; Proc. = processes (primary production/decomposition); Res. = resilience; WQ = water quality). \*Indicates Ramsar Site. # Indicates Directory of Important Wetlands (DIWA) Site

	Watering	Commonwealth		Flow	Expected outcomes (P = primary; S = secondary)								
Surface water region/asset	Action Number	water volume (ML)	Dates	component	Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Barwon-Darling: Barwon-Darling River and fringing wetlands (Mungindi to Menindee)	00111-49	6295	01/07/17 - 15/08/17	Fresh	S	-	-	-	-	-	-	Ρ	S
Barwon-Darling: Barwon-Darling River and fringing wetlands (Mungindi to Menindee)	00111-49	1717	26/10/17 - 31/10/17	Fresh	S	-	-	-	-	-	-	Р	S
Barwon-Darling: Barwon-Darling River and fringing wetlands (Mungindi to Menindee)	00111-49	735	02/12/17 - 04/12/17	Fresh	S	-	-	-	-	-	-	Ρ	S
Barwon-Darling: Barwon-Darling River and fringing wetlands (Mungindi to Menindee)	00111-49	696	28/02/18 - 02/03/18	Fresh	S	-	-	-	-	-	-	Ρ	S
Border Rivers: Severn River	00111-41	35	Late Nov 2017	Fresh	Р	-	-	-	-	-	-	-	S
Border Rivers: Severn River	00111-41	267	28/12/17 - 06/01/18	Fresh	Р	-	-	-	-	-	-	-	S
Border Rivers: Dumaresq- Macintyre River and Fringing Wetlands	00111-42	293	3/7/18	Fresh	Ρ	-	-	-	-	-	-	-	S
Border Rivers: Dumaresq- Macintyre River and Fringing Wetlands	00111-42	349	14/10/17 - 15/10/17	Fresh	Ρ	-	-	-	-	-	-	-	S
Border Rivers: Lower Moonie River and Fringing Wetlands	00111-44	1106	21/10/17 - 30/12/17	Fresh	Ρ	-	-	-	Ρ	S	-	-	S
Border Rivers: Lower Moonie River and Fringing Wetlands	00111-44	1217	03/02/18 - 26/03/18	Fresh	Р	-	-	-	Р	S	-	-	S

	Watering	Commonwealth		Elow		E	xpected o	outcomes	s (P = prim	ary; S =	secondary	()	
Surface water region/asset	Action Number	water volume (ML)	Dates	component	Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Border Rivers: Dumaresq- Macintyre River and Fringing Wetlands	10046-03	3252	26/09/17 - 26/10/17	Baseflow	Ρ	-	-	-	S	-	-	-	-
Border Rivers: Dumaresq- Macintyre River and Fringing Wetlands	10046-04	684	21/08/17 - 08/10/17	Fresh, Baseflow	Р	-	-	-	-	-	S	-	S
Border Rivers: Border Rivers including floodplain	10074-01	4286	13/04/18 - 21/04/18	Fresh	Р	-	-	-	-	-	-	S	-
Lower Broken Creek and fringing wetlands	10041-03	1552	01/07/17 - 17/08/17	Baseflow	Р	-	-	-	-	-	-	-	-
Lower Broken Creek and fringing wetlands	10041-03	1121	18/08/17 - 31/08/17	Fresh	-	Р	-	-	-	-	-	-	-
Lower Broken Creek and fringing wetlands	10041-03	4674	01/09/17 - 02/10/17	Baseflow	Р	-	-	-	-	-	-	-	Ρ
Lower Broken Creek and fringing wetlands	10041-03	6873	03/10/17 - 15/11/17	Baseflow, Fresh	Р	Р	-	-	-	-	-	-	Ρ
Lower Broken Creek and fringing wetlands	10041-03	3966	16/11/17 - 07/12/17	Baseflow	Р	-	-	-	-	-	-	-	Р
Lower Broken Creek and fringing wetlands	10041-03	1444	16/05/18 - 30/06/18	Baseflow	Р	-	-	-	-	-	-	-	-
Upper Broken Creek and Moodie Swamp	10042-03	498	18/04/18 - 07/06/18	Fresh, Wetland	Р	Р	Ρ	-	Ρ	-	-	-	Р
Lower Murray: Coorong, Lower Lakes and Murray Mouth*	10065-04	326320	01/07/17 - 30/09/17	Fresh	Ρ	S	-	-	S	-	S	-	S
Lower Murray: Coorong, Lower Lakes and Murray Mouth*	10065-04	354807	01/10/17 - 31/01/18	Fresh	Р	S	-	-	S	-	S	-	S
Lower Murray: Coorong, Lower Lakes and Murray Mouth*	10065-04	203279	01/02/18 - 31/05/18	Baseflow	Р	S	Р	-	S	-	S	-	S
Lower Murray: Coorong, Lower Lakes and Murray Mouth*	10065-04	9331	01/06/18 - 30/06/18	Baseflow	Р	S	-	-	S	-	S	-	S

	Watering	Commonwealth		Flow		E	epected of	outcomes	; (P = prim	ary; S =	secondar	y)	
Surface water region/asset	Action Number	water volume (ML)	Dates	component	Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Campaspe River Catchment	10003-05	6218	13/11/17-28/11/17	Fresh	Р	Р	-	-	Р	-	-	-	-
Central Murray: Barmah-Millewa Forest*	10065-02	3344	01/07/17 - 23/03/18	wetland	Р	-	-	-	-	-	Ρ	-	-
Central Murray: Gunbower Creek*	10030-03	20656	01/07/17 - 30/06/18	Baseflow	Р	-	-	-	-	Р	-	-	Р
Central Murray: Hattah Lakes*	10065-03	32145	03/07/17 - 31/10/17	Wetland	Р	Р	Р	-	-	Р	-	-	-
Central Murray: River Murray	10065-01	289606	01/07/17 - 31/12/17	Fresh, Overbank	Ρ	Р	Р	-	-	-	Р	-	-
Central Murray: Barham Lake	10065-08	102	23/01/18 - 23/03/18	Wetland	Р	S	S	S	-	-	-	-	-
Edward Wakool: Yallakool Wakool System	10070-01	16452	01/09/17 - 01/05/18	Fresh	S	S	-	S	S	S	S	S	S
Edward Wakool: Tuppal Creek	10070-01	1641	21/08/17 - 10/11/17	Baseflow	S	S	-	S	S	S	S	S	S
Edward Wakool: Colligen-Neimur	10070-03	13832	01/09/17 - 01/05/18	Fresh	S	S	-	S	S	S	S	S	S
Edward Wakool: Tuppal Creek	10070-04	933	29/03/18 - 05/05/18	Baseflow	S	S	-	S	S	S	S	S	S
Edward Wakool: Yallakool Wakool System	10054-11	7915	01/07/17 - 30/08/17	Baseflow	S	S	-	S	S	S	S	S	S
Edward Wakool: Colligen-Neimur	10054-12	6370	01/07/17 - 30/08/17	Baseflow	S	S	-	S	S	S	S	S	S
Goulburn: Lower Goulburn River	10064	112232	01/07/17 - 24/07/17	Fresh	Р	Р	-	-	Р	-	-	-	-
Goulburn: Lower Goulburn River	10064	74205	16/09/17 - 11/10/17	Fresh	-	Р	-	-	-	-	-	-	-
Goulburn: Lower Goulburn River	10064	3487	08/10/17 - 19/11/17	Baseflow	Р	Р	-	-	Р	-	-	-	Р
Goulburn: Lower Goulburn River	10064	11543	16/11/17 - 30/11/17	Fresh	Р	-	-	-	-	-	-	-	-
Goulburn: Lower Goulburn River	10064	852	27/11/17 - 05/12/17	Baseflow	Р	Р	-	-	Р	-	-	-	Р
Goulburn: Lower Goulburn River	10064	6112	02/12/17 - 22/12/17	Bankfull	Р	Р	-	-	Р	-	-	-	Р
Goulburn: Lower Goulburn River	10064	5560	19/12/17 - 09/01/18	Baseflow	Р	Р	-	-	Р	-	-	-	Р
Goulburn: Lower Goulburn River	10064	49989	22/06/18 - 30/06/18	Fresh	Р	Р	-	-	Р	-	-	-	-
Gwydir: Gwydir Wetlands*	10069-01	4000	19/12/17 - 17/01/18	Wetland	Р	Р	Р	-	Р	Р	Р	Р	-
Gwydir: Mehi River	10069-04	7000	26/08/17 - 04/09/17	Fresh	Р	-	-	-	-	Р	Р	-	Р

Watering Commonwealth Ex				Expected outcomes (P = primary; S = secondary)									
Surface water region/asset	Action Number	environmental water volume (ML)	Dates	component	Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Gwydir: Mehi River	10069-04	5000	30/10/17 - 20/11/17	Baseflow	Р	-	-	-	-	Р	Р	-	Р
Gwydir: Gwydir River system	10074-02	12290	20/04/18 - 23/05/18	Fresh	Р	-	-	-	-	Р	-	-	-
Lachlan: Lachlan River	10053	32572	27/09/17 - 19/11/17	Baseflow	Р	-	-	-	-	-	Р	-	-
Lachlan: Lachlan River	10053	951	27/09/17 - 16/10/17	Baseflow	Р	-	-	-	-	-	Р	-	-
Lower Darling: Lower Darling River	10072-01	2738	21/11/17 - 28/11/17	Fresh	Р	-	-	-	-	S	S	-	S
Loddon River Catchment	10001-05	3054	01/10/17 - 30/10/17	Fresh	Р	-	-	-	-	-	-	-	-
Lower Murray: Wingillie Station	10065-07	1459	28/09/17 - 20/04/18	Wetland	-	Р	Р	Р	-	-	-	-	-
Lower Murray: Lucerne Day	10065-07	82	28/09/17 - 28/09/17	Wetland	-	Р	Р	Р	-	-	-	-	-
Lower Murray: Lock 7	10065-01	409	08/09/17 - 10/12/17	Overbank	Р	Р	S	-	-	-	Р	-	-
Lower Murray: Lock 7	10065-01	409	22/02/18 - 31/05/18	Baseflow	Р	Р	-	-	-	-	S	-	-
Lower Murray: Lock 8	10065-01	409	10/09/17 - 06/12/17	Overbank	Р	Р	S	-	-	-	Р	-	-
Lower Murray: Lock 8	10065-01	409	22/02/18 - 31/05/18	Baseflow	Р	Р	-	-	-	-	S	-	-
Lower Murray: Lock 9	10065-01	409	30/08/17 - 09/10/17	Overbank	Р	Р	S	-	-	-	Р	-	-
Lower Murray: Lock 9	10065-01	409	22/02/18 - 30/05/18	Baseflow	Р	Р	-	-	-	-	S	-	-
Lower Murray: Lock 15	10065-01	409	05/09/17 - 26/11/17	Overbank	Р	Р	S	-	-	-	Р	-	-
Lower Murray: Lock 15	10065-01	409	23/03/18 - 31/05/18	Baseflow	Р	-	-	-	-	-	S	-	-
Lower Murray: Lock 2	10065-06	335	Mid Jul - Early Aug 17	Baseflow	Р	-	-	-	-	-	S	-	-
Lower Murray: Lock 2	10065-06	335	Aug – Oct 17	Overbank	Р	Р	S	-	-	-	Р	-	-
Lower Murray: Lock 5	10065-06	1266	Mid Jul - Early Aug 17	Baseflow	Р	-	-	-	-	-	S	-	-
Lower Murray: Lock 5	10065-06	1266	Aug - Mid Nov 17	Overbank	Р	Р	S	-	-	-	Р	S	-
Lower Murray: Banrock Station - Heron's Bend*	10045-02	24	11/12/17 - 27/12/17	Wetland	-	Р	Р	-	Р	-	-	-	-
Lower Murray: Banrock Station - Banrock Bend*	10045-02	24	11/12/17 - 27/12/17	Wetland	-	Р	Р	-	Р	-	-	-	-
Lower Murray: Banrock Station - Wigley Reach Depression*	10045-02	396	11/12/17 - 10/02/18	Wetland	-	Р	Р	-	Р	-	-	-	-

	Watering	Commonwealth		Гюш		E	xpected (	outcomes	s (P = prim	ary; S =	secondar	y)	
Surface water region/asset	Action Number	water volume (ML)	Dates	component	Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Lower Murray: Banrock Station - Eastern Lagoon*	10045-02	1429	11/12/17 - 23/05/18	Wetland	-	Р	Р	-	Р	-	-	-	-
Lower Murray: Banrock Station - Herons & Banrock's Bend flats*	10045-02	132	16/05/18 - 13/06/18	Wetland	-	Ρ	Р	-	Р	-	-	-	-
Lower Murray: Renmark Wetlands Site 5	10058-01	48	26/3/18 - 27/5/18	Wetland	-	Р	Р	Р	-	Р	-	Р	-
Lower Murray: Renmark Wetlands Site 8	10058-01	158	09/04/18 - 31/05/18	Wetland	-	Р	Р	Р	-	Р	-	Р	-
Lower Murray: Renmark Wetlands Site 9	10058-01	58	26/03/18 - 31/05/18	Wetland	-	-	Р	Р	-	-	-	Р	-
Lower Murray: Renmark Wetlands Site 14	10058-01	53	01/08/17 - 28/05/18	Wetland	-	Р	Р	Р	-	Р	-	Р	-
Lower Murray: Renmark Wetlands Site 15	10058-01	22	01/07/17 - 10/10/17	Wetland	-	Р	Р	Р	-	Р	-	-	-
Lower Murray: Berri Evaporation Basin	10065-06	1262	11/08/17 - 30/06/18	Wetland	Р	-	-	-	-	-	-	-	-
Lower Murray: Bookmark Creek	10065-06	448	11/08/17 - 30/06/18	Wetland	-	Р	Р	-	-	-	-	-	-
Lower Murray: Disher Creek	10065-06	50	31/01/18 - 14/02/18	Wetland	Р	-	-	-	-	-	-	-	-
Lower Murray: Rilli Reach	10065-09	9	Sept 2017 - June 2018	Wetland	-	Р	Р	Р	-	-	-	-	-
Lower Murray: Calperum Station	10065-09	3894	Oct 2017 - Apr 2018	Wetland	-	Р	Р	Р	-	-	-	-	-
Lower Murray: Riversleigh Lagoon	10065-09	650	Oct 2017 - Feb 2018	Wetland	-	Р	Р	Р	-	-	-	-	-
Lower Murray: Woolenook Bend	10065-09	33	30/10/17 - 13/04/18	Wetland	-	-	Р	-	-	-	-	-	-
Lower Murray: Gurra Gurra Lyrup Lagoon	10065-09	297	12/12/17 - 15/02/18	Wetland	-	I	Р	-	-	-	-	-	-
Lower Murray: Lake Alexandrina Milang Snipe Sanctuary*	10065-09	4	02/03/18 - 21/03/18	Wetland	-	-	Р	-	-	-	-	-	-
Lower Murray: Clarke's Floodplain	10065-09	13	22/03/18 - 01/06/18	Wetland	-	Р	Р	Р	-	-	-	-	-
Lower Murray: Pike River#	10065-09	19	01/04/18 - 27/04/18	Wetland	-	Р	Р	Р	-	-	-	-	-

	Watering	Commonwealth		Flow		E	epected of	outcomes	s (P = prim	ary; S =	secondar	y)	
Surface water region/asset	Action Number	water volume (ML)	Dates	component	Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Lower Murray: Ramco River Terrace	10065-09	5	01/04/18 - 01/06/18	Wetland	-	Ρ	Ρ	Р	-	-	-	-	-
Lower Murray: Greenways Landing	10065-09	20	01/04/18 - 30/04/18	Wetland	-	Ρ	Ρ	Ρ	I	-	-	-	-
Murrumbidgee: Nimmie-Caira	10034-13	1738	15/12/17 - 18/12/17	Baseflow	Р	S	Р	Р	Р	-	-	S	S
Murrumbidgee: Mid- Murrumbidgee wetlands	10062-01	159283	24/07/17 - 01/09/17	Fresh, Wetland	Ρ	Р	Р	-	Р	Ρ	Р	S	-
Murrumbidgee: Yarradda Lagon	10062-02	326	04/07/17 - 24/07/17	Wetland	S	S	S	-	S	-	-	-	-
Murrumbidgee: Gooragool Lagoon	10062-03	1426	18/07/17 - 11/08/17	Wetland	S	S	S	-	S	-	-	-	-
Murrumbidgee: North Redbank	10068-02	5528	09/10/17 - 19/10/17	Wetland	Р	S	Р	Р	Р	-	-	S	S
Murrumbidgee: Toogimbie IPA Wetlands	10068-03	1000	07/11/17 - 01/06/18	Wetland	-	-	-	Р	-	-	-	Р	-
Murrumbidgee: Coonancoocabil Lagoon	10068-04	900	11/12/17 - 02/01/18	Wetland	Р	S	Р	Р	Ρ	-	-	S	S
Murrumbidgee: Oak Creek	10068-05	620	28/12/17 - 02/01/18	Wetland	Р	S	Р	Р	Р	-	-	S	S
Murrumbidgee: Yarradda Lagoon	10068-06	178	20/11/17 - 25/11/17	Wetland	-	Р	-	-	-	-	-	S	S
Murrumbidgee: Waldaira Lagoon	10068-07	1500	09/02/18 - 07/05/18	Wetland	-	-	-	-	Р	-	-	Р	-
Murrumbidgee: Sandy Creek	10068-08	400	17/02/18 - 23/04/18	Wetland	Р	S	Р	Р	Р	-	-	S	S
Murrumbidgee: Tuckerbill Swamp	10068-09	600	09/04/18 - 16/04/18	Wetland	Р	Р	Р	Р	Р	-	-	S	-
Murrumbidgee: Nimmie-Caira	10068-10	5000	15/04/18 - 28/05/18	Wetland	Р	S	Р	Р	Р	-	-	S	S
Murrumbidgee: Gooragool Lagoon	10068-11	750	01/06/18 - 30/06/18	Wetland	Ρ	S	Ρ	Р	Ρ	-	-	S	S
Ma cquarie River: Mid-Macquarie River and Ma cquarie Marshes*	10067-01	48421	15/08/17 - 12/11/17	Fresh, Wetland	Р	Р	Р	-	Ρ	S	S	-	-
Namoi: Lower Namoi River	10066-01	4100	12/03/18 - 15/05/18	Baseflow	Р	S	-	-	-	S	S	-	S
Namoi: Peel River	10063-02	1257	05/06/18 - 18/06/18	Fresh	Р	-	-	-	-	-	Р	-	-
Ovens River System	10004-04	123	26/03/18 - 29/03/18	Baseflow	Р	-	-	-	-	Р	-	-	-

	Watering	Commonwealth		Flow	Expected outcomes (P = primary; S = secondary)								
Surface water region/asset	Action Number	water volume (ML)	Dates	component	Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Warrego: Upper Warrego River and fringing wetlands	00111-48	3347	01/07/17 - 30/06/18	Fresh	S	-	-	-	-	-	-	S	-
Warrego:Lower WarregoRiver and fringing wetlands	152-10	0	01/04/2018	Fresh	Р	-	-	-	-	S	-	-	-
Wimmera River	10007-01	2734	12/02/18 - 30/06/18	Baseflow	Р	Р	Р	-	Р	Р	-	-	Р
Mt William Creek	10007-01	374	09/04/18 - 18/04/18	Fresh	Р	Р	Р	-	Р	-	-	-	Р

# **Annex B.** Species and communities that potentially benefited from Commonwealth environmental water in 2014–18.

**Table B1.** ANAE aquatic ecosystem types likely to have been influenced by Commonwealth environmentalwater 2014–18 (Brooks 2019).

Australian National Aquatic Ecosystem (ANAE) wetland type	Total	% receiv	ving Cew		
	area (ha)	V1	vo	vo	VA
		14-15	15-16	16–17	17-18
Pt1 1 2. Temporary river red gum swamp	74 721	13.3	56.1	10 1	46.7
Pn2 1 2: Permanent tall emergent marsh	8005	43.1	51.9	0.0	43.1
Pn4 2: Permanent wetland	77 406	26.1	28.1	26.0	29.7
Psn/: Permanent saline wetland	2709	85	37.9	63	23.7
Pt4 1: Floodplain or rinarian wetland	11 489	7.6	19.2	8.8	23.2
Pt1: Temporary swamp	3767	7.4	18.5	3.5	15.3
In 1 1: Permanent lake	127 660	11	3.9	5.4	12.0
Pt2.2.2. Temporary sedge/grass/forh marsh	142 517	11 5	14 3	11 9	11 1
Pp2.3.2: Permanent grass marsh	1507	1.5	1.7	6.4	5.6
Pt2 1 2' Temporary tall emergent marsh	76 339	4 1	57	4 1	5.4
Pu1: Unspecified wetland	1763	0.0	0.0	0.0	5.4
Pp2.4.2: Permanent forb marsh	740	1.4	0.7	4.1	3.0
Pt2.3.2: Ereshwater meadow	125 192	15.1	16.8	16.4	2.9
Pt4.2: Temporary wetland	22 916	<0.1	2.5	0.0	2.6
Pt3.1.2: Claypan	138 725	2.3	2.7	1.2	1.2
Lst1.1: Temporary saline lake	27 897	0.0	0.5	0.0	1.1
Pt1.8.2: Temporary shrub swamp	234 419	0.7	3.2	0.9	0.9
Pt1.7.2: Temporary lignum swamp	49 965	1.1	7.0	24.9	0.9
Lt1.1: Temporary lake	459 375	0.6	1.7	0.5	0.8
Pp2.2.2: Permanent sedge/grass/forb marsh	3590	0.4	0.5	0.4	0.6
Pt1.2.2: Temporary black box swamp	60 272	1.8	10.4	0.4	0.4
Pt1.6.2: Temporary woodland swamp	216 625	<0.1	0.3	<0.1	0.2
Pst2.2: Temporary salt marsh	40 706	<0.1	1.6	<0.1	<0.1
Pst1.1: Temporary saline swamp	7942	1.2	0.0	0.0	0.0
Lsp1.1: Permanent saline lake	9229	0.0	0.0	0.0	0.0
Lt1.2: Temporary lake with aquatic bed	9052	0.0	0.0	0.0	0.0
Pt1.3.2: Temporary coolabah swamp	8271	0.0	0.0	0.0	0.0
Pst4: Temporary saline wetland	6631	0.0	0.0	0.0	0.0
Pp3: Peat bog or fen marsh	4425	0.0	0.0	0.0	0.0
Pst3.2: Salt pan or salt flat	3370	0.0	0.0	0.0	0.0
Lst1.2: Temporary saline lake with aquatic bed	2238	0.0	0.0	0.0	0.0
Lp1.2: Permanent lake with aquatic bed	2067	0.0	0.0	0.0	0.0
Pt1.5.2: Temporary paperbark swamp	412	0.0	0.0	0.0	0.0
Psp2.1: Permanent salt marsh	249	0.0	0.0	0.0	0.0
Lsp1.2: Perm. saline lake with aquatic bed	181	0.0	0.0	0.0	0.0
Psp1.1: Saline paperbark swamp	163	0.0	0.0	0.0	0.0
Pps5: Permanent spring	130	0.0	0.0	0.0	0.0
F1.11: River cooba woodland riparian zone or floodplain	11 541	9.8	2.0	6.7	7.3
F1.2: River red gum forest riparian zone or floodplain	639 022	3.8	4.1	1.0	4.0
F1.4: River red gum woodland riparian zone or floodplain	325 221	1.1	0.4	0.4	1.5
F2.2: Lignum shrubland riparian zone or floodplain	143 886	3.8	1.5	0.8	1.0
F1.8: Black box woodland riparian zone or floodplain	779 639	0.3	0.7	0.1	0.2
F1.6: Black box forest riparian zone or floodplain	131 442	0.4	1.0	<0.1	0.2
F2.4: Shrubland riparian zone or floodplain	408 614	0.3	1.5	0.6	0.1
F1.10: Coolabah woodland and forest riparian zone or floodplain	1 215 726	0.3	<0.1	<0.1	0.1
F1.12: Woodland riparian zone or floodplain	318 686	<0.1	<0.1	<0.1	<0.1
F4: Unspecified riparian zone or floodplain	201 086	<0.1	<0.1	<0.1	<0.1
F3.2: Sedge/forb/grassland riparian zone or floodplain	833 102	0.0	0.0	<0.1	0.0
F1.13: Paperbark riparian zone or floodplain	17	0.0	0.0	0.0	0.0

**Table B2.** Native plant species that potentially benefited from Commonwealth environmental water in 2014–18 (Capon & Campbell 2016; Capon & Mynott 2018; Capon & Campbell 2019).

Grasses	Subshrubs/shrubs	Sedges/rushes
Aristida leptopoda	Abutilon sp.	Carex bichenoviana
Echinochloa inundata.	Einadia nutans	Carex tereticaulis
Eragrostis australasica	Eremophila debilis	Cyperus difformis
Eragrostis elongata	Lycium australe	Cyperus exaltatus
Leptochloa spp.	Maireana aphylla	Eleocharis pallens
Paspalidium constrictum	Sida corrugate	Juncus amabilis
Paspalum distichum		Juncus flavidus
Poa labillardierei		Juncus usitatus
Themeda triandra		
Phragmites australis		
Rytidosperma		
Forbs	Forbs	Mistletoes
Ammannia multiflora	Hypercium gramineum	Dendrophthoe spp.
Azolla filiculoides	Lemna	
Brachyscome basaltica	Lythrum	
Brachyscome papillosa	Nymphoides crenata	
Callitriche	Oxalis exilis	
Calotis cuneate	Oxalis perennans	
Calotis hispidula	Persicaria hydropiper	
Calotis scapigera	Plantago cunninghamii	
Chrysocephalum apiculatum	Polygonum plebium	
Commelina cyanea	Portulaca oleracea	
Craspedia variabilis	Potamogeton crispus	Trees
Crassula helmsii	Ranunculus undosus	Myoporum acuminatum
Damasonium minus	Senecio quadridentatus	Acacia dealbata
Daucus glochidiatus	Spirodela polyrhiza	Acacia stenophylla
Dichondra repens	Tetragonia tetragonoides	
Euchiton involucratus	Triglochin procera	
Gnaphalium luteoalbum	Utricularia gibba	
Gnaphalium sphaericum	Vallisneria gigantea	
Goodenia spp.	Verbena gaudichaudii	
Gratiola pedunculata	Wahlenbergia gracilis	
Haloragis glauca	Xerochrysum	

**Table B3.** Fish species that potentially benefited from Commonwealth environmental water in 2014–18 (extracted from Stoffels *et al.* 2017; 2018, augmented with species recorded in monitoring outside LTIM).

Common name	Species name	Listing
Australiansmelt	Retropinna semoni	
Bonybream	Nematalosa erebi	
Carp gudgeon	Hypseleotris spp.	
Eel-tailed catfish	Tandanus tandanus	Endangered (NSW, Vic)
Flathead gudgeon	Phylipnodon grandiceps	
Goldenperch	Macquaria ambigua	
Hyrtl's catfish	Neosilurus hyrtlii	
Murraycod	Maccullochella peelii	Vulnerable (EPBC)
Murray–Darling rainbowfish	Melanotaenia fluviatilis	Vulnerable (Vic)
Murrayhardyhead	Craterocephalus fluviatilis	Endangered (EPBC)
Olive perchlet	Ambassis agassizii	Endangered population (NSW)
Purple-spotted gudgeon	Mogurnda adspersa	Endangered (NSW)
Silverperch	Bidyanus bidyanus	Endangered (EPBC)
Spangled perch	Leiopotherapon unicolor	
Trout cod	Maccullochella macquariensis	Endangered (EPBC)
Unspecked hardyhead	Craterocephalus stercusmuscarum	

Note: EPBC = listed under the *Environment Protection and Biodiversity Conservation Act 1999*; NSW = New South Wales, Vic = Victoria.

Common name	Species name	Listing
Barking marsh frog	Limnodynastes fletcheri	
Broad-palmed frog	Litoria latopalmata	
Crucifix frog	Notaden bennetti	
Desert froglet	Crinia deserticola	
Desert tree frog	Litoria rubella	
Eastern banjofrog	Limnodynastes dumerilii	
Green tree frog	Litoria caerulea	
Inland banjo frog	Limnodynastes interioris	
Ornate burrowing frog	Platyplectrum ornatum	
Painted burrowing frog	Neobatrachus sudelli	
Peron's tree frog	Litoria peronii	
Plains froglet	Crinia parinsignifera	
Salmon-striped frog	Limnodynastes salmini	
Southern bellfrog	Litoria raniformis	Vulnerable (EPBC)
Spotted marsh frog	Limnodynastes tasmaniensis	
Stripedburrowingfrog	Litoria alboguttata	
Sudell's frog	Neobatrachus sudallae	
Water-holding frog	Litoria platycephala	
Warty water-holding frog	Litoria verrucosa	
Wrinkled toadlet	Uperoleia rugosa	

#### Table B4. Frog species that potentially benefited from Commonwealth environmental water in 2014–18.

Note: EPBC = listed under the Environment Protection and Biodiversity Conservation Act 1999.

 Table B5. Turtle species that potentially benefited from Commonwealth environmental water in 2014–17.

Common name	Species name	Listing
Eastern long-necked turtle	Chelodina longicollis	
Broad shelled turtle	Chelodina expansa	
Ma cquarie ri ver turtle	Emydura macquarii	

**Table B6.** Bush bird species that potentially benefited from Commonwealth environmental water at HattahLakes (extracted from Loyn & Dutson 2016, showing species whose abundance increased during or afterenvironmental watering 2014–15 and those that continued to use the previously flooded site in 2015–16).

Common name	Species name	2014–15	2015–16
Apostlebird	Struthidea cinerea	х	х
Australian raven	Corvus coronoides	х	Х
Australian ringneck	Barnardius zonarius	Х	Х
Black-faced cuckoo-shrike	Coracina novaehollandiae	Х	Х
Blue bonnet	Northiella haematogaster	х	Х
Blue-faced honeyeater	Entomyzon cyanotis	Х	
Brown falcon	Falco berigora	х	х
Brown treecreeper	Climacteris picumnus	х	Х
Chestnut-rumped thornbill	Acanthiza uropygialis	Х	Х
Common bronzewing	Phaps chalcoptera	Х	х
Eastern rosella	Platycercus eximius	х	Х
Galah	Eolophus roseicapilla	Х	Х
Greyfantail	Rhipidura albiscapa	Х	х
Grey shrike-thrush	Colluricincla harmonica	Х	Х
Laughing kookaburra	Dacelo novaeguineae	Х	Х
Little corella	Cacatua sanguinea	Х	х
Little eagle	Hieraaetus morphnoides	х	Х
Little friarbird	Philemon citreogularis	Х	Х
Magpie-lark	Grallina cyanoleuca	Х	х
Major Mitchell's cockatoo	Lophochroa leadbeateri	Х	Х
Noisyminer	Manorina melanocephala	Х	Х
Rainbow bee-eater	Merops ornatus	х	х
Red-capped robin	Petroica goodenovii	Х	Х
Regent parrot (vulnerable; EPBC)	Polytelis anthopeplus	х	Х
Restless flycatcher	Myiagra inquieta	х	х
Rufous whistler	Pachycephala rufiventris	Х	Х
Sacred kingfisher	Todiramphus sanctus	Х	х
Singing honeyeater	Lichenostomus virescens	Х	х
Spiny-cheeked honeyeater	Acanthagenys rufogularis	Х	Х
Spotted pardalote	Pardalotus punctatus	Х	Х
Striated pardalote	Pardalotus striatus	Х	х
Striped honeyeater	Plectorhyncha lanceolata	х	х
Tree martin	Petrochelidon nigricans	x	х
Varied sittella	Daphoenositta chrysoptera	х	x

Common name	Species name	2014–15	2015–16
Weebill	Smicrornis brevirostris	х	Х
Welcome swallow	Hirundo neoxena	х	
Whistling kite	Haliastur sphenurus	х	Х
White-backed swallow	Cheramoeca leucosterna	х	Х
White-bellied sea-eagle (FFG listed)	Haliaeetus leucogaster	х	х
White-browed woodswallow	Artamus superciliosus	х	Х
White-plumed honeyeater	Lichenostomus penicillatus	х	Х
White-winged chough	Corcorax melanorhamphos	х	х
White-winged triller	Lalage tricolor	х	х
Willie wagtail	Rhipidura leucophrys	х	
Yellow rosella	Platycercus elegans flaveolus	х	Х
Yellow thornbill	Acanthiza nana	х	Х
Yellow-rumped thornbill	Acanthiza chrysorrhoa	х	Х
Yellow-throated miner	Manorina flavigula	х	

Note: EPBC = listed under the Environment Protection and Biodiversity Conservation Act 1999 (Cwth); listed under the FFG = Flora and Fauna Guarantee Act 1988 (Vic).

**Table B7.** Wetland dependent bird species that potentially benefited from Commonwealth environmental water in 2014–18 Across river systems for which data was available. Number represents the number of years that the species was recorded (Noting that species data outside of Selected Area monitoring is not necessarily available every year).

Species	Condamine Balonne	Warrego Darling	Macquarie	Gwydir	Murrum- bidgee	Mid- Murray	Lower Murray	Coorong Lower Lakes
Australasian bittern <sup>2</sup>			1	3	2	3		
Australasian darter	1	3	4	4	3	3	2	4
Australasiangrebe	1	2	4	2	4	3	3	2
Australasian shoveler <sup>4</sup>		4	3	2	2	3	3	3
Australian fairy tern <sup>3</sup>								2
Australian gull-billed tern	1		1			1		
Australian little bittern <sup>4</sup>			2			3		
Australian painted snipe <sup>3</sup>			1	2		1		
Australian pelican	1	4	4	4	4	3	4	4
Australian pied oystercatcher								4
Australian pratincole			2		1			
Australian reed warbler	1	1	4	3	3	2	1	1
Australian shelduck		2		2	4	3	3	4
Australian spotted crake			1		1		1	1
Australian white ibis	1	3	4	4	4	3	3	4
Australian wood duck	1	4	4	4	4	3	4	3
Ballion's crake <sup>4</sup>			1	1	1			
Bandedlapwing	1		1	2		2	1	1
Banded stilt <sup>4</sup>								4
Bar-tailed godwit <sup>2</sup>								2
Black swan	1	4	4	2	3	3	4	4

Species	Condamine Balonne	Warrego Darling	Macquarie	Gwydir	Murrum- bidgee	Mid- Murray	Lower Murray	Coorong Lower Lakes
Black-faced cormorant								2
Black-fronted dotterel		4	4	3	1	3	3	
Black-neckedstork <sup>4</sup>			3	1				
Black-tailed godwit⁵			1					1
Black-tailed native-hen	1	3	2	2	3	2	3	3
Black-winged stilt	1	2	4	4	2	2	3	3
Blue-billed duck <sup>4</sup>				1		1		3
Brolga <sup>4</sup>		2	4	2			1	
Buff-banded rail			2	1				
Cape barren goose								4
Caspiantern	1		1			3	4	4
Cattle egret	1		4	2	1			1
Chestnut teal			1	2		2	2	4
Comb-crested Jacana			1					
Common greenshank <sup>5</sup>			2				2	2
Common sandpiper <sup>5</sup>		1	1					2
Common tern								2
Crested tern								2
Curlew sandpiper <sup>1</sup>								2
Duskymoorhen		1	3	3	3	3	2	1
Eastern curlew <sup>1</sup>								2
Eastern great egret <sup>4</sup>	1	3	4	4	4	3	3	4
Eurasian coot	1	3	4	3	4	3	3	4
Freckled duck <sup>4</sup>	1	2	1	1		1	3	2
Glossyibis	1	1	4	4	1	1	2	3
Golden-headed cisticola			4	3	2			
Great cormorant	1	2	4	4	4	3	2	4
Great crested grebe		1		1	1	2		4
Greyplover <sup>5</sup>								1
Greyteal	1	4	4	4	4	3	4	4
Gull-billed tern								4
Hardhead <sup>4</sup>	1	3	3	2	3	3	3	4
Hoary-headed Grebe		2	2	2	3	3	3	4
Hooded plover <sup>3</sup>								3
Intermediate egret <sup>4</sup>	1	1	4	4	3	2	2	
Latham's snipe⁵			4	3	1			
Little black cormorant	1	2	4	4	4	3	1	4
Little egret <sup>4</sup>		1	3	2	2	3		3
Little grassbird	1	1	4	3	3	1	2	1
Little pied cormorant	1	1	4	4	4	3	2	4
Little tern⁴								2
Magpie goose <sup>4</sup>			4	3				1
Marsh sandpiper⁵			3	1		1		2
Maskedlapwing	1	4	4	3	3	3	4	4

Species	Condamine Balonne	Warrego Darling	Macquarie	Gwydir	Murrum- bidgee	Mid- Murray	Lower Murray	Coorong Lower Lakes
Musk duck <sup>4</sup>				1	1	3	3	4
Nankeen night-heron		1	3	2	3	3		1
Oriental plover <sup>5</sup>								2
Pacific black duck	1	4	4	4	4	3	4	4
Pacific golden plover <sup>5</sup>								2
Pacific gull <sup>4</sup>								4
Pied cormorant		3	4		3	3	1	4
Pink-eared duck	1	4	4	2	4	2	4	4
Plumed whistling-duck	1	2	4	2	1			
Purple swamphen	1	1	4	3	3	1	3	4
Red knot <sup>2</sup>								1
Red-backed kingfisher		1						
Red-capped plover		1				1	2	3
Red-kneed dotterel		3	4	3	1	2	3	3
Red-necked avocet	1	3	3	2		2	2	4
Red-necked stint						1	2	3
Royal spoonbill	1	1	3	4	3	1	1	4
Ruddy turnstone <sup>5</sup>								1
Ruff⁵								1
Sacred kingfisher	1	3	4	3	4	2	1	
Sanderling <sup>5</sup>								3
Sharp-tailed sandpiper <sup>5</sup>			3	3		1	3	3
Silvergull	1			1		2	2	4
Sootyoystercatcher								4
Spotlesscrake			1	1			1	
Straw-necked I bis	1	3	4	4	3	3	3	4
Swamp harrier			4	3	2	1	3	1
Tawnygrassbird			1	1				
Wandering whistling-duck			2					
Whimbrel <sup>5</sup>								1
Whiskeredtern	1	2	3	4	2			4
White-bellied sea eagle <sup>4</sup>	1	2	3	3	4	3	2	3
White-faced heron	1	4	4	4	4	3	2	4
White-necked heron	1	4	4	4	3	3	3	2
Wood sandpiper <sup>5</sup>		1					2	
Yellow-billed spoonbill	1	4	4	4	3	3	3	4

<sup>1</sup> Listed as critically endangered nationally under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

<sup>2</sup> Listed as endangered nationally under the EPBC Act.

<sup>3</sup> Listed as vulnerable nationally under the EPBC Act.

<sup>4</sup> Listed as threatened under state legislation.

<sup>5</sup> Listed under international migratory a greements JAMBA (Japan–Australia Migratory Bird Agreement); CAMBA (China–Australia Migratory Bird Agreement); ROKAMBA (Republic of Korea–Australia Migratory Bird Agreement).

Common name	Description
Piscivores	Waterbirds with a diet mainly of fish includes grebes, cormorants and terns
Dabbling ducks	Dabbling and filter-feeding ducks, shallow water feeders
Grazing ducks	Grazing ducks and geese
Diving ducks	Waterfowl that feed by diving beneath the surface, includes black swans
Crakes and rails	Members of the family Rallidae, shoreline foragers
Large wading birds	Storks, ibis, spoonbills; shallow water foragers
Australian shorebirds	Australian breeding Charadiiform shorebirds
Migratory shorebirds	International migratory Charadiiform shorebirds that breed outside Australia
Raptors	Wetland dependent birds of prey (white-bellied sea eagle, osprey, swamp harrier)
Other	Other wetland dependent bird species such as reed inhabiting passerines

 Table B8.
 Waterbird functional groups used in the LTIM project (Hale et al. 2014).