2016–17 Basin-scale evaluation of Commonwealth environmental water – Biodiversity

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2016–17 Basin-scale evaluation of Commonwealth environmental water — Biodiversity

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 2017a). Sixteen wetlands of international importance, listed under the Ramsar Convention, are within the Basin, as are over 200 nationally important wetlands (Leblanc *et al.* 2012). These ecosystems support a broad range of species and ecological communities that are inundation dependent, or dependent on vegetation communities that are classified as wetland or floodplain systems. The Basin's aquatic ecosystems also support a large number of nationally and internationally significant plant and animal species, including 95 species listed as threatened under national or state legislation (Leblanc *et al.* 2012).

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

Species and communities can be dependent on 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 (Brandis 2010; Beesley *et al.* 2011).

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. 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) benefited from Commonwealth environmental water?

1.1 Summary of water actions in 2016–17 with expected outcomes for biota

Commonwealth environmental water contributed to 93 watering actions in the 2016–17 water year with expected outcomes directly related to aquatic ecosystem dependent plant and vertebrate species (Annex A). Of these, 58 watering actions had expected outcomes for fish; 55 for plant species or vegetation communities; 36 for waterbirds, 13 for frogs, 2 for reptiles and 1 for mammals (rakali).

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 1):

- 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).

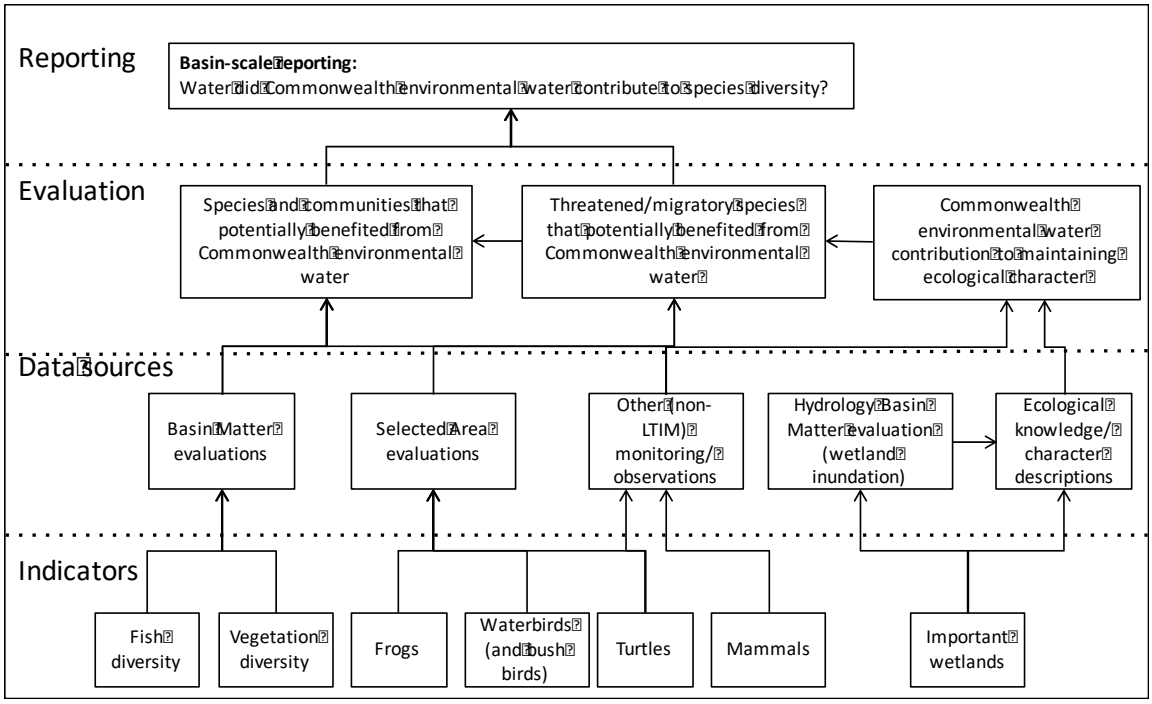


Figure 1. Basin evaluation of Biodiversity.

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 together 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 (Brooks 2018; Capon & Mynott 2018; Stoffels *et al.* 2018). 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 2016–17 watering year, several Selected Areas were monitored for waterbirds (diversity and breeding), frogs and/or turtles (Figure 2) (noting that aquatic ecosystem–dependent mammals were not included in any LTIM monitoring):

- Gwydir river system – waterbird diversity
- Lachlan river system – waterbird breeding
- Murrumbidgee river system – waterbird diversity and breeding, 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 2016–17.

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 2016–17 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?

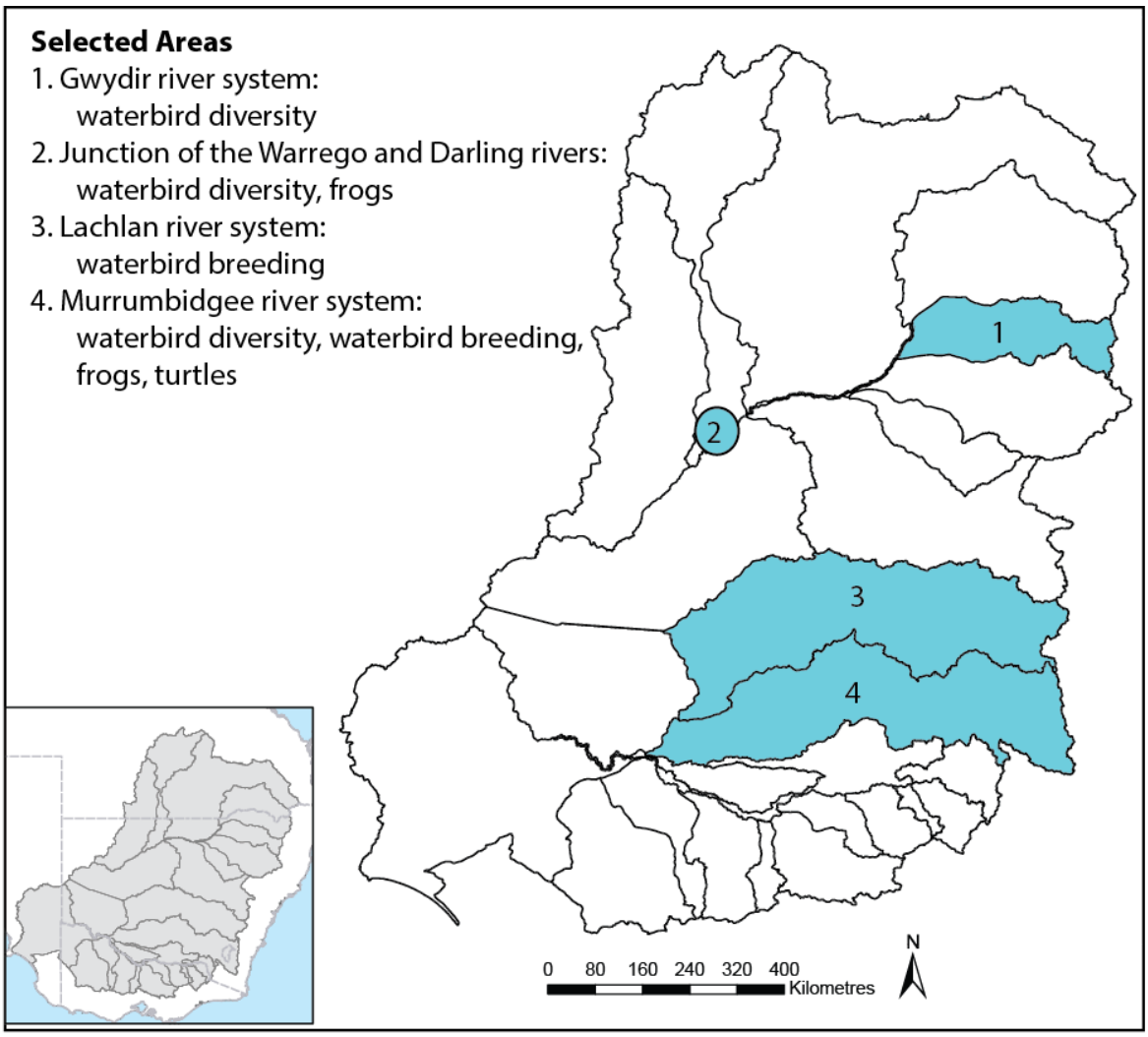


Figure 2. Locations of Selected Area monitoring for waterbirds, frogs and turtles 2016–17.

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

3.1 Highlights

- Commonwealth environmental water was delivered to increase the duration and extent of natural flooding in 2016–17 in several Selected Areas and contributed significantly to successful waterbird breeding. Large numbers of colonial nesting species bred in the Murrumbidgee and Lachlan river systems. Commonwealth environmental water contributed not only to maintaining water depths under nesting colonies, but also to proving important feeding habitat and maintaining productivity.
- Waterbird species diversity increased from previous years in the Murrumbidgee and Gwydir river systems and all functional groups were represented. A total of 74 species of wetland dependent birds have been recorded at sites that received Commonwealth environmental water in Selected Areas over the first three years of the LTIM project.
- The nationally listed endangered Australasian bittern (*Botaurus poiciloptilus*) was recorded in both the Murrumbidgee and Gwydir river systems at wetlands that received Commonwealth environmental water.
- 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 some evidence of breeding.

Monitoring of waterbirds, frogs and/or turtles in 2016–17 occurred across four Selected Areas – Lachlan river system, Murrumbidgee river system, Gwydir river system and the Junction of the Warrego and Darling rivers (Table 1). In addition, several watering actions were monitored for vegetation (see Capon & Mynott 2018) and for fish (see Stoffels et al. 2018).

Table 1. Summary of monitored watering actions related to waterbird, frog and turtle diversity at Selected Areas in 2016–17.

Selected Area (watering action reference)	Dates[1]	Commonwealth environmental water volume (ML)[1]	Flow component[1]	Expected ecological outcome[1]	Monitored site(s)[2]	Observed ecological outcome[2]	Influences[2]
Gwydir (100057-01)	27/12/16 - 28/02/17	30000	Wetland	Secondary: provide refuge habitat for waterbirds	Lower Gwydir River and wetlands – 7 locations	42 species of waterbird recorded; 6 species with evidence of breeding activity	Availability and timing of inundated habitat; productivity (vegetation and invertebrate food sources) responses to watering.
					Gingham watercourse and wetlands – 14 locations	55 species of waterbird recorded; 13 species with evidence of breeding activity	
Gwydir (100057-02)	13/01/17 - 01/04/17	7496	Wetland	Secondary: provide refuge habitat for waterbirds	Mallowa wetlands – 4 locations	20 species of waterbird recorded	
Gwydir (100057-04)	17/09/16 - 21/09/16	5000	Fresh	Primary: support in-stream ecological function and nutrient cycling, contributing to the health of in-stream habitat and maintaining water quality	Mehi River – 4 locations	19 species of waterbird recorded; 3 species with evidence of breeding activity	
Lachlan (10053-02)	09/01/17 - 17/03/17	1324	Wetland	Water levels are supported to maintain nesting waterbirds until the completion of the breeding event	Booligal wetlands (Blockbank)	More than 16 000 birds within nesting colony (mainly straw-necked ibis); reproductive success of > 60%	Extending the duration of inundation with environmental water maximised reproductive success.
Murrumbidgee (10034-09)	04/08/16 - 03/09/16	15507	Wetland	Provision of habitat for wetland dependent fauna (fish, frogs, turtles, waterbirds) including the southern bell frog (EPBC Act vulnerable).	Nimmie-Caira: Nap Nap	High abundance of southern bell frogs (over 400 adults recorded), suggesting successful breeding and recruitment. Tadpoles of at least three species including: southern bell frog, Peron's tree frog and inland banjo frog.	Direct link with environmental water, with repeat watering over multiple years maintaining refuges and habitat.

Selected Area (watering action reference)	Dates[1]	Commonwealth environmental water volume (ML)[1]	Flow component[1]	Expected ecological outcome[1]	Monitored site(s)[2]	Observed ecological outcome[2]	Influences[2]
Murrumbidgee (10052-04)	24/11/16 - 20/03/17	5425	Wetland	Maintain rookery water levels to support successful breeding, fledging and recruitment of waterbird species. Provide foraging habitat to prevent reduction in food sources due to drying.	Nimmie-Caira: Telephone Creek	Thirty species of waterbird recorded including the nationally endangered Australasian bittern. Large breeding event with over 30 000 nests recorded, dominated by straw-necked ibis. Four species of frog recorded including southern bell frog. Broad shell and eastern long-necked turtles recorded.	Provision of rookery and foraging habitat at a network of wetlands, supported both diversity and breeding success. Environmental water was essential to breeding success by extending the duration and depth of inundation until chicks had fledged. Possible avian botulism at several locations resulting in some bird deaths.
Murrumbidgee (10052-05)	28/11/16 - 03/03/17	2320	Wetland	Maintain rookery water levels to support successful breeding, fledging and recruitment of waterbird species. Provide foraging habitat to prevent reduction in food sources due to drying.	Nimmie-Caira: Eulimbah Swamp	Thirty-six species of waterbird including the nationally endangered Australasian bittern. Total of 15 000 nests of colonial nesting species. Five species of frog recorded including southern bell frog. Broad shell and eastern long-necked turtles recorded.	
Murrumbidgee (10052-06)	27/10/16 - 13/02/17	844	Wetland	Maintain rookery water levels to support successful breeding, fledging and recruitment of waterbird species. Provide foraging habitat to prevent reduction in food sources due to drying.	Redbank North: Tori Lignum Swamp	Five waterbirds recorded breeding with over 6000 nests (straw necked ibis).	
Murrumbidgee (10052-08)	29/10/16 - 13/02/17	2155	Wetland	Maintain rookery water levels to support successful breeding, fledging and recruitment of waterbird species. Provide foraging habitat to prevent reduction in food sources due to drying.	Yanga National Park: Two Bridges Swamp	Twenty-six species of waterbird recorded. Over 1100 nests across nine species. Dominant species included: nankeen night-herons and intermediate egrets.	

Selected Area (watering action reference)	Dates[1]	Commonwealth environmental water volume (ML)[1]	Flow component[1]	Expected ecological outcome[1]	Monitored site(s)[2]	Observed ecological outcome[2]	Influences[2]
						Four species of frog recorded including southern bell frog. High abundance of spotted and barking marsh frogs. Eastern long-necked turtles and hatchling Macquarie turtles.	
Murrumbidgee (10052-11)	03/01/17 - 07/01/17	630	Wetland	Maintain rookery water levels to support successful breeding, fledging and recruitment of waterbird species. Provide foraging habitat to prevent reduction in food sources due to drying.	Nimmie-Caira: Nap Nap	A total of 671 nests across ten species, dominated by nankeen night-herons, white-necked herons and cormorants.	
Murrumbidgee (10052-12)	10/02/17 - 20/03/17	5000	Wetland	Maintain water levels to support the successful breeding, fledging and recruitment of pelicans.	Nimmie-Caira: Kieeta and Kia Lakes	Forty species of waterbird recorded. Large breeding event of Australian pelicans with over 6000 nests.	
Warrego (multiple actions)	Multiple dates	795 1913 602 340 5865	Fresh Bankful	Refresh waterholes in the lower Warrego system and support long term refuge values. Fish migration and spawning opportunities especially large bodied species including golden perch.	Boera Dam, Booka Dam, Ross Billabong	Six species of frog, large numbers of barking marsh frog. Twenty-nine species of waterbird.	The waterholes, replenished by Commonwealth environmental water continue to provide important refuge values.
Warrego (multiple actions)	19/07/16 - 12/09/16 12/09/16 - 20/09/16	5023 4697	Wetland	Maintain wetland vegetation and waterbird habitat on Warrego Western Floodplain.	Western Floodplain	Five species of frog, large numbers of spotted marsh frog. Sixteen species of waterbird	Inundation of the Western Floodplain stimulated productivity and biodiversity.

[1] As reported by the Commonwealth Environmental Water Office (CEWO).

[2] As reported by the Monitoring and Evaluation (M&E) team for each Selected Area in Selected Area reports for 2016–17.

3.1.1 Waterbirds

Waterbird diversity was monitored in three Selected Areas in each of the first three years of LTIM; Murrumbidgee river system, Gwydir river system and the Junction of the Warrego and Darling rivers. In 2016–17 colonial waterbird breeding was monitored in two Selected Areas; Murrumbidgee river system and Lachlan river system.

Waterbird diversity

A total of 74 wetland-dependent species were recorded at aquatic ecosystems that received Commonwealth environmental water across the three years (Appendix B). This included several species that are listed as threatened. The nationally listed endangered Australasian bittern was recorded at wetlands that received Commonwealth environmental water in the Murrumbidgee in both 2015–16 and 2016–17 and in the Gwydir in 2016–17. Seven additional species listed as vulnerable in New South Wales (NSW) were also recorded: 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.

Ten of the 74 species were recorded in sites that received Commonwealth environmental water in all three Selected Areas across all years, including several species of duck, black swans (*Cygnus atratus*), Eurasian coot (*Fulica atra*), Australian pelican (*Pelecanus conspicillatus*), Australian white ibis (*Threskiornis molucca*) and white-faced heron (*Egretta novaehollandiae*). By contrast, 16 species were recorded at only one Selected Area and in one year. This includes two species of international migratory shorebirds, four species of crakes and rails and several fish-eating waterbirds.

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

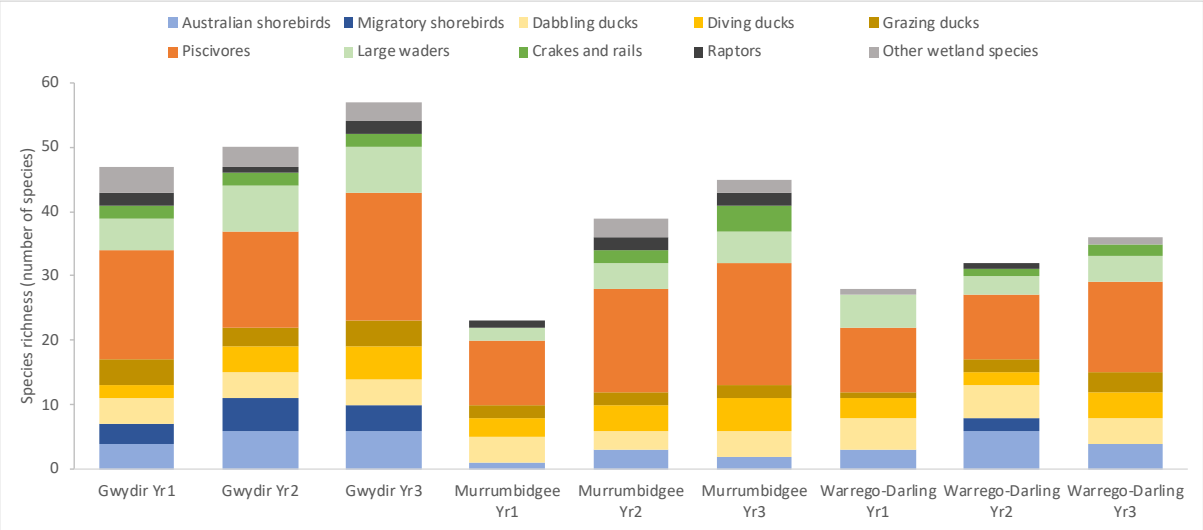


Figure 3. Species richness of functional groups in the three Selected Areas monitored for waterbirds as part of the LTIM project in 2014–15 (Yr1), 2015–16 (Yr2) and 2016–17 (yr3).

Table 2. Maximum counts (at single sites) of aquatic ecosystem–dependent waterbirds recorded in Selected Area monitoring at sites that received Commonwealth environmental water in the first three years of LTIM.

Functional group	Species	Gwydir			Murrumbidgee			Warrego–Darling			Significance[1]
		Yr1	Yr2	Yr3	Yr1	Yr2	Yr3	Yr1	Yr2	Yr3	
Australian shorebirds	Australian pratincole		1			1					
	Banded lapwing			20							
	Black-fronted dotterel	16	12	18				6	14	8	
	Black-winged stilt	4	14	168		2	5	1	7		
	Masked lapwing	12	20	11	2	2		3	4	2	
	Red-capped plover								8		
	Red-kneed dotterel	3	11	16			1		16	2	
	Red-necked avocet		8	4					3	1	
Migratory shorebirds	Black-tailed godwit		2								J,C,R V(NSW)
	Common greenshank	1	1								J, C, R
	Common sandpiper								1		J, C
	Latham's snipe	19	2	12							J, R
	Marsh sandpiper		31	22							J, C, R
	Sharp-tailed sandpiper	13	20	33							J, C, R
	Wood sandpiper								1		J, C, R
Dabbling ducks	Australasian shoveler	2		7	6		5	3	2	1	
	Chestnut teal		2								
	Freckled duck							1	1		V (NSW)
	Grey teal	137	89	142	312	383	98	97	130	40	
	Pacific black duck	203	77	215	52	100	18	73	10	10	
	Pink-eared duck	6	11	32	259	16	13	23	35	17	
Diving ducks	Black swan	5	2	10	57	31	13	2	3	3	
	Comb-crested jacana			1							
	Dusky moorhen		4	9		3	2			6	
	Eurasian coot	83	14	32	204	575	83	3	2	11	
	Hardhead		20	80	32	16	12	44		13	
	Musk duck						4				
Grazing ducks	Australian shelduck				3	2	6			2	
	Australian wood duck	32	58	43	38	23	30	15	42	15	
	Magpie goose	176	1	129							V (NSW)
	Plumed whistling-duck	399	80	410					8	54	
	Wandering whistling-duck	7		4							
Piscivores	Australasian bittern			1		2	1				E (EPBC)
	Australasian darter	12	5	13		19	26	21	2	3	
	Australasian grebe	12	5	58	45	20	8	6		10	
	Australian gull-billed tern			29							
	Australian little bittern	1									

Functional group	Species	Gwydir			Murrumbidgee			Warrego–Darling			Significance[1]
		Yr1	Yr2	Yr3	Yr1	Yr2	Yr3	Yr1	Yr2	Yr3	
	Australian pelican	10	21	42	64	20	16	8	14	48	
	Caspian tern			47							J
	Cattle egret	20	168	42			1				
	Eastern great egret	19	10	55	4	32	57	2	1		
	Great cormorant	5	7	6	38	65	36			3	
	Great crested grebe						18			4	
	Hoary-headed grebe	2		2	110	24	11	8	5		
	Intermediate egret	107	10	42		16	35			1	
	Little black cormorant	61	25	26	21	75	66	1		8	
	Little egret	2		12		4	9	1			
	Little pied cormorant	19	100	12	17	56	95			1	
	Nankeen night-heron		1	2	5		120			2	
	Pied cormorant	5	4	3		1	1		3	7	
	Red-backed kingfisher								2		
	Sacred kingfisher	3	3	1	2	2	3	2	3	2	
	Whiskered tern	2	2	18		120	68		1	9	
	White-faced heron	23	11	6	2	4	6	4	2	2	
	White-necked heron	29	17	9		4	16	4	1	3	
Large wading birds	Australian white ibis	60	43	64	10	135	76	5	1	3	
	Black-necked stork		1	2							E (NSW)
	Brolga	22	3	9				4	2		V (NSW)
	Glossy ibis	40	101	901			6			22	
	Royal spoonbill		21	10		12	15	6			
	Straw-necked ibis	120	65	180	40	28	1104	29		33	
	Yellow-billed spoonbill	11	8	7		16	18	4	5	1	
Crakes and rails	Australian spotted crake						6				
	Black-tailed native-hen	10				36	67		27	1	
	Buff-banded rail			1							
	Purple swamphen	10	5	6		8	18			1	
	Spotless crake		1								
	Ballion's crake						5				
Raptors	Swamp harrier	4	1	2		3	2				
	White-bellied sea-eagle	2		2	2	2	1		1		V (NSW)
Other wetland species	Australian reed warbler	20	16	31		6	13			2	
	Golden-headed cisticola	11	20	18		1					
	Little grassbird	4	3	8		1	4	2			
	Tawny grassbird	3									

[1] C = CAMBA (China–Australia Migratory Bird Agreement); J = JAMBA (Japan–Australia Migratory Bird Agreement); R = ROKAMBA (Republic of Korea – Australia Migratory Bird Agreement); E = endangered V = vulnerable.

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 similar in each year, reflecting that much of the northern Basin continued to experience dry conditions in all three LTIM years (Figure 4). In terms of abundance, there was a shift from duck dominated assemblages in the first two LTIM years in the Murrumbidgee and Gwydir 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.

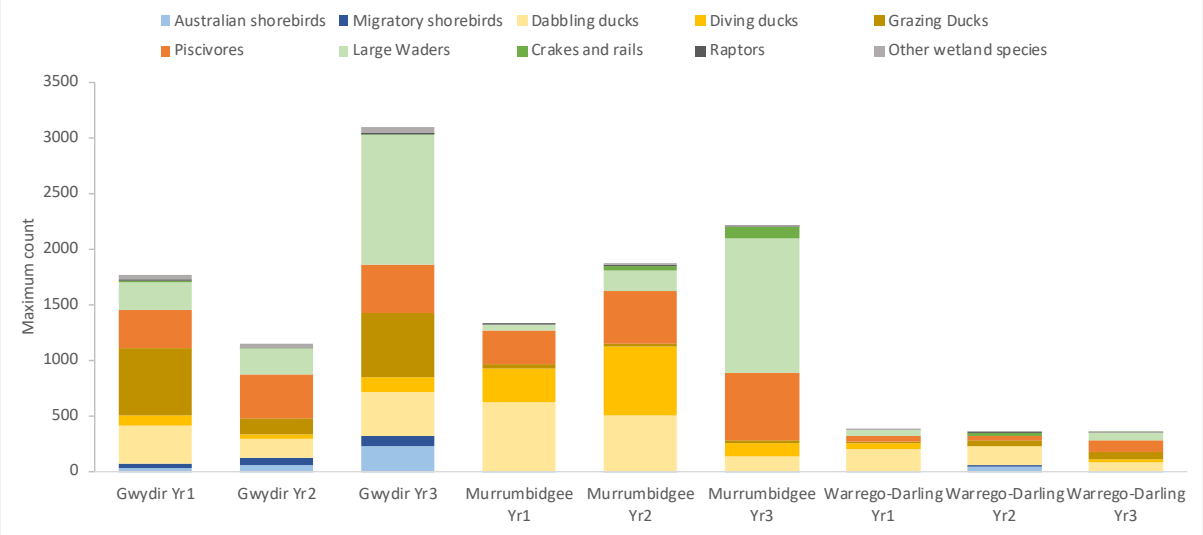


Figure 4. Abundance of functional groups (as indicated by maximum count for each species in a Selected Area) in 2014–15 (Yr1), 2015–16 (Yr2) and 2016–17 (Yr3).

Waterbird breeding

Waterbird breeding activity was observed at a number of sites in the Gwydir Selected Area, with evidence of breeding recorded for 14 species in 2016–17. Although this represents an increase in breeding activity over the first two years of LTIM in this Selected Area, the scale of breeding was relatively small.

In contrast, there were large scale waterbird breeding in both the Lachlan and Murrumbidgee Selected Areas and these were the subject of targeted monitoring. Only sites that received Commonwealth environmental water are considered here and summarised in Table 3.

Table 3. Summary of colonial waterbird breeding in the Lachlan and Murrumbidgee at sites that received Commonwealth environmental water in 2016–17.

Selected Area	Location	No. of nests	Dominant species
Lachlan	Booligal wetlands (Blockbank)	8000	Straw-necked ibis
Murrumbidgee	Eulimbah Swamp	15 104	Straw-necked ibis
	Kieeta Lakes	6000	Australian pelican
	Telephone Bank	30 799	Straw-necked ibis
	Nap Nap Swamp	671	Nankeen night heron, cormorants
	Two Bridges	1213	Nankeen night heron and egrets
	Tori Lignum Swamp	6106	Straw-necked ibis

Breeding success (percentage of chicks that fledged) was evaluated at several wetlands including:

- Booligal wetlands (Blockbank) – 64%
- Eulimbah Swamp – 60%
- Tori Lignum Swamp – 40%

At each of the wetlands in Table 3, Commonwealth environmental water (often in conjunction with other environmental water) was delivered to maintain the extent and duration of inundation and improve reproductive success. Maintaining water depths under breeding colonies is important to prevent nest abandonment, limit predation and maintain feeding grounds (Brandis 2010; Brandis *et al.* 2011). The importance of water depths and the effectiveness of environmental water was highlighted at Eulimbah Swamp in the Murrumbidgee where levee failures resulted in a premature drying of the system in November 2016. At this stage reproductive success dropped to < 20%. The levee banks were repaired, and the site inundated with environmental water commencing on November 28, 2016. Following this water delivery, reproductive success rates increased to 100% (Wassens *et al*. 2017).

3.1.2 Frogs

Frogs were monitored in two Selected Areas in all three LTIM years including 2016–17: 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 2016–17 in the Gwydir provided by NSW OEH (Ocock *et al.* 2017).

A total of 14 species of frog have been recorded at sites that received Commonwealth environmental water, including the nationally listed vulnerable southern bell frog.

Table 4. Frog species recorded at sites in Selected Areas that received Commonwealth environmental water.

Common name	Species name	Lachlan	Murrumbidgee			Gwydir		Warrego–Darling		
		Yr2	Yr1	Yr2	Yr3	Yr2	Yr3	Yr1	Yr2	Yr3
Desert froglet	*Crinia deserticola*							X		X
Plains froglet	*Crinia parinsignifera*	X	X	X	X	X	X		X	X
Striped burrowing frog	*Cyclorana alboguttata*						X			
Barking marsh frog	*Limnodynastes fletcheri*		X	X	X	X	X	X		X
Inland banjo frog	*Limnodynastes interioris*	X		X	X					
Salmon striped frog	*Limnodynastes salmini*						X			X
Spotted marsh frog	*Limnodynastes tasmaniensis*	X	X	X	X	X	X	X	X	
Green tree frog	*Litoria caerulea*						X	X		X
Broad-palmed rocket frog	*Litoria latopalmata*					X	X			
Peron's tree frog	*Litoria peronii*	X	X	X	X	X	X	X	X	X
Southern bell frog[1]	*Litoria raniformis*		X	X	X					
Desert tree frog	*Litoria rubella*							X		
Sudell's frog	*Neobatrachus sudallae*									X
Ornate burrowing frog	*Platyplectrum ornatum*						X			

[1] 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). In addition, there is evidence of breeding and recruitment at several wetlands in response to environmental water.

In the Warrego-Darling, a comparison of more permanent waterholes with the intermittent inundation on the Western Floodplain concluded that patterns of wetting and drying not only increased diversity (providing habitat for specialist frog species) but also abundance; with increased productivity supporting greater numbers of frogs (Commonwealth of Australia 2017).

3.1.3 Turtles

Turtles were monitored in the Murrumbidgee river system in all three 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*).

The combination of watering actions across the first three LTIM years has been associated with higher diversity of turtle populations (Wassens *et al.* 2017).

4 Unmonitored area outcomes

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

4.1 Highlights

- Benefits for vegetation, fish and waterbirds at the Ramsar listed Macquarie Marshes. Commonwealth environmental water contributed to summer deliveries that extended the duration of inundation at important colonial waterbird nesting sites. Tens of thousands of waterbirds bred at the site, with very high success rates.
- Provision of habitat for a wide range of waterbird species at the Narran Lakes Ramsar site and maintenance of some of the lignum shrubland community.
- Commonwealth environmental water contributed to the dispersal of juvenile fish (golden perch, silver perch and spangled perch) at several locations across the Basin including Gunbower Forest Ramsar site, the Lower Darling and the Macquarie–Barwon river systems.
- Inundation of wetlands along the Lower Murray improved the condition of floodplain vegetation communities including black box woodlands and lignum shrublands.

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 5. This table does not include important wetland sites such as Narran Lakes and Macquarie Marshes, which are considered in more detail in Section 4.3. The majority of the information collated is qualitative and includes very little additional evidence about the site that received Commonwealth environmental water or how species or communities responded to the water regime.

Table 5. Summary of observations and other information from unmonitored watering actions related to diversity in 2016–17. 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 2018). Ramsar wetlands such as Gunbower Forest, Narran Lakes and Macquarie Marshes are considered in section 4.3.

Surface water region/asset (watering action reference)[1]	Commonwealth environmental water volume (ML)[1]	Dates[1]	Flow component[1]	Expected ecological outcome[1]	Observed ecological outcome	Source of information
Border Rivers – Severn River (111-33)	823.53	01/07/16 - 30/06/17	Bankfull	Support movement/migration of large bodied fish including Murray cod, golden and silver perch, eel-tailed catfish.	Five native species of fish recorded, including three threatened species: eel-tailed catfish, Murray cod and silver perch. Flows considered too low to adequately inundate Murray cod spawning habitat.	NSW Department of Primary Industries & Queensland Department of Agriculture and Fisheries (2017).
Border Rivers - Dumaresq-Macintyre River and fringing wetlands	914.3 14376.8 6492.1	07/07/16 - 13/07/16	Fresh, Bankfull, Fresh	Support dispersal, reproduction and recruitment of native including Murray cod and eel-tailed catfish.	Ten native species of fish recorded including four threatened species: eel-tailed catfish, Murray cod, purple-spotted gudgeon and olive perchlet. Some evidence of spawning and recruitment of carp gudgeon and Murray cod.	
Lower Darling- Lower Darling River	71248.6	02/10/16 - 08/01/17 24/04/17 - 30/06/17	Fresh, Baseflow	Support Murray cod spawning, recruitment and larval dispersal in the Lower Darling main channel. Support golden and silver perch spawning and dispersal.	Strong spawning results observed for Murray cod, with 885 Murray cod larvae collected and follow-up monitoring indicated good recruitment. Also spawning of silver perch and golden perch. Recruitment and large-scale (500 – 1000 km) dispersal of golden perch from nursery grounds in the Menindee Lakes to the Lower Darling River.	Sharpe & Stuart (2018).
Lower Murray - Calperum Station	1276.74	01/06/16 - 01/06/17	Wetland	Prolong the benefits to black box communities higher in the floodplain and continuing to support black box recruits from the high flows in 2011. Support maintenance of lignum and chenopod shrubland communities. Provide seasonal waterbird habitat to support food sources and	Improved black box health (increased canopy cover) recorded for 60% of assessed trees. Forty species of waterbird recorded including four international migratory species (common greenshank, red-necked stint, sharp-tailed sandpiper and wood sandpiper). Seven species of frog recorded, including the nationally vulnerable southern bell frog.	CEWO acquittal report (unpublished)
Lower Murray - Pike River complex	5.35	01/11/16 - 01/06/17	Wetland		Waterbird abundance and diversity responses. Including observations of two species listed as	Summary of Environmental

Surface water region/asset (watering action reference)[1]	Commonwealth environmental water volume (ML)[1]	Dates[1]	Flow component[1]	Expected ecological outcome[1]	Observed ecological outcome	Source of information
				maintain species diversity and abundances. Provide seasonal wetland habitat to support frog breeding.	threatened in South Australia: the vulnerable freckled duck and the endangered white-bellied sea eagle.	Watering Event on the Pike Floodplain (unpublished report).
Lower Murray - Loxton Riverfront Reserve	32.33	01/04/17 - 01/06/17	Wetland		Maintaining and improving floodplain vegetation condition with seedlings, new buds on mature trees and flowering of lignum.	CEWO acquittal report (unpublished)
Lower Murray - Rillis Lagoons	35.43	01/04/17 - 01/06/17	Wetland		Significant vegetative growth of lignum and seedlings/saplings.	
Lower Murray - Kroehn's Landing	2.59	01/06/17 - 30/06/17	Wetland		Increase in condition of black box, as evidenced by increased buds on watered plants.	
Lower Murray - Riversleigh Lagoon	180.01	01/04/17 - 01/06/17	Wetland		Over 2000 waterbirds recorded, dominated by ducks. Large numbers (30-40) EPBC listed regent parrot.	
Lower Murray - Berri Evaporation Basin	707	01/01/17 - 30/06/17	Wetland	Support nationally threatened Murray hardyhead populations	No Murray hardyhead were caught in monitoring; but individuals were observed. Likely that the species dispersed due to the extensive flood event.	CEWO acquittal report (unpublished)

[1] 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

Seven DIWA/Ramsar sites were the target of Commonwealth environmental water in 2016–17 and had expected outcomes related to diversity. These included several sites within Selected Areas (e.g. Gingham and Lower Gwydir (Big Leather) watercourses, Booligal wetlands) as well as several sites for which little information on the effects of environmental water could be sourced (e.g. Pike–Mundic wetland system). Three Ramsar sites were selected as case studies to assess the effects of Commonwealth environmental water on important wetlands:

- Gunbower Forest
- Macquarie Marshes
- Narran Lakes.

4.3.1 Gunbower Forest

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 23 563 ML of Commonwealth environmental water was delivered over the full year (July 2016 to 2017) as baseflows, to provide a series of flows as follows: 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. A similar watering action was implemented in 2015-16 (13 606 ML of Commonwealth environmental water).

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 (VEWH 2017). 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 (Sharp *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 TLM program since 2008 and a recent review assessed trends in the fish community over this time (Bloink & Robinson 2016). In 2016 approximately 1300 fish from nine native species were recorded in Gunbower Creek. This included three nationally listed threatened species: Murray cod, silver perch and trout cod. The average abundance of Murray cod and silver perch in Gunbower Creek in 2016 was higher than in any previous year. Although three invasive fish species were recorded in the Creek, the relative abundance of natives was high, with over 80% of fish captured representing native species.

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 are now juvenile and sub-adult size classes of Murray cod clearly represented in Gunbower Creek (Bloink & Robinson 2016).

What species/communities potentially benefited?

There is clear evidence that Murray cod and silver perch have benefited from the restored hydrology in Gunbower Creek. In addition, other native fish species have either marginally increased or been maintained.

4.3.2 Macquarie Marshes

What was the expected outcome?

The expected outcomes were:

- *Support the completion of a colonial waterbird breeding event, particularly later nesting species such as royal spoonbills and egrets and maintain foraging habitat.*
- *Provide river conditions that allow for the movement, breeding and dispersal of native fish flow specialists including golden, silver and spangled perch.*
- *Maintain and improve the condition of semi-permanent and permanent wetland vegetation in the Macquarie Marshes by providing sufficient water for the flowering and recruitment of species such as river red gum and water couch.*

What information is available about the watering action?

Water was delivered across several watering actions (see Figure 5):

- Supplementary environmental water was delivered during announced events between July and December 2016 of which 7250 ML was Commonwealth environmental water.
- A total of 46 413 ML of was delivered to the Macquarie Marshes in January – February 2017, 17 039 ML of which was Commonwealth environmental water (waterbird breeding).
- A total of 6481 ML was delivered in early April 2017, 2648 ML of which was Commonwealth environmental water (fish dispersal).
- At total of 27 583 ML was delivered in mid-April to mid-May, all of which was Commonwealth environmental water (fish connection flow).

Over 155 000 hectares of the Macquarie Marshes was inundated in the 2016-17 water year (OEH 2017). Commonwealth environmental water contributed to the inundation of over 27 000 hectares of wetland, including over half (11 098 hectares) of the mapped wetlands within the 19 850 ha Ramsar site (Figure 10 and Table 6)[1]. Inundation of the wetland areas with environmental water occurred in late January to early February to extend the duration of breeding and feeding habitats for waterbirds.

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 6 is more accurately described as intermittent marsh with emergent vegetation, such as common reed (*Phragmites australis*), cumbungi (*Typha* spp.) and water couch (*Paspalum distichum*) (OEH 2012).

Two flows were then delivered for fish, a dispersal flow in early April to connect river and wetland habitats through the Macquarie Marshes. This was followed by a connection flow to connect the Macquarie River with the Barwon River system to support juvenile native fish species to emigrate into the Macquarie catchment (CEWO unpublished).

[1] Note the hydrology Basin Matter has separated Commonwealth environmental water, other sources of environmental water and natural inundation (see Stewardson & Guarino 2018 for further details).

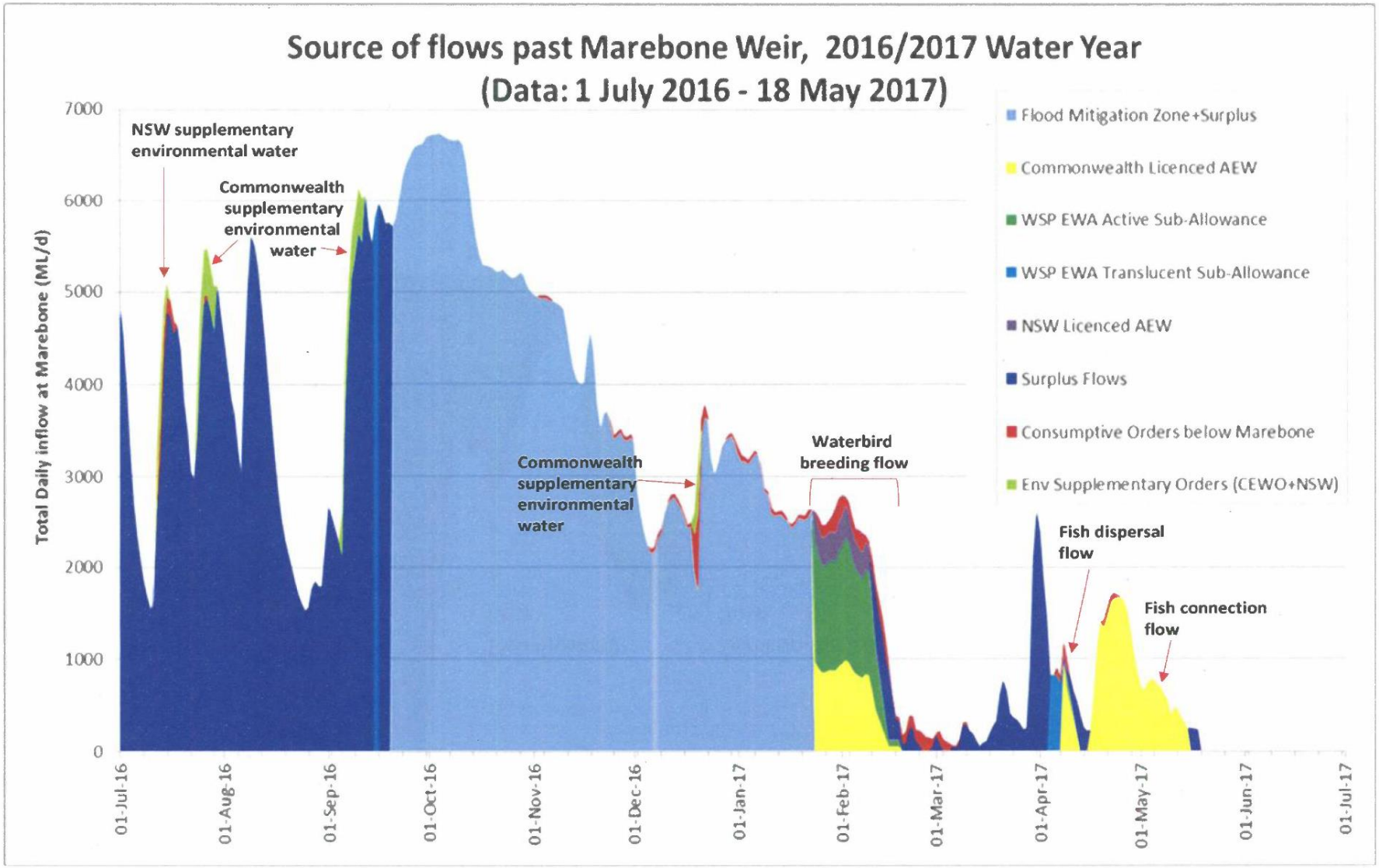


Figure 5. Hydrograph for 2016-17 including the delivery of environmental water into the Macquarie Marshes (CEWO unpublished).

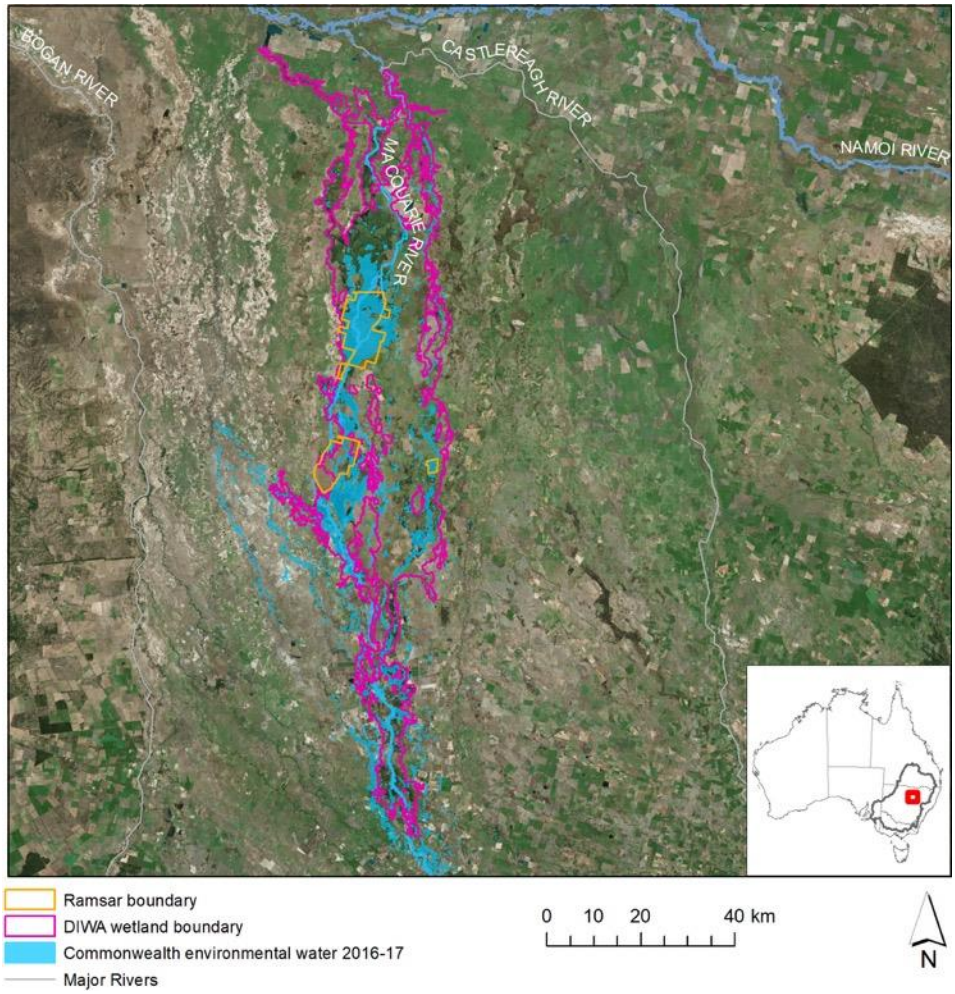


Figure 6. Extent of inundation at the Macquarie Marshes by Commonwealth environmental in 2016–17.

Table 6. ANAE wetland and floodplain types inundated from Commonwealth environmental watering in 2016–17 at the Macquarie Marshes Ramsar site.

Australian National Aquatic Ecosystem (ANAE) wetland type	Area inundated (hectares)
Pp4.2: Permanent wetland	9820
Pt2.2.2: Temporary sedge/grass/forb marsh	738
Pt2.1.2: Temporary tall emergent marsh	160
F1.4: River red gum woodland riparian zone or floodplain	149
Pt1.8.2: Temporary shrub swamp	119
Pt1.2.2: Temporary black box swamp	45
F1.2: River red gum forest riparian zone or floodplain	32
F1.10: Coolibah woodland and forest riparian zone or floodplain	12
Lt1.1: Temporary lake	12
F1.11: River cooba woodland riparian zone or floodplain	5
F2.2: Lignum shrubland riparian zone or floodplain	3
F1.8: Black box woodland riparian zone or floodplain	2
F2.4: Shrubland riparian zone or floodplain	1

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*) (OEH 2012).

Available data include waterbird counts on the Atlas of Living Australia, two reports on waterbird movements and breeding success (McGinness *et al.* 2017; Brandis 2017) and fish monitoring of the movement of fish during the connection flows (Davis *et al.* 2017) as well as preliminary observations as detailed in the CEWO acquittal report (unpublished). Key ecological outcomes were:

- Winter response from wetland vegetation with sprouting of common reed and flowering of water couch.
- Maintenance of wetland and floodplain tree communities, with extensive inundation of river red gum and more limited inundation of black box and coolibah (*Eucalyptus coolabah*).
- Over 40 species of waterbird recorded, abundance dominated by large wading birds (ibis, egrets and spoonbills) that bred in large colonies. The nationally endangered Australian bittern was recorded at the site as were the state listed freckled duck and blue-billed duck.
- Seventeen species of colonial nesting waterbirds were observed across 18 colonies (Spencer *et al*. 2018). The two largest of these comprising 35 000 nests, dominated by straw-necked ibis with smaller numbers of Australian white ibis and glossy ibis were outside the Ramsar boundary, but within the DIWA site. Egrets and spoonbills were part of breeding colonies in the Ramsar site and at least 13 non-colonial nesting species also bred at the site (including ducks, magpie geese and rails).
- Nest success at sites monitored in two locations was 63 – 66 % (Brandis 2017).
- Satellite tracking indicated foraging up to 50 kilometres from nest sites, in wetland areas, but also on adjacent private grazing lands.
- Juvenile golden perch and spangled perch migrated upstream from the Barwon to the Macquarie River in response to connecting flows.

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 2016–17 (Table 7).

Table 7. Species and communities that potentially benefitted from Commonwealth environmental water in the Macquarie Marshes in 2016–17.

Community/species	Evidence
River red gum forest and black box and coolibah woodland	Maintained or improved condition of wetland and floodplain trees in areas that were inundated.
Emergent marsh vegetation	Growth and flowering of emergent marsh vegetation in response to watering.
Australasian bittern	Observed calling in inundated wetland areas.
Waterbirds (general)	Over 40 species recorded spanning the full range of functional groups.
Waterbirds (colonial nesting species)	17 species recorded breeding in large colonies. Reproductive success of 63 – 66 %.
Golden perch and spangled perch	Upstream migration of juveniles in response to environmental water.

4.3.3 Narran Lakes

What was the expected outcome?

The expected outcome was:

- *Inundate/support core rookery habitat (lignum) in Narran Lakes.*

What information is available about the watering action?

A total of 28 870 ML of water, all of which was Commonwealth environmental water, was delivered through the Lower Balonne system, with an estimated 5600 ML arriving into Narran Lakes in spring 2016. This water contributed to the inundation of approximately 1500 hectares of mapped wetland, 700 hectares of which was inside the Narran Lakes Ramsar boundary (Figure 7). Commonwealth environmental water inundated the following mapped ANAE types within the Ramsar site[2]:

- Permanent wetland – 414 hectares of Clear Lake
- Temporary lignum swamp – 290 hectares.

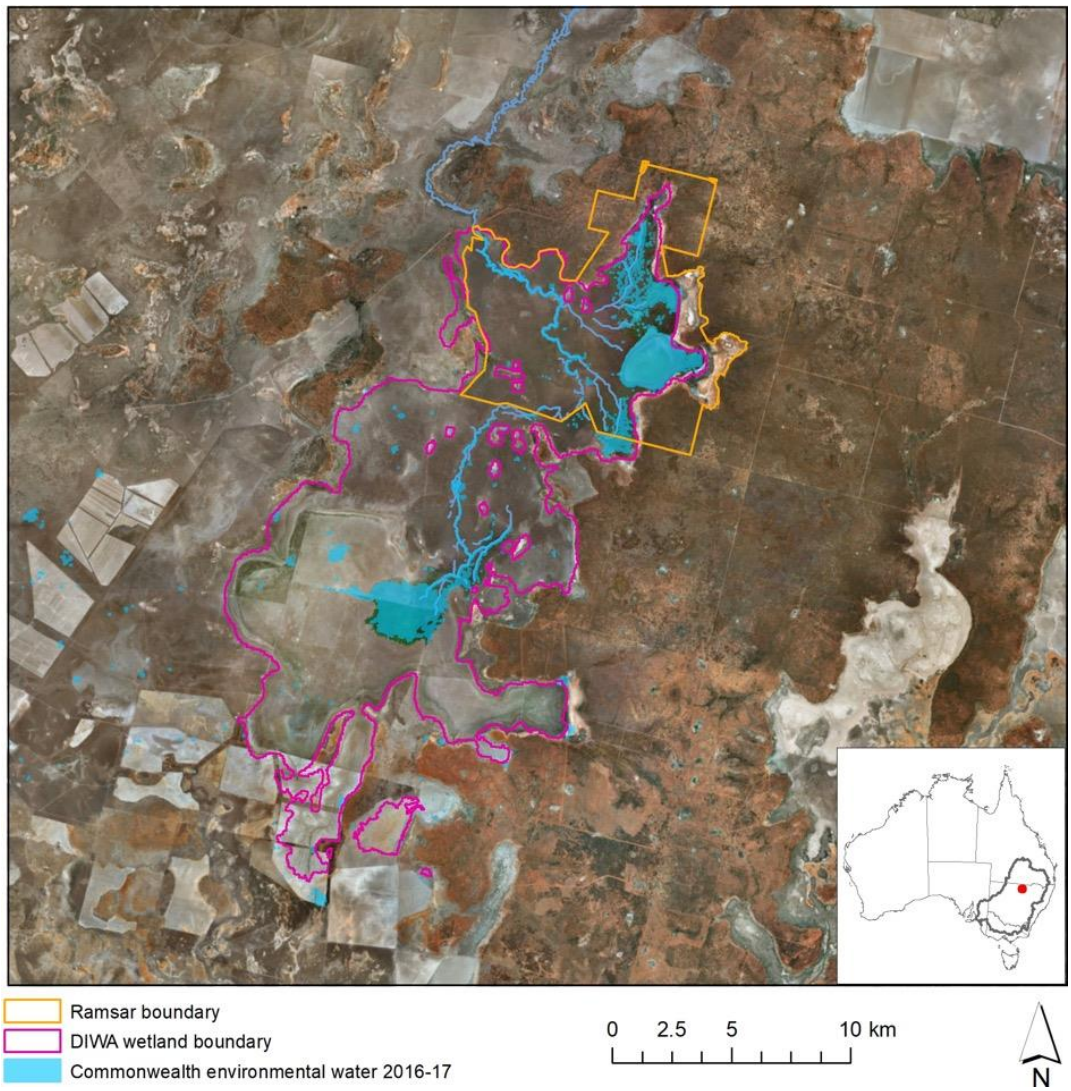


Figure 7. Extent of inundation at Narran Lakes by Commonwealth environmental in 2016–17.

[2] Note the hydrology Basin Matter has separated Commonwealth environmental water, other sources of environmental water and natural inundation (see Stewardson & Guarino 2018 for further details).

What evidence is available to evaluate the outcome?

Narran Lakes was listed as a Ramsar site in 1999 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, Murray cod and winged peppercress (*Lepidium monoplocoides*) (Butcher *et al.* 2011). The site was expanded in 2011 to capture additional waterbird breeding and feeding areas and now comprises approximately 8450 hectares.

There is limited information available to assess the effects of Commonwealth environmental water on the Narran Lakes Ramsar site. A summary of wetland monitoring for Narran Lakes (Spencer *et al*. 2018) provides high level summary information for vegetation and waterbirds and the CEWO acquittal report (unpublished) contained observational information. In addition, there was a MDBA aerial survey of waterbirds in November 2016, which coincided with the inundation from environmental water. A total of 39 species of wetland dependent bird were recorded (combining ground and aerial survey data), with high abundances of ducks (grey teal and plumed whistling duck) and moderate numbers of large bodied waders (glossy ibis and egrets; data supplied by MDBA). The extent and duration of inundation was insufficient to support waterbird breeding and the rookery area between Clear and Black Lakes was not inundated (Spencer *et al.* 2018).

There is some evidence that inundation of lignum shrublands maintained condition of this vegetation community. The duration of inundation was short, however, and by Autumn 2018, there had been a decline in average condition of vegetation at the site (Figure 8). It should be noted that although average condition declined, the areas that received water may have been in better condition than those that remained dry.

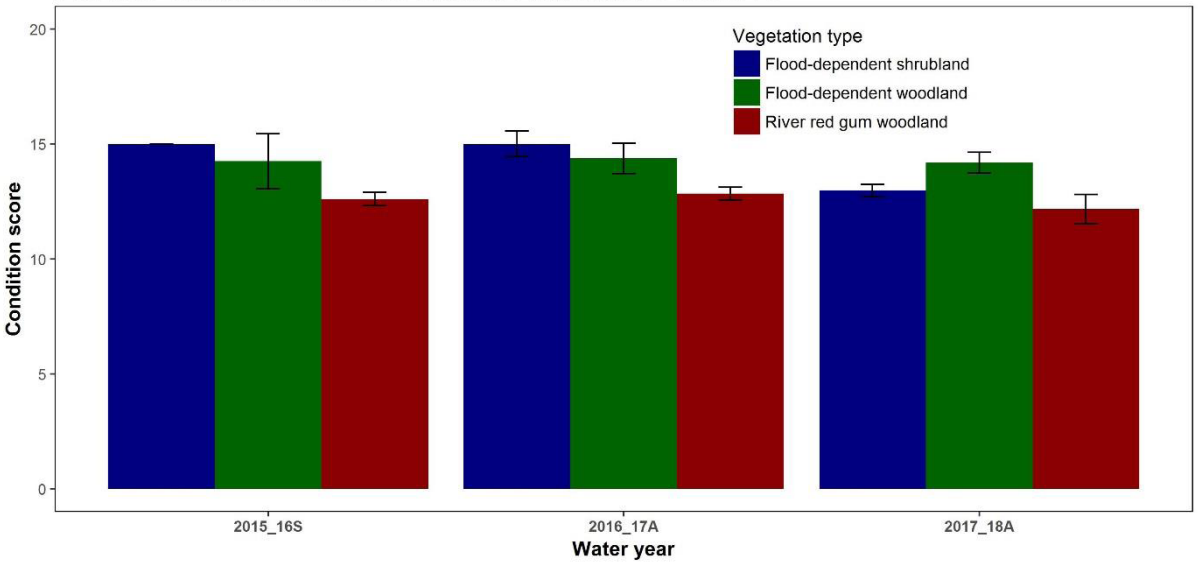


Figure 8. Condition of flood=dependent vegetation communities at the Narran Lakes. Note that scores range from 0 to 20, where 20 is excellent and 0 – 8.9 is poor. All vegetation communities in the graph above are in the "intermediate/poor" category scoring between 12 and 15 (Spencer *et al*. 2018).

What species/communities potentially benefited?

There is limited evidence to suggest that a number of species and communities potentially benefited from Commonwealth environmental water at Narran Lakes in 2016–17:

- Waterbirds – a diversity and abundance of several species.
- Vegetation – short-lived maintenance of lignum shrubland, with 290 hectares inundated.

5 Basin-scale outcomes

5.1 Highlights

- Commonwealth environmental water has contributed to maintaining the ecological character of nine of the sixteen Ramsar sites in the Basin over the first three years of the LTIM project. In 2016–17 Commonwealth environmental water was delivered to five Ramsar sites.
- Thirty-eight species of conservation significance were recorded at sites that received Commonwealth environmental water in the period 2014–17.
- Commonwealth environmental water contributed to significant ecological outcomes, particularly for waterbirds, by augmenting natural floods at critical locations across the Basin.

5.2 Effect of Commonwealth environmental water on species diversity

5.2.1 Number of species

Commonwealth environmental watering actions over the first three years of the LTIM Project contributed to the inundation of a wide range of ecosystem types within the Basin that included approximately 51% of the different wetland types and 83% of the different floodplain types, and all (100%) of the river channel and estuarine ecosystem types.

Lists of ecosystems, species and communities that potentially benefited from Commonwealth environmental water in the first three years of LTIM (2014–17) are provided in Annex B and comprise:

- 46 species of native plants
- 16 species of native fish
- 48 species of bush bird
- 78 species of wetland dependent bird
- 20 species of frog
- 3 species of turtle.

5.2.2 Waterbird abundance and diversity

Aerial survey data from the MDBA Aerial Waterbird Survey provides data across a number of wetlands in the Basin. The total waterbirds at sites that received Commonwealth environmental water in the first three years of LTIM indicates that substantial numbers of waterbirds potentially benefited (Figure 9). It should be noted that the number of waterbirds at sites that received Commonwealth environmental water is likely to be higher for several reasons. Firstly, the aerial survey method under represents certain small and cryptic species that are difficult to see from the air. Secondly, not all sites that received water were monitored by the MDBA program. Finally, the timing of the monitoring may not have coincided with peak abundance. Nevertheless, a total of 370 000 waterbirds have been recorded at sites that received Commonwealth environmental water over the past three years (data from MDBA).

Wetlands International (2015) 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 several waterbird species (Table 8).

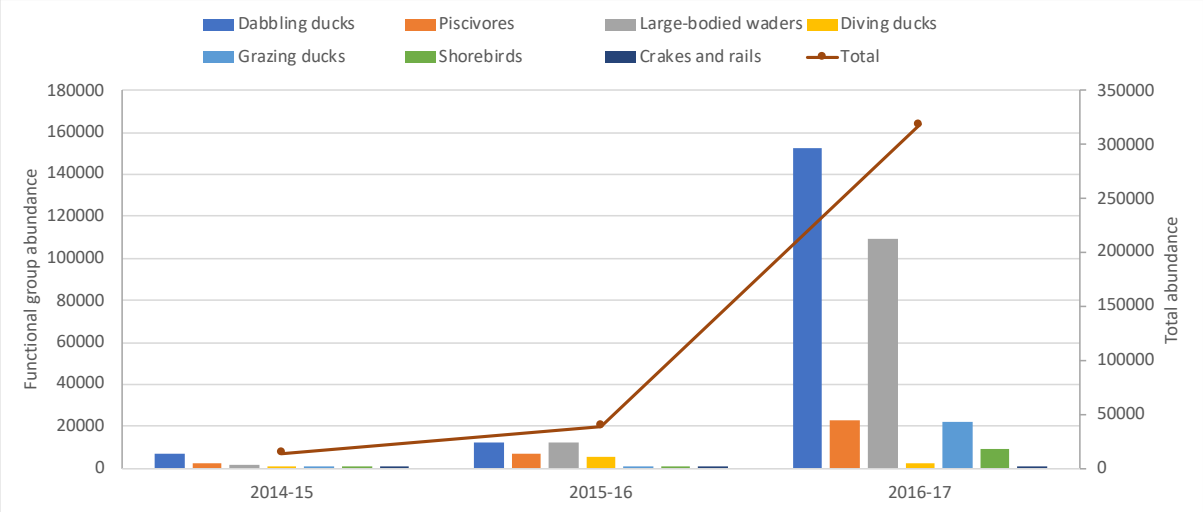


Figure 9. Total abundance of waterbirds from sites that received Commonwealth environmental water (source MDBA Aerial Waterbird Survey; data provided by MDBA).

Table 8. Waterbird species for which > 1% of the population have been recorded in a single year at sites that received Commonwealth environmental water (data provided by MDBA, with breeding colonies from Selected Area monitoring added).

Species	1% of the population*	Total abundance from multiple sites		
		2014–15	2015–16	2016–17
Australian pelican	1400		4051	13 191
Australian wood duck	10 000			17 658
Banded lapwing	1000			1984
Black-winged stilt	1750			5043
Eastern great egret	1000			2295
Grey teal	20 000			138 795
Straw-necked ibis	10 000			74 725
White-faced heron	1000			2338
White-necked heron	250		302	792
Yellow-billed spoonbill	250	436	2480	

* Population estimates from Wetlands International (2012).

5.3 Synthesis

Assessing the significance of Commonwealth environmental water at the Basin–scale has a high degree of uncertainty. As the portfolio of watering actions increases over time and we have results from multiple years at a larger number of locations, confidence will increase in our evaluation of Basin-scale outcomes. There are three clear ways in which Commonwealth environmental water has affected biodiversity at the Basin scale:

1. Contributions to maintaining the ecological character of Ramsar sites are of international significance and so can be considered significant at the Basin scale.
2. Benefits to threatened species and communities are, by definition, also considered significant at the Basin scale.
3. Capitalising on natural inundation for improved ecological outcomes.

5.3.1 Maintaining the ecological character of Ramsar sites

There are 16 Ramsar sites in the Basin and over the first three years of the LTIM Project, Commonwealth environmental water has been delivered to nine of these sites (Table 9).

Table 9. Ramsar sites that have been the target of Commonwealth environmental watering actions in the first three years of the LTIM Project.

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

A closer evaluation has been completed for three case study Ramsar sites that received Commonwealth environmental water in this third year: Gunbower Forest, Narran Lakes and the Macquarie Marshes. For each case study, consideration has been given to the relationship of Commonwealth environmental water and the components, processes and services identified as critical to maintaining ecological character.

At the Narran Lakes there are ten critical components, processes and services, of which the recent environmental watering action targeted one directly (vegetation, specifically lignum shrubland) and one indirectly (waterbirds) through the maintenance of habitat. The duration and extent of inundation was limited, but there is some evidence to suggest that Commonwealth environmental water contributed to maintaining lignum condition under what would have otherwise been dry conditions (Spencer 2018). In addition, there were 39 species of waterbird recorded including large numbers of waterfowl, that took advantage of the stimulation in productivity during the flood event.

At Gunbower Forest water was delivered in 2015–16 and 2016–17 as part of a three year Environmental Water Agreement with the Commonwealth Environmental Water Office (CEWO) to provide the fish hydrograph from 2015–2018 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 (Sharp 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 are now juvenile and sub-adult size classes of Murray cod clearly represented in Gunbower Creek (Bloink & Robinson 2016). 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.

The ecological character description for the Macquarie Marshes Ramsar site identifies seven components/process and services as critical to ecological character (OEH 2012). Potential contribution of Commonwealth environmental water to maintaining each of these identified critical components, processes and services is provided in Table 10. While watering actions in the first two years of the LTIM Project were focussed on maintaining condition and refuges during dry periods, in 2016–17, Commonwealth environmental water was delivered to extend durations of flooding to improve waterbird outcomes and to aid in the migration of native fish. There is good evidence that these multi-year strategies are contributing to the maintenance of ecological character at the site.

Table 10. Contribution of Commonwealth environmental water in 2014–17 to maintaining the ecological character of the Macquarie Marshes Ramsar site.

Critical components, processes and services	Description	Contribution of Commonwealth environmental water
Wetland types and vegetation	River red gum woodland and forests (6500 ha) Common reed beds (3350 ha) Cumbungi rushland (280 ha) Water couch marsh (1100 ha) Mixed marsh grasslands (50 ha) Lagoons (90 ha) Coolibah woodland and black box woodland (720 ha) Lignum (200 ha)	Environmental water inundated a range of vegetation communities in both 2014–15 and 2015–16, although for only a relatively short duration, would have contributed to maintaining condition during a regionally dry period. In 2016–17 large areas of emergent wetland vegetation were inundated extending the benefits of natural floods. There is evidence of maintaining tree condition, particularly river red gum communities that were inundated in both years and of growth and reproduction in common reed and water couch emergent marshes.
Aquatic invertebrates	High densities of micro-invertebrates, which are am important food source for fish. Also supports a diversity of macroinvertebrate species.	Possible that the inundation of the wetland and floodplain systems resulted in increased productivity and abundance of microinvertebrates in all years and helped to maintain waterbird foraging areas in 2016–17.
Fish species diversity	11 species of native fish recorded. Provides rich productive feeding habitats, and spawning habitat for several species.	Some evidence of spawning of bony bream, and potential increase in productivity from inundation of the Ramsar site in 2014–15. In 2016–17 connectivity between wetlands, the Macquarie River and the Barwon River allowed for migration of native fish.
Waterbird abundance and diversity	Supports over 70 species of waterbirds, with between 10 000 and 30 000 adult waterbirds reliant on the site each season.	Over the three years, 49 waterbird species have been recorded in the marshes, with very large numbers > 40 000 birds recorded in 2016–17
Waterbird breeding	16 species of colonial nesting waterbirds, with colonies of more than 500 nests on average in 9 in every 15 years.	Clear evidence that Commonwealth environmental water helped to improve reproductive outcomes for the large numbers of waterbirds that nested at the site. 17 species of colonial-nesting waterbirds detected during 2016-17 surveys.
Migratory birds and waders	17 species listed under international migratory agreements have been recorded at the site.	4 international migratory waders recorded at the site, albeit in small numbers.
Supports threatened wetland species	Australasian bittern, Australian painted snipe, superb parrot, Murray cod and basalt peppercress.	Australasian bittern (2015–16; 2016–17) and Australian painted snipe (2015–16) both recorded using the inundated habitats of the site.

5.3.2 Threatened species

Thirty-eight significant species were recorded at sites that received environmental water in 2014–17 (Table 11). This includes eight international migratory waterbird species, 11 nationally listed threatened species and 15 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 sites that received Commonwealth environmental water. The Australasian bittern was recorded in all three years and the Australian painted snipe in 2015–16. Given the cryptic nature of both these species, it is likely that they were present at sites in all years. There is now a good body of evidence suggesting that Commonwealth environmental water is helping to maintain the Australasian bittern (Text box 1).

Table 11. Listed species that were recorded at sites that received Commonwealth environmental water in 2014–17.

Group	Common name	Species name	Significance[1]
Birds	Black-tailed godwit	*Limosa lapponica*	JAMBA, CAMBA, ROKAMBA, V (NSW)
	Common greenshank	*Tringa nebularia*	JAMBA, CAMBA, ROKAMBA
	Common sandpiper	*Actitis hypoleucos*	JAMBA, CAMBA, ROKAMBA
	Latham's snipe	*Gallinago hardwickii*	JAMBA, CAMBA, ROKAMBA
	Marsh sandpiper	*Tringa stagnatilis*	JAMBA, CAMBA, ROKAMBA
	Red-necked stint	*Calidris ruficollis*	JAMBA, CAMBA, ROKAMBA
	Sharp-tailed sandpiper	*Calidris acuminata*	JAMBA, CAMBA, ROKAMBA
	Wood sandpiper	*Tringa glareola*	JAMBA, CAMBA, ROKAMBA
	Australasian bittern	*Botaurus poiciloptilus*	Endangered (EPBC)
	Australian little bittern	*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)
	Freckled duck	*Stictonetta naevosa*	Vulnerable (SA)
	Hardhead	*Aythya australis*	Vulnerable (VIC)
	Intermediate egret	*Ardea intermedia*	Endangered (VIC)
	Little egret	*Egretta garzetta*	Endangered (VIC)
	Magpie goose	*Anseranas semipalmata*	Vulnerable (NSW)
	Musk duck	*Biziura lobata*	Vulnerable (VIC)
	Regent parrot	*Polytelis anthopeplus*	Vulnerable (EPBC)
	Superb parrot	*Polytelis swainsonii*	Vulnerable (EPBC)
	White-bellied sea-eagle	*Haliaeetus leucogaster*	Vulnerable (NSW, VIC)
Fish	Eel-tailed catfish	*Tandanus tandanus*	Endangered (NSW, VIC)
	Flat-headed galaxias	*Galaxias rostratus*	Critically endangered (EPBC)
	Murray cod	*Maccullochella peelii*	Vulnerable (EPBC)
	Murray hardyhead	*Craterocephalus fluviatilis*	Endangered (EPBC)
	Olive perchlet	*Ambassis agassizii*	Endangered population (NSW)
	Purple-spotted gudgeon	*Mogurnda adspersa*	Endangered (NSW)
	Silver perch	*Bidyanus bidyanus*	Endangered (EPBC)
	Trout cod	*Maccullochella macquariensis*	Endangered (EPBC)
Frogs	Southern bell frog	*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)

[1] 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).

Habitat for the Australasian bittern

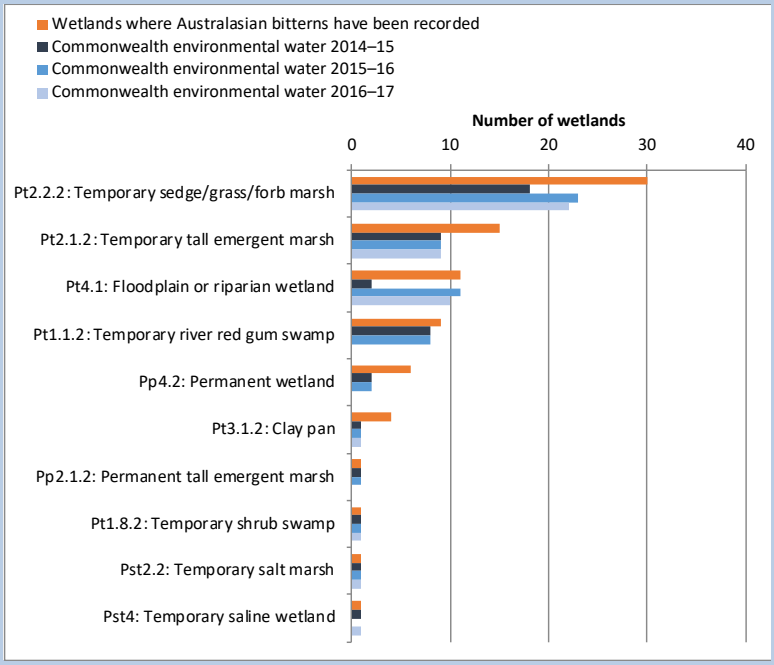
The Australasian bittern is listed as endangered under the EPBC Act and under the International Union for Conservation of Nature (IUCN) Red List. The species occurs also in New Zealand and New Caledonia, within Australia it is largely limited to the Basin, Tasmania and south-west Western Australia. Population estimates vary, but the total global population is suspected to be 1500 to 4000 individuals (Herring 2016) and Wetlands International (2015) indicate just five individuals represents 1% of the south-eastern Australian population.

Although Australasian bitterns have been observed in many habitat types, including saltmarsh, it is only large, shallow wetlands with emergent vegetation (but not trees) that support them for long periods (Herring 2016). A decline in these habitats and particularly extended drying of these wetlands has been identified as a serious threat and one of the reasons the species is considered endangered (TSSC 2010).

Australasian bitterns are cryptic species and there are many knowledge gaps with respect to lifecycle and behaviours. They were long considered to be sedentary, not moving far from their core wetland (Marchant and Higgins 1990). More recent evidence has indicated that they can and do travel long distances between breeding grounds in the mid to southern Basin to coastal areas (Herring 2016). The limited number of birds that have been tracked to date suggest that birds travel to and from the same wetlands suggesting site fidelity (Herring 2016) but more information is required to confirm this.

Australasian bitterns have been recorded by LTIM and TLM monitoring at six sites in the Basin following the delivery of Commonwealth environmental from the Gwydir in the northern Basin to the Coorong in the south. We also have evidence of Commonwealth environmental water supporting large numbers of bitterns (46 to 48 males) in Barmah-Millewa in 2015–16. If the unheard females were included in the tally, it is possible that the site supported up to one third of the total population (Belcher *et al.* 2016).

To try and extrapolate benefits of Commonwealth environmental water into sites that were not monitored, all bittern records from the Atlas of Living Australia and LTIM monitoring were overlaid with aquatic ecosystem types and over the past few decades. The species has been recorded in 79 wetlands in the Basin. Of these 58 (73 %) have received Commonwealth environmental water in the first three years of LTIM (see below). While there are still uncertainties with respect to whether bitterns occurred at these sites when environmental water was delivered and if attributes of water delivery such as timing, depth and duration of inundation matched bittern habitat requirements, the high site fidelity of the species provides us with some degree of confidence of the benefit of Commonwealth environmental water to Australian bitterns at the Basin scale.



Wetlands were Australasian bitterns have been recorded in the Basin (Atlas of Living Australia) and those that received Commonwealth environmental water in the first three years of LTIM.

Text box 1. Commonwealth environmental water benefiting Australasian bitterns.

Although there are several other waterbird species listed as threatened under the EPBC Act that can occur in the Basin, these are largely shorebirds that rely mostly on coastal habitats and would not be expected in these inland wetlands on a regular basis. 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.

The olive perchlet (*Ambassis agassizii*), which is listed as an endangered population in the NSW portion of the Basin, was recorded in the Gingham Waterhole in the Gwydir river system in the past two years. Without Commonwealth environmental water, key refuge pools such as the Gingham Waterhole would have dried, water quality within those pools would have deteriorated, and longitudinal connectivity between those pools would have ceased (Stoffels *et al*. 2017). There is also 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 (Bloink and Robinson 2016).

5.3.3 Capitalising on natural inundation for improved ecological outcomes

In the first two years of LTIM, the climate was largely dry and Commonwealth environmental water was delivered in many places with the express aim of maintain condition of long-lived vegetation in a dry landscape and on providing refuges for fauna. This is supported by recent research that indicates that, during dry times, the use of environmental water to maintain key wetland habitats is important for ongoing survival of waterbird populations in the Basin (Bino *et al.* 2015) and can be effective in maintaining other biota, such as frogs and turtles (Howard *et al.* 2017).

In 2016–17, much of the Basin experienced wetter conditions and Commonwealth environmental water was delivered to extend and improve the outcomes of natural floods. This is evident in rivers and streams where Commonwealth environmental water was used to improve connectivity between ecosystems and catchments. For example, in the Lower Darling there were good outcomes for fish in terms of recruitment and dispersal from connecting wetland, and river habitats (Sharp & Stuart 2018). Similarly, there were reported outcomes for dispersal of fish from connecting flows in the Macquarie – Barwon Rivers and in Gunbower Creek.

Perhaps the most obvious biodiversity outcomes from Commonwealth environmental water in 2016–17 were for waterbirds. 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. 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. A summary of measured breeding success at sites that received Commonwealth environmental water indicates success rates of 40 to 66 % (Table 12). Although less well studied, large numbers of waterfowl and other waterbirds would also have bred in response to the floods and drawn benefits from environmental water.

Table 12. Colonial waterbird breeding success at sites that received Commonwealth environmental water in 2016–17 (Brandis 2017, Wassens *et al.* 2017).

Location	Breeding period	Commonwealth environmental water		No. of nests	Success rate (%)
		Volume (ML)	Timing		
Murrumbidgee: Eulimbah	Oct – Mar	2320	28/11/16 - 03/03/17	15 104	59
Murrumbidgee: Telephone B.	Oct - Jan	5425	24/11/16 - 20/03/17	30 779	#
Murrumbidgee: Tori Swamp	Jan - Mar	844	27/10/16 - 13/02/17	6106	40
Lachlan: Booligal	Jan - Mar	1324	09/01/17 - 17/03/17	8000	58
Macquarie: Zoo Paddock	Oct – Jan	17039	24/01/17 - 18/02/17	21 210	66
Macquarie: Monkeygar	Oct – Jan			15 000	63

Not monitored

6 Contribution to achievement of Basin Plan objectives

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

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

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 13).

Table 13. Contribution of Commonwealth environmental water in 2014–17 to Basin Plan objectives associated with biodiversity.

Basin Plan objectives	Basin outcomes		5-year expected outcomes	1-year expected outcomes	Measured and predicted 1-year outcomes 2016–17	Measured and predicted 1–3-year outcomes 2014–17
Biodiversity (Basin Plan S. 8.05)	Ecosystem diversity		None identified	None identified	More than 77 500 ha of lakes and wetlands, 14 000 ha of floodplains and 21 000 km of rivers in the Basin upstream of the Lower Lakes were supported by Commonwealth environmental water.	51% of the different aquatic ecosystem types inundated with Commonwealth environmental water.
	Species diversity	Vegetation	Vegetation diversity	Reproduction	Presence of some native species likely to be dependent on inundation by Commonwealth environmental water. Decrease in exotic taxa.	Presence of some native species likely to be dependent on inundation by Commonwealth environmental water. Decrease in exotic taxa.
				Condition		
			Growth and survival	Germination Dispersal	Increased total cover and dominance of inundated vegetation communities and mostly higher species richness (though highly dependent on range of intrinsic and extrinsic factors).	Greater vegetation cover in plots/transects subjected to at least some wetting during this period.
		Macro-invertebrates	Macroinvertebrate diversity	-	-	-
		Fish	Fish diversity	Condition	Comparatively high level of nativeness in fish assemblages. Increase in condition of Murray cod and golden perch	Comparatively high level of nativeness in fish assemblages. Golden perch, silver perch, Australian smelt, carp gudgeon and bony herring exhibited species-specific responses to flows.
				Larval abundance Reproduction		Spawning by golden perch and bony bream.
			Larval and juvenile recruitment			Evidence of Murray hardyhead recruitment.
		Waterbirds	Waterbird diversity		Foraging habitat provided at a number of locations, especially to support waterbird breeding and successful recruitment.	Different foraging habitats provided for the full range of waterbird guilds across the three years. Productivity in temporary habitats is important for diversity.

Basin Plan objectives	Basin outcomes		5-year expected outcomes	1-year expected outcomes	Measured and predicted 1-year outcomes 2016–17	Measured and predicted 1–3-year outcomes 2014–17
			Waterbird diversity and population condition (abundance and population structure)	Survival and condition	Supporting greater than 1% of the relevant populations of nine species of waterbird.	-
				Chicks	Large scale colonial waterbird breeding across several location in the Basin with reproductive success rates of 40 – 65%.	Smaller scale breeding at localised sites that receive environmental water in drier years. Commonwealth environmental water augmenting large floods in wet periods to improve reproductive success.
				Fledglings		
		Other vertebrate diversity		Young	Breeding of many frog species including some temporary wetland specialists. Some evidence of turtle breeding.	Breeding of frogs at several locations across the three years.
			Adult abundance		Large numbers of several species recorded including the southern bell frog.	Continued foraging habitat provided.

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Annex A. Watering actions contributed to by Commonwealth environmental water in 2016–17 with expected outcomes for fish, vegetation, waterbirds, frogs or other vertebrates

Table A1. Watering actions contributed to by Commonwealth environmental water in 2016–17 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).

Surface water region/asset	Watering Action Number	Commonwealth environmental water volume (ML)	Dates	Flow component	Expected outcomes (P = primary; S = secondary)								
					Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Barwon Darling: Barwon-Darling River and fringing wetlands	111-40	9446	01/07/16 - 15/08/16	Fresh							S	P	S
Barwon Darling: Barwon-Darling River and fringing wetlands	111-40	3631	20/08/16 - 31/08/16	Fresh							S	P	S
Barwon Darling: Barwon-Darling River and fringing wetlands	111-40	13719	13/09/16 - 01/10/16	Fresh							S	P	S
Border Rivers - Severn River	111-33	823.53	01/07/16 - 30/06/17	Bankfull	P	S						P	
Border Rivers - Dumaresq-Macintyre River and Fringing Wetlands	111-34	914.3	07/07/16 - 13/07/16	Fresh	P								
Border Rivers - Dumaresq-Macintyre River and Fringing Wetlands	111-34	14376.8	25/08/16 - 25/10/16	Bankfull	P						S		
Border Rivers - Dumaresq-Macintyre River and Fringing Wetlands	111-34	6492.1	20/03/17 - 03/04/17	Bankfull	P								
Border Rivers - Macintyre Brook and fringing wetlands	111-99	919.23	19/09/16 - 04/10/16 30/04/17 - 04/04/17	Fresh	S				S	S		S	
Border Rivers - Lower Moonie River and fringing wetlands	111-35	1415	25/08/16 - 24/09/16	Fresh	P				P	S		S	
Broken - Lower Broken Creek	10041-03	11893	29/10/16 - 31/12/16	Base flow	P								
Broken - Lower Broken Creek	10041-03	18691	01/01/17 - 31/05/17	Base flow									P
Broken - Lower Broken Creek	10041-03	783	01/06/17 - 30/06/17	Base flow	P								

Surface water region/asset	Watering Action Number	Commonwealth environmental water volume (ML)	Dates	Flow component	Expected outcomes (P = primary; S = secondary)								
					Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Lower Murray: Coorong, Lower Lakes and Murray Mouth	10050-02	618476	01/06/16 - 30/06/17	Fresh, base flow	P	S	S			S	S		S
Central Murray: Barmah-Millewa Forest	10050-01	39170	22/06/16 - 31/12/16	Overbank	S	S					S		
Central Murray: Murray River	10050-01	124754	01/01/17 - 30/06/17	Fresh	S	S					S		
Central Murray - Gunbower Creek	10030-02	23563	01/07/16 - 30/06/17	Base flow	P					P	P		P
Condamine: Lower Balonne floodplain system	111-37	28869.6	21/09/16 - 03/10/16	Bankfull	S	P	P						
Condamine: Lower Balonne floodplain system	111-37	16892.2	06/04/17 - 16/04/17	Fresh						P		S	
Edward Wakool: Wakool River	10054-03	29306.63	31/10/16 - 31/12/17	Fresh	P								P
Edward Wakool: Edward River	10054-04	74822.7	24/10/16 - 08/12/16	Fresh	P								P
Edward Wakool: Colligen-Neimur	10054-05	3240.67	17/10/16 - 16/12/17	Fresh	P								P
Edward Wakool: Colligen-Neimur	10054-06	21542	01/01/17 - 30/06/17	Base flow	S	P							
Edward Wakool: Wakool River	10054-07	2770	01/01/17 - 30/06/17	Base flow		P							
Edward Wakool: Yallakool Creek	10054-08	27581	01/01/17 - 30/03/17	Fresh	P	P							
Edward Wakool: Merran Creek	10054-09	1107	16/02/17 - 28/03/17	Base flow	P								
Edward Wakool: Tuppal Creek	10054-10	1320	30/03/17 - 15/05/17	Base flow		P				P			P
Goulburn - Lower Goulburn River	10051-01	9250	01/07/16 - 05/08/16	Base flow	P				P				S
Goulburn - Lower Goulburn River	10051-01	8200	02/11/16 - 09/01/17	Base flow	P				P				S
Goulburn - Lower Goulburn River	10051-01	64290	01/03/17 - 03/04/17	Fresh	S	P			S		P		
Goulburn - Lower Goulburn River	10051-01	39585	04/04/17 - 25/06/17	Base flow	S	P			S		P		
Goulburn - Lower Goulburn River	10051-01	21119	26/06/17 - 26/06/17	Fresh		P					P		
Gwydir - Gwydir Wetlands	100057-01	9000	27/12/16 - 28/02/17	Wetland	S	P	S		S	S	S	S	
Gwydir - Mallowa Wetlands	100057-02	7496	13/01/17 - 01/04/17	Wetland		S	S	S	S	P			
Gwydir - Carole Creek	100057-03	1351	15/09/16 - 21/09/16	Base flow						S	P		S
Gwydir - Mehi River	100057-04	5000	17/09/16 - 21/09/16	Fresh						S	P		S

Surface water region/asset	Watering Action Number	Commonwealth environmental water volume (ML)	Dates	Flow component	Expected outcomes (P = primary; S = secondary)								
					Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Lachlan - Lachlan River	10053-02	28168	04/11/16 - 02/01/17	Fresh									P
Lachlan - Booligal Wetlands	10053-02	1324	09/01/17 - 17/03/17	Wetland			P						
Lower Darling- Lower Darling River	10059-01	71248.6	02/10/16 - 08/01/17 24/04/17 - 30/06/17	Fresh, base flow	P	S				S			S
Lower Darling- Great Darling Anabranch	10059-01	89204	16/02/17 - 30/06/17	Fresh	P	S	S	S		P			S
Loddon- Loddon River		479	18/04/17 - 30/04/17	Base flow	S				S	P			
Loddon- Loddon River		1100	13/05/17 - 30/05/17	Fresh		P			S				
Lower Murray - Calperum Station	10050-03	1276.74	01/06/16 - 01/06/17	Wetland		S	S	S					
Lower Murray - Pike River complex	10050-03	5.35	01/11/16 - 01/06/17	Wetland		S	S	S					
Lower Murray - Loxton Riverfront Reserve	10050-03	32.33	01/04/17 - 01/06/17	Wetland		S	S	S					
Lower Murray - Rillis Lagoons	10050-03	35.43	01/04/17 - 01/06/17	Wetland		S	S	S					
Lower Murray - Kroehn's Landing	10050-03	2.59	01/06/17 - 30/06/17	Wetland		S	S	S					
Lower Murray - Thieles Lagoon	10050-03	11.19	01/04/17 - 01/06/17	Wetland		S	S	S					
Lower Murray - Ramco River Terrace	10050-03	2.71	01/05/16 - 01/06/17	Wetland		S	S	S					
Lower Murray - Gurra Gurra-Lyrup Lagoon	10050-03	110.54	01/04/17 - 01/06/17	Wetland		S	S	S					
Lower Murray - Riversleigh Lagoon	10050-03	180.01	01/04/17 - 01/06/17	Wetland		S	S	S					
Lower Murray - Berri Evaporation Basin	10050-04	707	01/01/17 - 30/06/17	Wetland	P								
Lower Murray - Bookmark Creek	10050-04	239	01/01/17 - 30/06/17	Wetland		P	P						
Lower Murray - Rufus River	10050-06	29570	17/12/16 - 01/01/17	Fresh	P	P					P		
Lower Murray - Lock 15	10050-01	0	04/07/16 - 28/07/16	Fresh	S	P	S			P	S		
Lower Murray - Lock 15	10050-01	0	19/03/17 - 09/05/17	Fresh	S						S		

Surface water region/asset	Watering Action Number	Commonwealth environmental water volume (ML)	Dates	Flow component	Expected outcomes (P = primary; S = secondary)								
					Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Lower Murray - Lock 9	10050-01	0	15/07/16 - 30/12/16	Fresh	S	P					S		
Lower Murray - Lock 9	10050-01	0	30/04/17 - 30/06/17	Fresh	S	P					S		
Lower Murray - Lock 8	10050-01	0	20/7/16 - 14/10/16	Fresh	S	P	S				S		
Lower Murray - Lock 8	10050-01	0	26/01/17 - 23/05/17 12/06/17 - 30/06/17	Fresh	S	P					S		
Lower Murray - Lock 7	10050-01	0	01/08/16 - 01/01/17 01/02/17 01/03/17	Fresh	S	P	S				S		
Lower Murray - Lock 7	10050-01	0	01/05/17 - 01/06/17	Fresh	S	P					S		
Lower Murray - Lock 5	10050-02	0	01/07/16 - 01/10/16	Fresh	S	P	S				S		
Lower Murray - Lock 2	10050-02	0	01/07/16 - 01/10/16	Fresh	S	P	S				S		
Murrumbidgee - Murrumbidgee River	10052-02	150978	28/10/16 - 05/01/17	Fresh, bankfull	P						P		P
Murrumbidgee - Yanco-Billabong-Forest Creek system: Wanganella Swamp	10052-03	5000	19/11/16 - 04/01/17	Wetland	S	S	P						S
Murrumbidgee - Nimmie-Caira: Eulimbah	10052-05	2320	28/11/16 - 03/03/17	Wetland	S	S	P						S
Murrumbidgee - Nimmie-Caira: Telephone Bank	10052-06	5425	24/11/16 - 20/03/17	Wetland	S	S	P						S
Murrumbidgee - Yanga National Park	10052-08	2155	29/10/16 - 13/02/17	Wetland	S	S	P						S
Murrumbidgee - North Redbank: Tori Lignum Swamp	10052-09	844	27/10/16 - 13/02/17	Wetland	S	S	P						S
Murrumbidgee - Toogimbie IPA Wetlands	10052-10	998	18/3/17 - 04/04/17 07/05/17 - 24/06/17	Wetland	S	P	S	S	S			P	
Murrumbidgee - Nimmie-Caira: Nap Nap	10052-11	630	03/01/17 - 07/01/17	Wetland	S	S	P						S
Murrumbidgee - Nimmie-Caira: Is-Y-Coed (Kieeta and Kia Lakes)	10052-12	5000	10/02/17 - 20/03/17	Wetland	S	S	P						S

Surface water region/asset	Watering Action Number	Commonwealth environmental water volume (ML)	Dates	Flow component	Expected outcomes (P = primary; S = secondary)								
					Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Murrumbidgee - Lower Murrumbidgee River	10052-13	47548	01/04/17 - 20/04/17	Fresh	P	S				S	S		S
Murrumbidgee - Lower Murrumbidgee Floodplain	10034-09	15507	04/08/16 - 03/09/16	Wetland	S	S	S	S	S				
Murrumbidgee - Western Lakes	10034-10	5060	07/11/16 - 19/12/16	Wetland		S	S						
Macquarie - Macquarie Marshes	10055-01	17039	24/01/17 - 18/02/17	Wetland	S	S	P				S		
Macquarie - Mid-Macquarie River and Macquarie Marshes	10055-02	2648	04/04/17 - 12/04/17	Fresh	P								
Macquarie - Lower Macquarie River	10055-03	27583	16/04/17 - 15/05/17	Fresh	P	S	S			S			
Macquarie - Macquarie Marshes	10032-02	3000	24/07/16 - 30/07/16	Wetland		P				S			
Macquarie - Macquarie Marshes	10032-02	3500	06/09/16 - 13/09/16	Wetland		P				S			
Macquarie - Macquarie Marshes	10032-02	750	19/12/16 - 21/12/16	Wetland	S	S	P			S			
Namoi - Lower Namoi River	10056-01	7852	28/02/17 - 20/05/17	Base flow	P	S			S	S			
Namoi - Peel River	10063-01	1257	04/06/17 - 30/06/17	Fresh	P						S		
Ovens: Ovens River	10004-03	20	15/02/17 - 23/02/17	Fresh						P			
Ovens: Ovens River	10004-03	50	12/03/17 - 13/03/17	Base flow						P			
Warrego: Upper Warrego River and fringing wetlands.	111-38	795	19/09/16 - 29/09/16	Fresh						S		S	
Warrego: Lower Warrego River and fringing wetlands.	111-39	1912.96	01/07/16 - 07/07/16	Fresh						S		S	
Warrego: Lower Warrego River and fringing wetlands.	111-39	601.99	31/07/16 - 02/08/16	Fresh						S		S	
Warrego: Lower Warrego River and fringing wetlands.	111-39	340.01	06/09/16 - 07/09/16	Fresh						S		S	
Warrego: Lower Warrego River and fringing wetlands.	111-39	5865	23/09/16 - 10/10/16	Bankfull	S					S		S	
Warrego: Lower Warrego River and fringing wetlands.	152-07	7762.5	08/10/16 - 28/10/16	Fresh	P					P	S		

Surface water region/asset	Watering Action Number	Commonwealth environmental water volume (ML)	Dates	Flow component	Expected outcomes (P = primary; S = secondary)								
					Fish	Veg	Birds	Frogs	Other biota	Con.	Proc.	Res.	WQ
Warrego: Toorale Western Floodplain	152-08	5023	19/07/16 - 12/09/16	Wetland		P	P						
Warrego: Toorale Western Floodplain	152-08	4697	12/09/16 - 20/09/16	Wetland		P	P						

Annex B. Species and communities that potentially benefited from Commonwealth environmental water in 2014–17.

Table B1. ANAE aquatic ecosystem types likely to have been influenced by Commonwealth environmental water 2014–17 (Brooks 2018).

Australian National Aquatic Ecosystem (ANAE) wetland type	Total area (ha)	% receiving Cew		
		Y1 14-15	Y2 15–16	Y3 16–17
Pp4.2: Permanent wetland	77 300	26.2	28.2	26.0
Pt1.7.2: Temporary lignum swamp	49 962	1.1	7.0	24.9
Pt2.3.2: Freshwater meadow	125 128	15.1	16.8	16.4
Pt2.2.2: Temporary sedge/grass/forb marsh	135 475	12.1	15.1	12.5
Pt1.1.2: Temporary river red gum swamp	74 721	13.3	56.1	10.1
Pt4.1: Floodplain or riparian wetland	10 494	8.3	21.0	9.6
Psp4: Permanent saline wetland	2114	10.9	48.6	8.1
Pp2.3.2: Permanent grass marsh	1507	1.5	1.7	6.4
Lp1.1: Permanent lake	127 660	1.1	3.9	5.4
Pt2.1.2: Temporary tall emergent marsh	68 622	4.5	6.3	4.5
Pp2.4.2: Permanent forb marsh	738	1.4	0.7	4.1
Pt1: Temporary swamp	3767	7.4	18.5	3.5
Pt3.1.2: Clay pan	129 736	2.4	2.9	1.3
Pt1.8.2: Temporary shrub swamp	234 393	0.7	3.2	0.9
Lt1.1: Temporary lake	459 347	0.6	1.7	0.5
Pp2.2.2: Permanent sedge/grass/forb marsh	3590	0.4	0.5	0.4
Pt1.2.2: Temporary black box swamp	60 272	1.8	10.4	0.4
Pst2.2: Temporary salt marsh	40 294	<0.1	1.6	<0.1
Pt1.6.2: Temporary woodland swamp	216 625	<0.1	0.3	<0.1
Pp2.1.2: Permanent tall emergent marsh	7995	43.1	52.0	-
Pt4.2: Temporary wetland	26 892	<0.1	2.2	-
Lst1.1: Temporary saline lake	27 897	-	0.5	-
Pst1.1: Temporary saline swamp	5728	1.6	-	-
Lsp1.1: Permanent saline lake	9229	-	-	-
Lt1.2: Temporary lake with aquatic bed	9052	-	-	-
Pst4: Temporary saline wetland	6118	-	-	-
Pp3: Peat bog or fen marsh	4425	-	-	-
Pst3.2: Salt pan or salt flat	3201	-	-	-
Lst1.2: Temporary saline lake with aquatic bed	2238	-	-	-
Lp1.2: Permanent lake with aquatic bed	2067	-	-	-
Pu1: Unspecified wetland	1763	-	-	-
Pt1.5.2: Temporary paperbark swamp	412	-	-	-
Psp2.1: Permanent salt marsh	248	-	-	-
Lsp1.2: Permanent saline lake with aquatic bed	181	-	-	-
Psp1.1: Saline paperbark swamp	163	-	-	-
Pps5: Permanent spring	130	-	-	-
Pp1.1.2: Permanent paperbark swamp	1	-	-	-
F1.11: River cooba woodland riparian zone or floodplain	11 541	9.8	10.9	6.7
F1.2: River red gum forest riparian zone or floodplain	639 022	3.8	5.2	1.0
F2.2: Lignum shrubland riparian zone or floodplain	143 852	3.8	1.7	0.8
F2.4: Shrubland riparian zone or floodplain	407 981	0.3	1.8	0.6
F1.4: River red gum woodland riparian zone or floodplain	325 221	1.1	0.6	0.4
F1.10: Coolibah woodland and forest riparian zone or floodplain	427 507	0.8	0.4	0.2
F1.8: Black box woodland riparian zone or floodplain	779 636	0.3	0.9	0.1
F4: Unspecified riparian zone or floodplain	989 305	<0.1	<0.1	<0.1
F1.12: Woodland riparian zone or floodplain	318 686	<0.1	<0.1	<0.1
F1.6: Black box forest riparian zone or floodplain	131 442	0.4	1.3	<0.1
F3.2: Sedge/forb/grassland riparian zone or floodplain	833 102	-	-	<0.1
F1.13: Paperbark riparian zone or floodplain	17	-	-	-

Table B2. Plant species that potentially benefited from Commonwealth environmental water in 2014–17 (Capon & Campbell 2016; Capon & Mynott 2018).

Grasses	Subshrubs/shrubs	Sedges/rushes
Aristida leptopoda	*Abutilon sp.*	*Carex bichenoviana*
Echinochloa inundata.	*Eremophila debilis*	*Cyperus difformis*
Eragrostis leptostachya	*Lycium australe*	*Cyperus eragrostis**
Leptochloa spp.		*Eleocharis pallens*
Paspalidium constrictum		*Juncus flavidus*
Paspalum distichum		*Juncus usitatus*
Forbs	**Trees**	**Mistletoes**
Ammannia multiflora	*Myoporum acuminatum*	*Dendrophthoe* spp.
*Arctotheca calendula**		
Brachyscome basaltica		
Calotis cuneate		
Calotis scapigera		
Chrysocephalum apiculatum		
Commelina cyanea		
Crassula helmsii		
Daucus glochidiatus		
Dichondra spp.		
*Eichhornia crassipes**		
*Emex australis**		
Gnaphalium spp.		
Goodenia spp.		
Gratiola pedunculata		
Haloragis glauca		
Hypercium gramineum		
*Medicago lupulina**		
Persicaria hydropiper		
Persicaria spp.		
Plantago cunninghamii		
Polygonum plebium		
Portulaca oleracea		
*Rhaponticum repens**		
Spirodela polyrhiza		
*Taraxacum officinale**		
*Verbena officinalis**		
*Veronica catenata**		
Xerochrysum		

Note: asterisks (*) indicate exotic species.

Table B3. Fish species that potentially benefited from Commonwealth environmental water in 2014–17 (extracted from Stoffels *et al.* 2017; 2018, augmented with species recorded in monitoring outside LTIM).

Common name	Species name	Listing
Australian smelt	*Retropinna semoni*	
Bony bream	*Nematalosa erebi*	
Carp gudgeon	*Hypseleotris* spp.	
Eel-tailed catfish	*Tandanus tandanus*	Endangered (NSW, Vic)
Flathead gudgeon	*Phylipnodon grandiceps*	
Golden perch	*Macquaria ambigua*	
Hyrtl's catfish	*Neosilurus hyrtlii*	
Murray cod	*Maccullochella peelii*	Vulnerable (EPBC)
Murray–Darling rainbowfish	*Melanotaenia fluviatilis*	
Murray hardyhead	*Craterocephalus fluviatilis*	Endangered (EPBC)
Olive perchlet	*Ambassis agassizii*	Endangered population (NSW)
Purple-spotted gudgeon	*Mogurnda adspersa*	Endangered (NSW)
Silver perch	*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.

Table B4. Frog species that potentially benefited from Commonwealth environmental water in 2014–17.

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 banjo frog	*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 bell frog	*Litoria raniformis*	Vulnerable (EPBC)
Spotted marsh frog	*Limnodynastes tasmaniensis*	
Striped burrowing frog	*Litoria alboguttata*	

Common name	Species name	Listing
Sudell's frog	*Neobatrachus sudallae*	
Water-holding frog	*Litoria platycephala*	
Warty water-holding frog	*Litoria verrucosa*	
Wrinkled toadlet	*Uperoleia rugosa*	

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*	
Macquarie river turtle	*Emydura macquarii*	

Table B6. Bush bird species that potentially benefited from Commonwealth environmental water at Hattah Lakes (extracted from Loyn & Dutson 2016, showing species whose abundance increased during or after environmental 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*	X	X
Australian raven	*Corvus coronoides*	X	X
Australian ringneck	*Barnardius zonarius*	X	X
Black-faced cuckoo-shrike	*Coracina novaehollandiae*	X	X
Blue bonnet	*Northiella haematogaster*	X	X
Blue-faced honeyeater	*Entomyzon cyanotis*	X	
Brown falcon	*Falco berigora*	X	X
Brown treecreeper	*Climacteris picumnus*	X	X
Chestnut-rumped thornbill	*Acanthiza uropygialis*	X	X
Common bronzewing	*Phaps chalcoptera*	X	X
Eastern rosella	*Platycercus eximius*	X	X
Galah	*Eolophus roseicapilla*	X	X
Grey fantail	*Rhipidura albiscapa*	X	X
Grey shrike-thrush	*Colluricincla harmonica*	X	X
Laughing kookaburra	*Dacelo novaeguineae*	X	X
Little corella	*Cacatua sanguinea*	X	X
Little eagle	*Hieraaetus morphnoides*	X	X
Little friarbird	*Philemon citreogularis*	X	X
Magpie-lark	*Grallina cyanoleuca*	X	X
Major Mitchell's cockatoo	*Lophochroa leadbeateri*	X	X
Noisy miner	*Manorina melanocephala*	X	X
Rainbow bee-eater	*Merops ornatus*	X	X
Red-capped robin	*Petroica goodenovii*	X	X
Regent parrot (vulnerable; EPBC)	*Polytelis anthopeplus*	X	X
Restless flycatcher	*Myiagra inquieta*	X	X

Common name	Species name	2014–15	2015–16
Rufous whistler	*Pachycephala rufiventris*	X	X
Sacred kingfisher	*Todiramphus sanctus*	X	X
Singing honeyeater	*Lichenostomus virescens*	X	X
Spiny-cheeked honeyeater	*Acanthagenys rufogularis*	X	X
Spotted pardalote	*Pardalotus punctatus*	X	X
Striated pardalote	*Pardalotus striatus*	X	X
Striped honeyeater	*Plectorhyncha lanceolata*	X	X
Tree martin	*Petrochelidon nigricans*	X	X
Varied sittella	*Daphoenositta chrysoptera*	X	X
Weebill	*Smicrornis brevirostris*	X	X
Welcome swallow	*Hirundo neoxena*	X	
Whistling kite	*Haliastur sphenurus*	X	X
White-backed swallow	*Cheramoeca leucosterna*	X	X
White-bellied sea-eagle (FFG listed)	*Haliaeetus leucogaster*	X	X
White-browed woodswallow	*Artamus superciliosus*	X	X
White-plumed honeyeater	*Lichenostomus penicillatus*	X	X
White-winged chough	*Corcorax melanorhamphos*	X	X
White-winged triller	*Lalage tricolor*	X	X
Willie wagtail	*Rhipidura leucophrys*	X	
Yellow rosella	*Platycercus elegans flaveolus*	X	X
Yellow thornbill	*Acanthiza nana*	X	X
Yellow-rumped thornbill	*Acanthiza chrysorrhoa*	X	X
Yellow-throated miner	*Manorina flavigula*	X	

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 2014–17 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	Gwydir	Murrum-bidgee	Warrego–Darling	Lower Murray	Goulburn	Mid-Murray	Macquarie	Condamine Balonne
Australasian bittern[1]	1	2			1	2	2	
Australasian darter	3	2	3	2		2	3	1
Australasian grebe	3	3	2	2		2	2	1
Australasian shoveler	2	2	3	2		2	2	
Australian gull-billed tern	1							1
Australian little bittern[3]	1					2		
Australian painted snipe[2]							1	
Australian pelican	3	3	3	3		2	3	1
Australian pratincole	1	1						
Australian reed warbler	3	2	1	1		2	3	1
Australian shelduck		3	1	2		2	2	
Australian spotted crake		1						

Species	Gwydir	Murrum-bidgee	Warrego–Darling	Lower Murray	Goulburn	Mid-Murray	Macquarie	Condamine Balonne
Australian white ibis	3	3	3	2		2	3	1
Australian wood duck	3	3	3	3		2	3	1
Ballion's crake		1					1	
Banded lapwing	1			1		2	2	1
Black swan	3	3	3	3	1	2	2	1
Black-fronted dotterel	3		3	2		2	3	
Black-necked stork[3]	2						1	
Black-tailed godwit[4]	1							
Black-tailed native-hen	1	2	2	2		1	2	1
Black-winged stilt	3	2	2	2		1	3	1
Blue-billed duck[3]						1	1	
Brolga[3]	3		2	1	1		2	
Buff-banded rail	1						1	
Caspian tern	1			3		2		1
Cattle egret	3	1					2	1
Chestnut teal	1			2		2	2	
Comb-crested jacana[3]	1							
Common greenshank[4]	2			1				
Common sandpiper[4]	1		1					
Dusky moorhen	2	2	1	2		2	3	
Eastern great egret[3]	3	3	2	2		2	3	1
Eurasian coot	3	3	3	2		2	3	1
Freckled duck[3]			2	2			1	1
Glossy ibis	3	1	1	1			3	1
Golden-headed cisticola	3	1					3	
Great cormorant	3	3	1	1		2	3	1
Great crested grebe		1	1			1	1	
Grey teal	3	3	3	3		2	3	1
Hardhead[3]	2	3	2	2		2	2	1
Hoary-headed grebe	2	3	2	2		2	2	
Intermediate egret[3]	3	2	1	1		1	3	1
Latham's snipe[4]	3						3	
Little black cormorant	3	3	2	1		2	3	1
Little egret[3]	2	2	1			2	2	
Little grassbird	3	2	1	1		1	3	1
Little pied cormorant	3	3	1	1		2	3	1
Magpie goose	3						2	
Marsh sandpiper	2					1		
Masked lapwing	3	2	3	3		2	3	1
Musk duck[3]		1		2		2	1	
Nankeen night-heron	2	2	1			2	2	
Pacific black duck	3	3	3	3		2	3	1
Pied cormorant	3	2	2	1		2		
Pink-eared duck	3	3	3	3		1	2	1

Species	Gwydir	Murrum-bidgee	Warrego–Darling	Lower Murray	Goulburn	Mid-Murray	Macquarie	Condamine Balonne
Plumed whistling-duck	3		2				2	1
Purple swamphen	3	2	1	2			3	1
Red-backed kingfisher			1					
Red-capped plover			1	1		1		
Red-kneed dotterel	3	1	2	2		1	3	
Red-necked avocet	2		2	1		1	1	1
Red-necked stint[4]				1		1		
Royal spoonbill	2	2	1	1			3	1
Sacred kingfisher	3	3	3	1		2	3	1
Sharp-tailed sandpiper[4]	3			2		1	2	
Silver gull				1		2	1	1
Spotless crake	1						1	
Straw-necked ibis	3	3	2	2		2	3	1
Swamp harrier	3	2		2		1	3	
Tawny grassbird	1						1	
Wandering whistling-duck	2							
Whiskered tern	3	2	2				3	1
White-bellied sea-eagle	2	3	1	1		2	3	1
White-faced heron	3	3	3	1		2	3	1
White-necked heron	3	2	3	2		2	3	1
Wood sandpiper[4]			1	1				
Yellow-billed spoonbill	3	2	3	2		2	3	1

[1] Listed as endangered nationally under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

[2] Listed as vulnerable nationally under the EPBC Act.

[3] Listed as threatened under state legislation.

[4] Listed under international migratory agreements JAMBA (Japan–Australia Migratory Bird Agreement); CAMBA (China–Australia Migratory Bird Agreement); ROKAMBA (Republic of Korea– Australia Migratory Bird Agreement).