

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

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

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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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# Introduction

The Murray–Darling Basin (the Basin) contains over 23 000 square kilometres of lakes and wetlands, 50 000 square kilometres of floodplain and 600 000 kilometres of mapped river channel (Brooks 2017). Sixteen wetlands of international importance, listed under the Ramsar Convention, are located within the Basin, as are over 200 nationally important wetlands (Leblanc *et al.* 2012). These ecosystems support a broad range of species and ecological communities that are inundation dependent, or dependent on vegetation communities that are classified as wetland or floodplain systems. The Basin’s aquatic ecosystems also support a large number of nationally and internationally significant plant and animal species, including 95 species listed as threatened under national or state legislation (Leblanc *et al.* 2012).

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

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

The Biodiversity component of the Commonwealth Environmental Water Office’s (CEWO’s) Long Term Intervention Monitoring (LTIM) Project aims to evaluate the contribution of Commonwealth environmental water to achieving diversity-related objectives of the Basin Plan (section 8.05(3)). This is accomplished through the consolidation of information from multiple sources to provide a summary of species and communities that potentially benefited from Commonwealth environmental water to address the following evaluation question:

* What did Commonwealth environmental water contribute to species diversity?
  + How did Commonwealth environmental water affect the presence, distribution and abundance of plant, fish, bird, frog, turtle and aquatic ecosystem dependent mammal species?
  + What listed threatened species and ecological communities benefited from Commonwealth environmental water?
  + What migratory species listed under international agreements (Bonn Convention, CAMBA, JAMBA or ROKAMBA[[1]](#footnote-1)) benefited from Commonwealth environmental water?

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

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



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

# Methods

## General approach

The main output of the Biodiversity evaluation is an aggregated list of species and communities that potentially benefited from Commonwealth environmental water each year. This list has been derived from a number of sources, including other Basin Matter reports, Selected Area reports, and other monitoring programs (external to LTIM).

Determining if a species or community benefited from Commonwealth environmental water is not straightforward. The presence of a species at a site that received Commonwealth environmental water does not necessarily indicate that the species benefited, nor does it provide any indication of the temporal or spatial scale over which that species may have benefited. The Biodiversity Basin Matter (formerly termed “generic diversity”) undertakes a qualitative evaluation of expected outcomes of watering actions undertaken by CEWO. The approach uses information from different sources to identify species that potentially benefited from Commonwealth environmental water. The sources of information include (Figure 2):

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

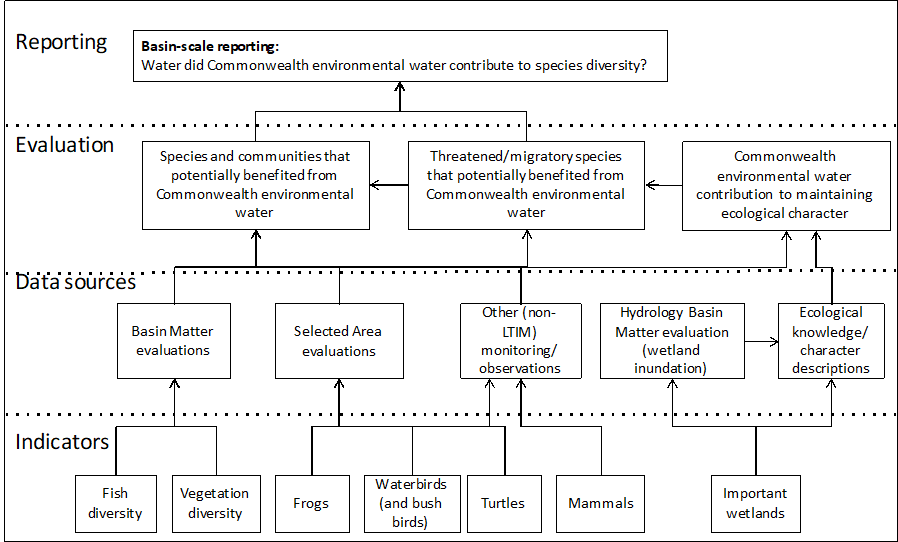


Figure 2. Basin evaluation of Biodiversity.

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.

## Other Basin Matters

The effects of Commonwealth environmental water on vegetation, fish and ecosystem diversity have been evaluated as other Basin Matters. These evaluations adopted different approaches and methods for assessing the effect of Commonwealth environmental water, which are documented in each report. Species and communities that were identified in each of these evaluations as benefiting (or potentially benefiting) from Commonwealth environmental water have been extracted and included in the aggregated list of species in Annex B.

## Waterbirds, frogs, turtles and mammals

### Selected Area outcomes

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

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

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

### Unmonitored sites

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

Where information on the effects of environmental watering in the 2017–18 watering year was available, this has been extracted and aggregated into a list of species and communities for each aquatic ecosystem.

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

For case study sites, information related to the watering action, known species and habitats at the site and any complementary monitoring data were used to evaluate the effects of the watering action through the following questions:

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

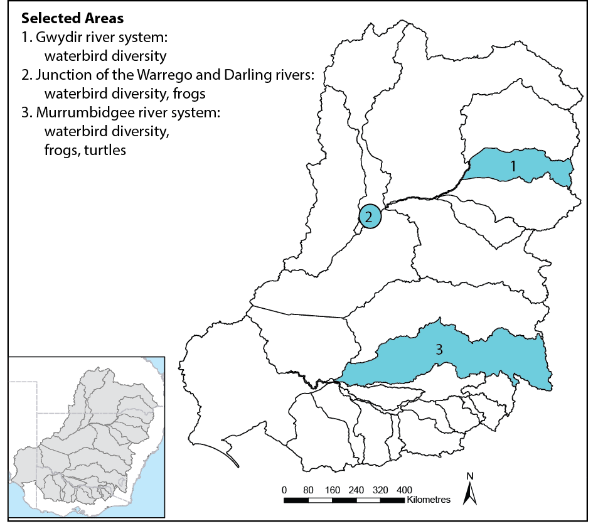


Figure 3. Locations of Selected Area monitoring for waterbirds, frogs and turtles 2017–18.

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

## Highlights

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

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

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

| Selected Area (watering action reference) | Dates1 | Commonwealth environmental water volume (ML)1 | Flow component1 | Expected ecological outcome1 | Monitored site(s)2 | Observed ecological outcome2 | Influences2 |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Gwydir (10069-01) | 19/12/17 - 17/01/18 | 4000 | Wetland | Provide refuge habitat for waterbirds, fish and other aquatic species | Lower Gwydir River and Gingham watercourse – 21 locations | 54 species of waterbird recorded including the endangered Australian painted snipe; eight waterbird species with evidence of breeding activity | Availability and timing of inundated habitat; productivity (vegetation and food sources) responses to watering. |
| Murrumbidgee (10062-01) | 24/07/17 - 01/09/17 | 159 283 | Fresh, Wetland | Support reproduction and improved condition of vegetation, waterbirds, native fish and other biota. | Mid-Murrumbidgee wetlands (Sunshower, Gooragool, Yarradda and McKennas) | 32 species of waterbird recorded including Latham’s snipe which is listed under the international migratory agreements JAMBA and ROKAMBA. Small number of colonial nesting species observed breeding.  Six species of frog and three turtle species supported, including small numbers of the vulnerable southern bell frog. Tadpoles recorded in all mid-Murrumbidgee monitoring sites. | Direct link with environmental water, with repeat watering over multiple years maintaining refuges and habitat for waterbirds, frogs and turtles.  Impacts of carp on tadpoles and foxes on turtle hatching success. The importance of permanent water for turtle species. |
| Murrumbidgee (10062-02) | 04/07/17 - 24/07/17 | 326 | Wetland | Support the habitat requirements of waterbirds, native fish and other aquatic animals. |
| Murrumbidgee (10062-03) | 18/07/17 - 11/08/17 | 1426 | Wetland |
| Murrumbidgee (10068-06) | 20/11/17 - 25/11/17 | 178 | Wetland |
| Warrego: Lower Warrego River  (152-10) | Dec 2017 | 0 | Fresh | Provide opportunities for native fish (e.g. fish spawning, recruitment and movement) (Warrego River) | Boera Dam, Booka Dam, Ross Billabong | 22 species of waterbird, in relatively low numbers. Twelve species of frog including first record for the water holding frog at this location. | Dry conditions and limited water / inundation resulted in reduced numbers and diversity of waterbirds and frogs. |

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

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

### Waterbirds

#### Waterbird diversity

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

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

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



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

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



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

#### Waterbird breeding

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



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

### Frogs

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

Table 2. 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 | Yr4 | Yr2 | **Yr3** | Yr1 | Yr2 | Yr3 | Yr4 |
| Desert froglet | *Crinia deserticola* |  |  |  |  |  |  |  | X |  | X | X |
| Plains froglet | *Crinia parinsignifera* | X | X | X | X | X | X | X |  | X | X |  |
| Striped burrowing frog | *Cyclorana alboguttata* |  |  |  |  |  |  | X |  |  |  |  |
| Water-holding frog | *Cyclorana platycephala* |  |  |  |  |  |  |  |  |  |  | X |
| Barking marsh frog | *Limnodynastes fletcheri* |  | X | X | X | X | X | X | X |  | X | X |
| Inland banjo frog | *Limnodynastes* *interioris* | X |  | X | X | X |  |  |  |  |  |  |
| Salmon striped frog | *Limnodynastes salmini* |  |  |  |  |  |  | X |  |  | X |  |
| Spotted marsh frog | *Limnodynastes tasmaniensis* | X | X | X | X | X | X | X | X | X |  | X |
| Green tree frog | *Litoria caerulea* |  |  |  |  |  |  | X | 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 | X | X |
| Southern bell frog1 | *Litoria raniformis* |  | X | X | X | X |  |  |  |  |  |  |
| Desert tree frog | *Litoria rubella* |  |  |  |  |  |  |  | X |  |  | X |
| Sudell’s frog | |  | | --- | | *Neobatrachus sudallae* | |  |  |  |  |  |  |  |  |  | X |  |
| Ornate burrowing frog | *Platyplectrum ornatum* |  |  |  |  |  |  | X |  |  |  |  |
| Small-headed toadlet | *Uperoleia capitulata* |  |  |  |  |  |  |  |  |  |  | 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). The drier conditions in 2017–18 lead to a reduction in abundance and limited evidence of breeding in the Selected Area.

### Turtles

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

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

# Unmonitored area outcomes

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

## Highlights

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

## Aggregation of data from other sources

### Effects of Commonwealth environmental water on waterbird, frog, turtle and mammal species diversity at unmonitored sites

Information on the ecological responses of waterbirds, frogs, turtles and mammals is summarised in Table 3. This table does not include important wetland sites such as Barmah Forest and Macquarie Marshes, which are considered in more detail in Section 4.3. The majority of the information collated is qualitative and includes very little additional evidence about the site that received Commonwealth environmental water or how species or communities responded to the water regime.

Table 3. Summary of observations and other information from unmonitored watering actions related to waterbirds, frogs, turtles and mammals in 2017–18. Note that many of these actions involved multiple water sources (in addition to Commonwealth environmental water). Additional information on the portfolio of environmental water can be found in the Basin Matter Hydrology report (Stewardson & Guarino 2019). Ramsar wetlands are considered in section 4.3.

| Surface water region/asset | Commonwealth environmental water volume (ML)1 | Dates1 | Flow component1 | Expected ecological outcome1 | Observed ecological outcome | Source of information |
| --- | --- | --- | --- | --- | --- | --- |
| Upper Broken Creek and Moodie Swamp | 498 | 18/04/18 - 07/06/18 | Fresh, Wetland | Provide a more natural flooding regime to ensure the success of bird breeding events (incl Brolga) and to provide growth conditions for water dependant vegetation. | Moodie Swamp: Autumn watering event triggered a response in frogs and macroinvertebrates priming the site for spring ecological outcomes.  Platypus recorded in the Upper Broken Creek. | CEWO acquittal report (unpublished) |
| Lower Murray - Calperum Station | 3894 | Oct 2017 - Apr 2018 | Wetland | Provide seasonal waterbird habitat to support food sources and maintain species diversity and abundances.  Provide seasonal wetland habitat to support frog breeding. | Supported variety of waterbirds with 51 species recorded over three wetland sites. This included four migratory shorebirds: common greenshank (*Tringa nebularia*); red-necked stint (*Calidris ruficollis*); sharp-tailed sandpiper (*Calidris acuminata*) and wood sandpiper (*Tringa glareola*) as well as two species listed under South Australian threatened species legislation: freckled duck and white-bellied sea eagle.  Six species of frog recorded: Peron’s tree frog, plains froglet, barking marsh frog and spotted marsh frog. While there was evidence of breeding for all species, abundance was low due to low temperatures. | Cale (2018) |
| Lower Murray: Wingillie Station | 1459 | 28/09/17 - 20/04/18 | Wetland | Support suitable habitat condition for waterbirds. Support and maintain vegetation condition and habitat for the nationally endangered southern bell frog. | Watering provided a range of habitats that supported foraging and breeding of different functional groups of waterbirds as well as frogs. This included large-bodied waders, Australian shorebirds, dabbling ducks and fish-eating species. Species of conservation significance recorded included: southern bell frog, regent parrot, freckled duck and white-bellied sea eagle. Breeding recorded for several species of duck as well as eastern great egret (*Ardea modesta*) and yellow-billed spoonbill (*Platalea flavipes*). | CEWO acquittal report (unpublished) |
| Lower Murray: Lucerne Day | 82 | 28/09/17 - 28/09/17 | Wetland |
| Lower Murray: Renmark Wetlands Site 8 | 158 | 09/04/18 - 31/05/18 | Wetland | Increase diversity and abundance of waterbirds through aquatic habitat improvements.  Increase diversity and abundance of frogs through aquatic habitat improvements. | An increase in waterbird usage across 19.2 ha of inundated floodplain. There were hundreds of ducks including the South Australian threatened species freckled duck | CEWO acquittal report (unpublished) |
| Lower Murray: Renmark Wetlands Site 15 | 22 | 01/07/17 - 10/10/17 | Wetland | 9.9 ha of floodplain inundation and an increase in frog activity observed over the course of watering. |
| Lower Murray: Bookmark Creek | 448 | 11/08/17 - 30/06/18 | Wetland | Provide waterbird habitat. | A total of 22 species of waterbirds recorded using the site following watering representing several functional groups including large bodied waders, ducks and piscivores. | CEWO acquittal report (unpublished) |
| Lower Murray: Riversleigh Lagoon | 650 | Oct 2017 - Feb 2018 | Wetland | Provide seasonal waterbird habitat to support food sources and maintain species diversity and abundances. Provide seasonal wetland habitat to support frog breeding. | Large numbers of duck as the lagoon filled including 2000 grey teal (*Anas gracilis*) and breeding of black swans (*Cygnus atratus*). Numbers of Australian waders such as red-necked avocets (*Recurvirostra novaehollandiae*) and stilts also recorded. | CEWO acquittal report (unpublished) |
| Lower Murray: Pike River | 19 | 01/04/18 - 27/04/18 | Wetland | Several species of waterbird recorded including royal spoonbill, black-winged stilt, chestnut r=teal and red-necked avocet. Four species of frog including popplebonk (*Limnodynastes dumerilii*). |

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.

## Important wetland case studies

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

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

### Banrock Station

#### What was the expected outcome?

The expected outcomes were:

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

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

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

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

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

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

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

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

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

#### What species/communities potentially benefited?

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

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

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

### Barmah–Millewa Forest

#### What was the expected outcome?

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

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

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

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

Inundation mapping indicates around 11 780 ha of ANAE wetland types within the Ramsar sites were inundated (Figure 8 and Table 4). This is less than the maximum extent of inundation reported by Borrell (2018a) of 17 600 ha of inundation, which is likely due to inundation outside the Ramsar boundaries.

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

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

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

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

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

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

##### Vegetation

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

##### Fish

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

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

##### Waterbirds

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

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

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

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

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

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

#### What species/communities potentially benefited?

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

Table 7. Species and communities that potentially benefitted from Commonwealth environmental water at Barmah–Millewa Forest in 2017–18.

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

### Gunbower Forest[[3]](#footnote-3)

#### What was the expected outcome?

The expected outcomes were:

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

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

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

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

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

The fish community of Gunbower Forest has been monitored under the MDBA TLM program since 2006. Native fish abundance in 2017 was the highest since monitoring began in 2006. In terms of size classes, the population structure of Murray cod was more robust, with the expected age classes increasing to 47 %. Although three invasive fish species were recorded in the Creek, the relative abundance of natives was high, with around two-thirds of fish captured representing native species (CPS Enviro 2018).

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

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

#### What species/communities potentially benefited?

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

### Hattah-Kulkyne Lakes

#### What was the Expected Outcome?

The Expected Outcomes related to Ramsar values were:

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

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

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

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

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

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

There is a good record of inundation in the Hattah-Kulkyne Lakes. The lakes filled from natural floods in 2010–11 and were dry in 2011–12 and 2012–13. In 2013, environmental works were completed which included the construction of a permanent pump station, regulators and environmental levees to allow for more effective environmental watering at the site. The lakes were inundated extensively in 2013–14 and 2014–15 (Henderson *et al.* 2014) and in 2015–16 planned drying cycles were implemented at several of the lakes. The 2017–18 environmental watering action was the first artificial flooding of the floodplain following on from the natural flooding in 2016–17 (Wood *et al.* 2018).

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

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

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

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

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

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

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

#### What species / communities potentially benefited?

There is evidence to suggest that a wide range of species benefited from Commonwealth environmental water at Hattah-Kulkyne Lakes in 2017–18 (Table 9).

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

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

### Macquarie Marshes

#### What was the expected outcome?

The expected outcomes were:

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

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

Water was delivered across two watering actions:

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

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

A close up of a logo

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

Table 10. ANAE wetland and floodplain types inundated from Commonwealth environmental watering in 2017–18 at the Macquarie Marshes Ramsar site.

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

The Ramsar site comprises the northern and southern sections of the Macquarie Marshes Nature Reserve as well as two additional disjunct areas, ‘U-block’ and ‘Wilgara’. Within the Ramsar site, the inundation was predominantly of ANAE wetland type ‘permanent wetland’. It should be noted, however, that ANAE classifications are broad, and the ecological character description for the site indicates that the area described as ‘permanent wetland’ in Table 10 is more accurately described as intermittent marsh with emergent vegetation, such as common reed (*Phragmites australis*), cumbungi (*Typha* spp.) and water couch (*Paspalum distichum*) (Office of Environment and Heritage 2012).

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

The Macquarie Marshes was listed as a Ramsar site in 1986 for its extensive wetland vegetation communities; abundance of waterbirds; supporting migratory birds listed under international treaties; supporting waterbird breeding, particularly colonial nesting species; the native fish community and supporting threatened species – Australasian bittern, Australian painted snipe, superb parrot, Murray cod and basalt peppercress (*Lepidium hyssopifolium*) (Office of Environment and Heritage 2012).

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

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

The site supported a diversity of waterbirds with 50 species recorded in ground surveys including several threatened species (Australasian bittern, Australian painted snipe) as well as international migratory waders (marsh sandpipers and sharp-tailed sandpipers). Aerial surveys recorded over 16 000 waterbirds in the Macquarie Marshes, with 1000s of ducks and large bodied wading birds (MDBA unpublished). The inundation provided a variety of feeding and foraging habitats, which supported the diversity of birds. Although breeding activity was low in 2017–18, seven species were confirmed breeding at the site including black swan, red-kneed dotterel (*Erythrogonys cinctus*), Australasian grebe (*Tachybaptus novaehollandiae*), Australian white ibis, little pied cormorant, Australasian darter and royal spoonbill (Spencer & Ocock 2018).

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

#### What species/communities potentially benefited?

There is evidence to suggest that a number of species and communities potentially benefited from Commonwealth environmental water at the Macquarie Marshes in 2017–18 (Table 11).

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

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

# Basin-scale outcomes 2014–18

## Highlights

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

## Effect of Commonwealth environmental water on species diversity

### Number of species

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

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

* 71 species of native plants
* 16 species of native fish
* 48 species of bush bird
* 101 species of wetland dependent bird[[5]](#footnote-5)
* 20 species of frog
* 3 species of turtle.

### Waterbird abundance and diversity

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

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



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

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

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

\* Population estimates from Wetlands International (2012).

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

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

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

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

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

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

**Supporting international migratory species**

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

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

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

|  |  |
| --- | --- |
| **Maintaining drought refuges in dry times**  With the exception of 2016–17 in the southern basin, the first four years of the LTIM project have been characterised by dry climatic conditions. Commonwealth environmental water has contributed significantly to maintaining wet habitat for waterbirds and other biota across much of the Basin. This includes providing large artificial floods in Hattah-Kulkyne Lakes and Macquarie Marches during 2017–18 as well as keeping areas of the Gwydir wetlands inundated each year. Waterbirds benefit both directly by the immediate provision of foraging habitat and indirectly through maintaining important habitats for critical life stages over longer periods. | A close up of a bird  Description automatically generated  **White ibis chicks at Barmah (Keith Ward).** |

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

## Maintaining the ecological character of Ramsar sites

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

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

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

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

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

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

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

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

#### Large scale inundation at high value sites

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

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

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

A picture containing text, map

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**Map of inundation extent in 2016–17 and 2017–18 at the Macquarie Marshes.**

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

## Supporting threatened species

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

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

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

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

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

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

Table 15. Listed species that were recorded at sites that received Commonwealth environmental water in 2014–18.

| Group | Common name | Species name | Significance1 |
| --- | --- | --- | --- |
| Birds | Australian fairy tern | *Sternula nereis neries* | V (EPBC) |
| Bar-tailed godwit | *Limosa lapponica* | V (EPBC), JAMBA, CAMBA, ROKAMBA |
| Black-tailed godwit | *Limosa limosa* | JAMBA, CAMBA, ROKAMBA, V (NSW) |
| Common greenshank | *Tringa nebularia* | JAMBA, CAMBA, ROKAMBA |
| Common sandpiper | *Actitis hypoleucos* | JAMBA, CAMBA, ROKAMBA |
| Curlew sandpiper | *Calidris ferruginea* | CE (EPBC), JAMBA, CAMBA, ROKAMBA |
| Eastern curlew | *Numenius madagascariensis* | CE (EPBC), JAMBA, CAMBA, ROKAMBA |
| Latham’s snipe | *Gallinago hardwickii* | JAMBA, CAMBA, ROKAMBA |
| Marsh sandpiper | *Tringa stagnatilis* | JAMBA, CAMBA, ROKAMBA |
| Oriental pratincole | *Glareola maldivarum* | JAMBA, CAMBA, ROKAMBA |
| Pacific golden plover | *Pluvialis fulva* | JAMBA, CAMBA, ROKAMBA |
| Red knot | *Calidris canutus* | V (EPBC), JAMBA, CAMBA, ROKAMBA |
| Red-necked stint | *Calidris ruficollis* | JAMBA, CAMBA, ROKAMBA |
| Ruddy turnstone | *Arenaria interpres* | JAMBA, CAMBA, ROKAMBA |
| Ruff | *Philomachus pugnax* | JAMBA, CAMBA, ROKAMBA |
| Sanderling | *Calidris alba* | JAMBA, CAMBA, ROKAMBA |
| Sharp-tailed sandpiper | *Calidris acuminata* | JAMBA, CAMBA, ROKAMBA |
| Whimbrel | *Numenius phaeopus* | 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).

# Contribution to achievement of Basin Plan objectives

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

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

The outcomes framework provides a template for synthesising outcomes of environmental water and progress towards meeting Basin Plan objectives. There is evidence across the Basin that Commonwealth environmental water is contributing to Basin Plan objectives for ecosystem and species diversity (Table 16).

Table 16. Contribution of Commonwealth environmental water in 2014–18 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 2017–18 | Measured and predicted 1–4-year outcomes 2014–18 |
| --- | --- | --- | --- | --- | --- | --- |
| Biodiversity  (Basin Plan S. 8.05) | Ecosystem diversity | | None identified | None identified | Over 296 000 hectares of mapped wetland and floodplain inundated  71% of the different aquatic ecosystem types represented in areas influenced by Commonwealth environmental water | 75% of the different aquatic ecosystem types inundated with Commonwealth environmental water. |
| Species diversity | Vegetation | Vegetation diversity | Reproduction | A significant proportion of native species, including numerous aquatic forbs, grasses and sedges/rushes, only present in areas inundated by Commonwealth environmental water. | 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 | Greater vegetation cover in wetlands inundated by Commonwealth environmental water in the Murrumbidgee river system.  Significant increases in species richness in wetlands inundated by Commonwealth environmental water during draw down phase. | Enhanced diversity of vegetation communities at Basin scale in response to delivery of Commonwealth environmental water. |
| Waterbirds | Waterbird diversity |  | 70 species of waterbird recorded across all functional feeding groups | 101 waterbird species recorded at sites that have received Commonwealth environmental water. |
| Waterbird diversity and population condition (abundance and population structure) | Survival and condition | Supporting greater than 1% of the relevant populations of nine species of waterbird. | Greater than 1 % of the population of 21 species. |
| Chicks | Breeding recorded for several species in low to moderate numbers. | 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 four 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 2017–18 with expected outcomes for fish, vegetation, waterbirds, frogs or other vertebrates

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

| **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 (Mungindi to Menindee) | 00111-49 | 6295 | 01/07/17 - 15/08/17 | Fresh | S | - | - | - | - | - | - | P | S |
| Barwon-Darling: Barwon-Darling River and fringing wetlands (Mungindi to Menindee) | 00111-49 | 1717 | 26/10/17 - 31/10/17 | Fresh | S | - | - | - | - | - | - | P | S |
| Barwon-Darling: Barwon-Darling River and fringing wetlands (Mungindi to Menindee) | 00111-49 | 735 | 02/12/17 - 04/12/17 | Fresh | S | - | - | - | - | - | - | P | S |
| Barwon-Darling: Barwon-Darling River and fringing wetlands (Mungindi to Menindee) | 00111-49 | 696 | 28/02/18 - 02/03/18 | Fresh | S | - | - | - | - | - | - | P | S |
| Border Rivers: Severn River | 00111-41 | 35 | Late Nov 2017 | Fresh | P | - | - | - | - | - | - | - | S |
| Border Rivers: Severn River | 00111-41 | 267 | 28/12/17 - 06/01/18 | Fresh | P | - | - | - | - | - | - | - | S |
| Border Rivers: Dumaresq-Macintyre River and Fringing Wetlands | 00111-42 | 293 | 3/7/18 | Fresh | P | - | - | - | - | - | - | - | S |
| Border Rivers: Dumaresq-Macintyre River and Fringing Wetlands | 00111-42 | 349 | 14/10/17 - 15/10/17 | Fresh | P | - | - | - | - | - | - | - | S |
| Border Rivers: Lower Moonie River and Fringing Wetlands | 00111-44 | 1106 | 21/10/17 - 30/12/17 | Fresh | P | - | - | - | P | S | - | - | S |
| Border Rivers: Lower Moonie River and Fringing Wetlands | 00111-44 | 1217 | 03/02/18 - 26/03/18 | Fresh | P | - | - | - | P | S | - | - | S |
| Border Rivers: Dumaresq-Macintyre River and Fringing Wetlands | 10046-03 | 3252 | 26/09/17 - 26/10/17 | Baseflow | P | - | - | - | S | - | - | - | - |
| Border Rivers: Dumaresq-Macintyre River and Fringing Wetlands | 10046-04 | 684 | 21/08/17 - 08/10/17 | Fresh, Baseflow | P | - | - | - | - | - | S | - | S |
| Border Rivers: Border Rivers including floodplain | 10074-01 | 4286 | 13/04/18 - 21/04/18 | Fresh | P | - | - | - | - | - | - | S | - |
| Lower Broken Creek and fringing wetlands | 10041-03 | 1552 | 01/07/17 - 17/08/17 | Baseflow | P | - | - | - | - | - | - | - | - |
| Lower Broken Creek and fringing wetlands | 10041-03 | 1121 | 18/08/17 - 31/08/17 | Fresh | - | P | - | - | - | - | - | - | - |
| Lower Broken Creek and fringing wetlands | 10041-03 | 4674 | 01/09/17 - 02/10/17 | Baseflow | P | - | - | - | - | - | - | - | P |
| Lower Broken Creek and fringing wetlands | 10041-03 | 6873 | 03/10/17 - 15/11/17 | Baseflow, Fresh | P | P | - | - | - | - | - | - | P |
| Lower Broken Creek and fringing wetlands | 10041-03 | 3966 | 16/11/17 - 07/12/17 | Baseflow | P | - | - | - | - | - | - | - | P |
| Lower Broken Creek and fringing wetlands | 10041-03 | 1444 | 16/05/18 - 30/06/18 | Baseflow | P | - | - | - | - | - | - | - | - |
| Upper Broken Creek and Moodie Swamp | 10042-03 | 498 | 18/04/18 - 07/06/18 | Fresh, Wetland | P | P | P | - | P | - | - | - | P |
| Lower Murray: Coorong, Lower Lakes and Murray Mouth\* | 10065-04 | 326320 | 01/07/17 - 30/09/17 | Fresh | P | S | - | - | S | - | S | - | S |
| Lower Murray: Coorong, Lower Lakes and Murray Mouth\* | 10065-04 | 354807 | 01/10/17 - 31/01/18 | Fresh | P | S | - | - | S | - | S | - | S |
| Lower Murray: Coorong, Lower Lakes and Murray Mouth\* | 10065-04 | 203279 | 01/02/18 - 31/05/18 | Baseflow | P | S | P | - | S | - | S | - | S |
| Lower Murray: Coorong, Lower Lakes and Murray Mouth\* | 10065-04 | 9331 | 01/06/18 - 30/06/18 | Baseflow | P | S | - | - | S | - | S | - | S |
| Campaspe River Catchment | 10003-05 | 6218 | 13/11/17-28/11/17 | Fresh | P | P | - | - | P | - | - | - | - |
| Central Murray: Barmah-Millewa Forest\* | 10065-02 | 3344 | 01/07/17 - 23/03/18 | wetland | P | - | - | - | - | - | P | - | - |
| Central Murray: Gunbower Creek\* | 10030-03 | 20656 | 01/07/17 - 30/06/18 | Baseflow | P | - | - | - | - | P | - | - | P |
| Central Murray: Hattah Lakes\* | 10065-03 | 32145 | 03/07/17 - 31/10/17 | Wetland | P | P | P | - | - | P | - | - | - |
| Central Murray: River Murray | 10065-01 | 289606 | 01/07/17 - 31/12/17 | Fresh, Overbank | P | P | P | - | - | - | P | - | - |
| Central Murray: Barham Lake | 10065-08 | 102 | 23/01/18 - 23/03/18 | Wetland | P | S | S | S | - | - | - | - | - |
| Edward Wakool: Yallakool Wakool System | 10070-01 | 16452 | 01/09/17 - 01/05/18 | Fresh | S | S | - | S | S | S | S | S | S |
| Edward Wakool: Tuppal Creek | 10070-01 | 1641 | 21/08/17 - 10/11/17 | Baseflow | S | S | - | S | S | S | S | S | S |
| Edward Wakool: Colligen-Neimur | 10070-03 | 13832 | 01/09/17 - 01/05/18 | Fresh | S | S | - | S | S | S | S | S | S |
| Edward Wakool: Tuppal Creek | 10070-04 | 933 | 29/03/18 - 05/05/18 | Baseflow | S | S | - | S | S | S | S | S | S |
| Edward Wakool: Yallakool Wakool System | 10054-11 | 7915 | 01/07/17 - 30/08/17 | Baseflow | S | S | - | S | S | S | S | S | S |
| Edward Wakool: Colligen-Neimur | 10054-12 | 6370 | 01/07/17 - 30/08/17 | Baseflow | S | S | - | S | S | S | S | S | S |
| Goulburn: Lower Goulburn River | 10064 | 112232 | 01/07/17 - 24/07/17 | Fresh | P | P | - | - | P | - | - | - | - |
| Goulburn: Lower Goulburn River | 10064 | 74205 | 16/09/17 - 11/10/17 | Fresh | - | P | - | - | - | - | - | - | - |
| Goulburn: Lower Goulburn River | 10064 | 3487 | 08/10/17 - 19/11/17 | Baseflow | P | P | - | - | P | - | - | - | P |
| Goulburn: Lower Goulburn River | 10064 | 11543 | 16/11/17 - 30/11/17 | Fresh | P | - | - | - | - | - | - | - | - |
| Goulburn: Lower Goulburn River | 10064 | 852 | 27/11/17 - 05/12/17 | Baseflow | P | P | - | - | P | - | - | - | P |
| Goulburn: Lower Goulburn River | 10064 | 6112 | 02/12/17 - 22/12/17 | Bankfull | P | P | - | - | P | - | - | - | P |
| Goulburn: Lower Goulburn River | 10064 | 5560 | 19/12/17 - 09/01/18 | Baseflow | P | P | - | - | P | - | - | - | P |
| Goulburn: Lower Goulburn River | 10064 | 49989 | 22/06/18 - 30/06/18 | Fresh | P | P | - | - | P | - | - | - | - |
| Gwydir: Gwydir Wetlands\* | 10069-01 | 4000 | 19/12/17 - 17/01/18 | Wetland | P | P | P | - | P | P | P | P | - |
| Gwydir: Mehi River | 10069-04 | 7000 | 26/08/17 - 04/09/17 | Fresh | P | - | - | - | - | P | P | - | P |
| Gwydir: Mehi River | 10069-04 | 5000 | 30/10/17 - 20/11/17 | Baseflow | P | - | - | - | - | P | P | - | P |
| Gwydir: Gwydir River system | 10074-02 | 12290 | 20/04/18 - 23/05/18 | Fresh | P | - | - | - | - | P | - | - | - |
| Lachlan: Lachlan River | 10053 | 32572 | 27/09/17 - 19/11/17 | Baseflow | P | - | - | - | - | - | P | - | - |
| Lachlan: Lachlan River | 10053 | 951 | 27/09/17 - 16/10/17 | Baseflow | P | - | - | - | - | - | P | - | - |
| Lower Darling: Lower Darling River | 10072-01 | 2738 | 21/11/17 - 28/11/17 | Fresh | P | - | - | - | - | S | S | - | S |
| Loddon River Catchment | 10001-05 | 3054 | 01/10/17 - 30/10/17 | Fresh | P | - | - | - | - | - | - | - | - |
| Lower Murray: Wingillie Station | 10065-07 | 1459 | 28/09/17 - 20/04/18 | Wetland | - | P | P | P | - | - | - | - | - |
| Lower Murray: Lucerne Day | 10065-07 | 82 | 28/09/17 - 28/09/17 | Wetland | - | P | P | P | - | - | - | - | - |
| Lower Murray: Lock 7 | 10065-01 | 409 | 08/09/17 - 10/12/17 | Overbank | P | P | S | - | - | - | P | - | - |
| Lower Murray: Lock 7 | 10065-01 | 409 | 22/02/18 - 31/05/18 | Baseflow | P | P | - | - | - | - | S | - | - |
| Lower Murray: Lock 8 | 10065-01 | 409 | 10/09/17 - 06/12/17 | Overbank | P | P | S | - | - | - | P | - | - |
| Lower Murray: Lock 8 | 10065-01 | 409 | 22/02/18 - 31/05/18 | Baseflow | P | P | - | - | - | - | S | - | - |
| Lower Murray: Lock 9 | 10065-01 | 409 | 30/08/17 - 09/10/17 | Overbank | P | P | S | - | - | - | P | - | - |
| Lower Murray: Lock 9 | 10065-01 | 409 | 22/02/18 - 30/05/18 | Baseflow | P | P | - | - | - | - | S | - | - |
| Lower Murray: Lock 15 | 10065-01 | 409 | 05/09/17 - 26/11/17 | Overbank | P | P | S | - | - | - | P | - | - |
| Lower Murray: Lock 15 | 10065-01 | 409 | 23/03/18 - 31/05/18 | Baseflow | P | - | - | - | - | - | S | - | - |
| Lower Murray: Lock 2 | 10065-06 | 335 | Mid Jul - Early Aug 17 | Baseflow | P | - | - | - | - | - | S | - | - |
| Lower Murray: Lock 2 | 10065-06 | 335 | Aug – Oct 17 | Overbank | P | P | S | - | - | - | P | - | - |
| Lower Murray: Lock 5 | 10065-06 | 1266 | Mid Jul - Early Aug 17 | Baseflow | P | - | - | - | - | - | S | - | - |
| Lower Murray: Lock 5 | 10065-06 | 1266 | Aug - Mid Nov 17 | Overbank | P | P | S | - | - | - | P | S | - |
| Lower Murray: Banrock Station - Heron's Bend\* | 10045-02 | 24 | 11/12/17 - 27/12/17 | Wetland | - | P | P | - | P | - | - | - | - |
| Lower Murray: Banrock Station - Banrock Bend\* | 10045-02 | 24 | 11/12/17 - 27/12/17 | Wetland | - | P | P | - | P | - | - | - | - |
| Lower Murray: Banrock Station - Wigley Reach Depression\* | 10045-02 | 396 | 11/12/17 - 10/02/18 | Wetland | - | P | P | - | P | - | - | - | - |
| Lower Murray: Banrock Station - Eastern Lagoon\* | 10045-02 | 1429 | 11/12/17 - 23/05/18 | Wetland | - | P | P | - | P | - | - | - | - |
| Lower Murray: Banrock Station - Herons & Banrock's Bend flats\* | 10045-02 | 132 | 16/05/18 - 13/06/18 | Wetland | - | P | P | - | P | - | - | - | - |
| Lower Murray: Renmark Wetlands Site 5 | 10058-01 | 48 | 26/3/18 - 27/5/18 | Wetland | - | P | P | P | - | P | - | P | - |
| Lower Murray: Renmark Wetlands Site 8 | 10058-01 | 158 | 09/04/18 - 31/05/18 | Wetland | - | P | P | P | - | P | - | P | - |
| Lower Murray: Renmark Wetlands Site 9 | 10058-01 | 58 | 26/03/18 - 31/05/18 | Wetland | - | - | P | P | - | - | - | P | - |
| Lower Murray: Renmark Wetlands Site 14 | 10058-01 | 53 | 01/08/17 - 28/05/18 | Wetland | - | P | P | P | - | P | - | P | - |
| Lower Murray: Renmark Wetlands Site 15 | 10058-01 | 22 | 01/07/17 - 10/10/17 | Wetland | - | P | P | P | - | P | - | - | - |
| Lower Murray: Berri Evaporation Basin | 10065-06 | 1262 | 11/08/17 - 30/06/18 | Wetland | P | - | - | - | - | - | - | - | - |
| Lower Murray: Bookmark Creek | 10065-06 | 448 | 11/08/17 - 30/06/18 | Wetland | - | P | P | - | - | - | - | - | - |
| Lower Murray: Disher Creek | 10065-06 | 50 | 31/01/18 - 14/02/18 | Wetland | P | - | - | - | - | - | - | - | - |
| Lower Murray: Rilli Reach | 10065-09 | 9 | Sept 2017 - June 2018 | Wetland | - | P | P | P | - | - | - | - | - |
| Lower Murray: Calperum Station | 10065-09 | 3894 | Oct 2017 - Apr 2018 | Wetland | - | P | P | P | - | - | - | - | - |
| Lower Murray: Riversleigh Lagoon | 10065-09 | 650 | Oct 2017 - Feb 2018 | Wetland | - | P | P | P | - | - | - | - | - |
| Lower Murray: Woolenook Bend | 10065-09 | 33 | 30/10/17 - 13/04/18 | Wetland | - | - | P | - | - | - | - | - | - |
| Lower Murray: Gurra Gurra Lyrup Lagoon | 10065-09 | 297 | 12/12/17 - 15/02/18 | Wetland | - | - | P | - | - | - | - | - | - |
| Lower Murray: Lake Alexandrina Milang Snipe Sanctuary\* | 10065-09 | 4 | 02/03/18 - 21/03/18 | Wetland | - | - | P | - | - | - | - | - | - |
| Lower Murray: Clarke's Floodplain | 10065-09 | 13 | 22/03/18 - 01/06/18 | Wetland | - | P | P | P | - | - | - | - | - |
| Lower Murray: Pike River# | 10065-09 | 19 | 01/04/18 - 27/04/18 | Wetland | - | P | P | P | - | - | - | - | - |
| Lower Murray: Ramco River Terrace | 10065-09 | 5 | 01/04/18 - 01/06/18 | Wetland | - | P | P | P | - | - | - | - | - |
| Lower Murray: Greenways Landing | 10065-09 | 20 | 01/04/18 - 30/04/18 | Wetland | - | P | P | P | - | - | - | - | - |
| Murrumbidgee: Nimmie-Caira | 10034-13 | 1738 | 15/12/17 - 18/12/17 | Baseflow | P | S | P | P | P | - | - | S | S |
| Murrumbidgee: Mid-Murrumbidgee wetlands | 10062-01 | 159283 | 24/07/17 - 01/09/17 | Fresh, Wetland | P | P | P | - | P | P | P | S | - |
| Murrumbidgee: Yarradda Lagon | 10062-02 | 326 | 04/07/17 - 24/07/17 | Wetland | S | S | S | - | S | - | - | - | - |
| Murrumbidgee: Gooragool Lagoon | 10062-03 | 1426 | 18/07/17 - 11/08/17 | Wetland | S | S | S | - | S | - | - | - | - |
| Murrumbidgee: North Redbank | 10068-02 | 5528 | 09/10/17 - 19/10/17 | Wetland | P | S | P | P | P | - | - | S | S |
| Murrumbidgee: Toogimbie IPA Wetlands | 10068-03 | 1000 | 07/11/17 - 01/06/18 | Wetland | - | - | - | P | - | - | - | P | - |
| Murrumbidgee: Coonancoocabil Lagoon | 10068-04 | 900 | 11/12/17 - 02/01/18 | Wetland | P | S | P | P | P | - | - | S | S |
| Murrumbidgee: Oak Creek | 10068-05 | 620 | 28/12/17 - 02/01/18 | Wetland | P | S | P | P | P | - | - | S | S |
| Murrumbidgee: Yarradda Lagoon | 10068-06 | 178 | 20/11/17 - 25/11/17 | Wetland | - | P | - | - | - | - | - | S | S |
| Murrumbidgee: Waldaira Lagoon | 10068-07 | 1500 | 09/02/18 - 07/05/18 | Wetland | - | - | - | - | P | - | - | P | - |
| Murrumbidgee: Sandy Creek | 10068-08 | 400 | 17/02/18 - 23/04/18 | Wetland | P | S | P | P | P | - | - | S | S |
| Murrumbidgee: Tuckerbill Swamp | 10068-09 | 600 | 09/04/18 - 16/04/18 | Wetland | P | P | P | P | P | - | - | S | - |
| Murrumbidgee: Nimmie-Caira | 10068-10 | 5000 | 15/04/18 - 28/05/18 | Wetland | P | S | P | P | P | - | - | S | S |
| Murrumbidgee: Gooragool Lagoon | 10068-11 | 750 | 01/06/18 - 30/06/18 | Wetland | P | S | P | P | P | - | - | S | S |
| Macquarie River: Mid-Macquarie River and Macquarie Marshes\* | 10067-01 | 48421 | 15/08/17 - 12/11/17 | Fresh, Wetland | P | P | P | - | P | S | S | - | - |
| Namoi: Lower Namoi River | 10066-01 | 4100 | 12/03/18 - 15/05/18 | Baseflow | P | S | - | - | - | S | S | - | S |
| Namoi: Peel River | 10063-02 | 1257 | 05/06/18 - 18/06/18 | Fresh | P | - | - | - | - | - | P | - | - |
| Ovens River System | 10004-04 | 123 | 26/03/18 - 29/03/18 | Baseflow | P | - | - | - | - | P | - | - | - |
| Warrego: Upper Warrego River and fringing wetlands | 00111-48 | 3347 | 01/07/17 - 30/06/18 | Fresh | S | - | - | - | - | - | - | S | - |
| Warrego: Lower Warrego River and fringing wetlands | 152-10 | 0 | 01/04/2018 | Fresh | P | - | - | - | - | S | - | - | - |
| Wimmera River | 10007-01 | 2734 | 12/02/18 - 30/06/18 | Baseflow | P | P | P | - | P | P | - | - | P |
| Mt William Creek | 10007-01 | 374 | 09/04/18 - 18/04/18 | Fresh | P | P | P | - | P | - | - | - | P |

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

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

| **Australian National Aquatic Ecosystem (ANAE) wetland type** | **Total**  **area (ha)** | **% receiving Cew** | | | |
| --- | --- | --- | --- | --- | --- |
| Y1  14-15 | Y2  15–16 | Y3  16–17 | Y4  17-18 |
| Pt1.1.2: Temporary river red gum swamp | 74 721 | 13.3 | 56.1 | 10.1 | 46.7 |
| Pp2.1.2: Permanent tall emergent marsh | 8005 | 43.1 | 51.9 | 0.0 | 43.1 |
| Pp4.2: Permanent wetland | 77 406 | 26.1 | 28.1 | 26.0 | 29.7 |
| Psp4: Permanent saline wetland | 2709 | 8.5 | 37.9 | 6.3 | 23.2 |
| Pt4.1: Floodplain or riparian wetland | 11 489 | 7.6 | 19.2 | 8.8 | 21.7 |
| Pt1: Temporary swamp | 3767 | 7.4 | 18.5 | 3.5 | 15.3 |
| Lp1.1: Permanent lake | 127 660 | 1.1 | 3.9 | 5.4 | 12.0 |
| Pt2.2.2: Temporary sedge/grass/forb marsh | 142 517 | 11.5 | 14.3 | 11.9 | 11.1 |
| Pp2.3.2: Permanent grass marsh | 1507 | 1.5 | 1.7 | 6.4 | 5.6 |
| Pt2.1.2: Temporary tall emergent marsh | 76 339 | 4.1 | 5.7 | 4.1 | 5.4 |
| Pu1: Unspecified wetland | 1763 | 0.0 | 0.0 | 0.0 | 5.4 |
| Pp2.4.2: Permanent forb marsh | 740 | 1.4 | 0.7 | 4.1 | 3.0 |
| Pt2.3.2: Freshwater meadow | 125 192 | 15.1 | 16.8 | 16.4 | 2.9 |
| Pt4.2: Temporary wetland | 22 916 | <0.1 | 2.5 | 0.0 | 2.6 |
| Pt3.1.2: Clay pan | 138 725 | 2.3 | 2.7 | 1.2 | 1.2 |
| Lst1.1: Temporary saline lake | 27 897 | 0.0 | 0.5 | 0.0 | 1.1 |
| Pt1.8.2: Temporary shrub swamp | 234 419 | 0.7 | 3.2 | 0.9 | 0.9 |
| Pt1.7.2: Temporary lignum swamp | 49 965 | 1.1 | 7.0 | 24.9 | 0.9 |
| Lt1.1: Temporary lake | 459 375 | 0.6 | 1.7 | 0.5 | 0.8 |
| Pp2.2.2: Permanent sedge/grass/forb marsh | 3590 | 0.4 | 0.5 | 0.4 | 0.6 |
| Pt1.2.2: Temporary black box swamp | 60 272 | 1.8 | 10.4 | 0.4 | 0.4 |
| Pt1.6.2: Temporary woodland swamp | 216 625 | <0.1 | 0.3 | <0.1 | 0.2 |
| Pst2.2: Temporary salt marsh | 40 706 | <0.1 | 1.6 | <0.1 | <0.1 |
| Pst1.1: Temporary saline swamp | 7942 | 1.2 | 0.0 | 0.0 | 0.0 |
| Lsp1.1: Permanent saline lake | 9229 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lt1.2: Temporary lake with aquatic bed | 9052 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pt1.3.2: Temporary coolabah swamp | 8271 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pst4: Temporary saline wetland | 6631 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pp3: Peat bog or fen marsh | 4425 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pst3.2: Salt pan or salt flat | 3370 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lst1.2: Temporary saline lake with aquatic bed | 2238 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lp1.2: Permanent lake with aquatic bed | 2067 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pt1.5.2: Temporary paperbark swamp | 412 | 0.0 | 0.0 | 0.0 | 0.0 |
| Psp2.1: Permanent salt marsh | 249 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lsp1.2: Perm. saline lake with aquatic bed | 181 | 0.0 | 0.0 | 0.0 | 0.0 |
| Psp1.1: Saline paperbark swamp | 163 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pps5: Permanent spring | 130 | 0.0 | 0.0 | 0.0 | 0.0 |
| F1.11: River cooba woodland riparian zone or floodplain | 11 541 | 9.8 | 2.0 | 6.7 | 7.3 |
| F1.2: River red gum forest riparian zone or floodplain | 639 022 | 3.8 | 4.1 | 1.0 | 4.0 |
| F1.4: River red gum woodland riparian zone or floodplain | 325 221 | 1.1 | 0.4 | 0.4 | 1.5 |
| F2.2: Lignum shrubland riparian zone or floodplain | 143 886 | 3.8 | 1.5 | 0.8 | 1.0 |
| F1.8: Black box woodland riparian zone or floodplain | 779 639 | 0.3 | 0.7 | 0.1 | 0.2 |
| F1.6: Black box forest riparian zone or floodplain | 131 442 | 0.4 | 1.0 | <0.1 | 0.2 |
| F2.4: Shrubland riparian zone or floodplain | 408 614 | 0.3 | 1.5 | 0.6 | 0.1 |
| F1.10: Coolabah woodland and forest riparian zone or floodplain | 1 215 726 | 0.3 | <0.1 | <0.1 | 0.1 |
| F1.12: Woodland riparian zone or floodplain | 318 686 | <0.1 | <0.1 | <0.1 | <0.1 |
| F4: Unspecified riparian zone or floodplain | 201 086 | <0.1 | <0.1 | <0.1 | <0.1 |
| F3.2: Sedge/forb/grassland riparian zone or floodplain | 833 102 | 0.0 | 0.0 | <0.1 | 0.0 |
| F1.13: Paperbark riparian zone or floodplain | 17 | 0.0 | 0.0 | 0.0 | 0.0 |

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

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

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

|  |  |  |
| --- | --- | --- |
| Common name | Species name | Listing |
| 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* | Vulnerable (Vic) |
| 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 2014–18.

| 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* |  |
| 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 |
| 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 2014–18 Across river systems for which data was available. Number represents the number of years that the species was recorded (Noting that species data outside of Selected Area monitoring is not necessarily available every year).

| Species | Condamine Balonne | Warrego Darling | Macquarie | Gwydir | Murrum-bidgee | Mid-Murray | Lower Murray | Coorong Lower Lakes |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Australasian bittern2 |  |  | 1 | 3 | 2 | 3 |  |  |
| Australasian darter | 1 | 3 | 4 | 4 | 3 | 3 | 2 | 4 |
| Australasian grebe | 1 | 2 | 4 | 2 | 4 | 3 | 3 | 2 |
| Australasian shoveler4 |  | 4 | 3 | 2 | 2 | 3 | 3 | 3 |
| Australian fairy tern3 |  |  |  |  |  |  |  | 2 |
| Australian gull-billed tern | 1 |  | 1 |  |  | 1 |  |  |
| Australian little bittern4 |  |  | 2 |  |  | 3 |  |  |
| Australian painted snipe3 |  |  | 1 | 2 |  | 1 |  |  |
| Australian pelican | 1 | 4 | 4 | 4 | 4 | 3 | 4 | 4 |
| Australian pied oystercatcher |  |  |  |  |  |  |  | 4 |
| Australian pratincole |  |  | 2 |  | 1 |  |  |  |
| Australian reed warbler | 1 | 1 | 4 | 3 | 3 | 2 | 1 | 1 |
| Australian shelduck |  | 2 |  | 2 | 4 | 3 | 3 | 4 |
| Australian spotted crake |  |  | 1 |  | 1 |  | 1 | 1 |
| Australian white ibis | 1 | 3 | 4 | 4 | 4 | 3 | 3 | 4 |
| Australian wood duck | 1 | 4 | 4 | 4 | 4 | 3 | 4 | 3 |
| Ballion's crake4 |  |  | 1 | 1 | 1 |  |  |  |
| Banded lapwing | 1 |  | 1 | 2 |  | 2 | 1 | 1 |
| Banded stilt4 |  |  |  |  |  |  |  | 4 |
| Bar-tailed godwit2 |  |  |  |  |  |  |  | 2 |
| Black swan | 1 | 4 | 4 | 2 | 3 | 3 | 4 | 4 |
| Black-faced cormorant |  |  |  |  |  |  |  | 2 |
| Black-fronted dotterel |  | 4 | 4 | 3 | 1 | 3 | 3 |  |
| Black-necked stork4 |  |  | 3 | 1 |  |  |  |  |
| Black-tailed godwit5 |  |  | 1 |  |  |  |  | 1 |
| Black-tailed native-hen | 1 | 3 | 2 | 2 | 3 | 2 | 3 | 3 |
| Black-winged stilt | 1 | 2 | 4 | 4 | 2 | 2 | 3 | 3 |
| Blue-billed duck4 |  |  |  | 1 |  | 1 |  | 3 |
| Brolga4 |  | 2 | 4 | 2 |  |  | 1 |  |
| Buff-banded rail |  |  | 2 | 1 |  |  |  |  |
| Cape barren goose |  |  |  |  |  |  |  | 4 |
| Caspian tern | 1 |  | 1 |  |  | 3 | 4 | 4 |
| Cattle egret | 1 |  | 4 | 2 | 1 |  |  | 1 |
| Chestnut teal |  |  | 1 | 2 |  | 2 | 2 | 4 |
| Comb-crested Jacana |  |  | 1 |  |  |  |  |  |
| Common greenshank5 |  |  | 2 |  |  |  | 2 | 2 |
| Common sandpiper5 |  | 1 | 1 |  |  |  |  | 2 |
| Common tern |  |  |  |  |  |  |  | 2 |
| Crested tern |  |  |  |  |  |  |  | 2 |
| Curlew sandpiper1 |  |  |  |  |  |  |  | 2 |
| Dusky moorhen |  | 1 | 3 | 3 | 3 | 3 | 2 | 1 |
| Eastern curlew1 |  |  |  |  |  |  |  | 2 |
| Eastern great egret4 | 1 | 3 | 4 | 4 | 4 | 3 | 3 | 4 |
| Eurasian coot | 1 | 3 | 4 | 3 | 4 | 3 | 3 | 4 |
| Freckled duck4 | 1 | 2 | 1 | 1 |  | 1 | 3 | 2 |
| Glossy ibis | 1 | 1 | 4 | 4 | 1 | 1 | 2 | 3 |
| Golden-headed cisticola |  |  | 4 | 3 | 2 |  |  |  |
| Great cormorant | 1 | 2 | 4 | 4 | 4 | 3 | 2 | 4 |
| Great crested grebe |  | 1 |  | 1 | 1 | 2 |  | 4 |
| Grey plover5 |  |  |  |  |  |  |  | 1 |
| Grey teal | 1 | 4 | 4 | 4 | 4 | 3 | 4 | 4 |
| Gull-billed tern |  |  |  |  |  |  |  | 4 |
| Hardhead4 | 1 | 3 | 3 | 2 | 3 | 3 | 3 | 4 |
| Hoary-headed Grebe |  | 2 | 2 | 2 | 3 | 3 | 3 | 4 |
| Hooded plover3 |  |  |  |  |  |  |  | 3 |
| Intermediate egret4 | 1 | 1 | 4 | 4 | 3 | 2 | 2 |  |
| Latham's snipe5 |  |  | 4 | 3 | 1 |  |  |  |
| Little black cormorant | 1 | 2 | 4 | 4 | 4 | 3 | 1 | 4 |
| Little egret4 |  | 1 | 3 | 2 | 2 | 3 |  | 3 |
| Little grassbird | 1 | 1 | 4 | 3 | 3 | 1 | 2 | 1 |
| Little pied cormorant | 1 | 1 | 4 | 4 | 4 | 3 | 2 | 4 |
| Little tern4 |  |  |  |  |  |  |  | 2 |
| Magpie goose4 |  |  | 4 | 3 |  |  |  | 1 |
| Marsh sandpiper5 |  |  | 3 | 1 |  | 1 |  | 2 |
| Masked lapwing | 1 | 4 | 4 | 3 | 3 | 3 | 4 | 4 |
| Musk duck4 |  |  |  | 1 | 1 | 3 | 3 | 4 |
| Nankeen night-heron |  | 1 | 3 | 2 | 3 | 3 |  | 1 |
| Oriental plover5 |  |  |  |  |  |  |  | 2 |
| Pacific black duck | 1 | 4 | 4 | 4 | 4 | 3 | 4 | 4 |
| Pacific golden plover5 |  |  |  |  |  |  |  | 2 |
| Pacific gull4 |  |  |  |  |  |  |  | 4 |
| Pied cormorant |  | 3 | 4 |  | 3 | 3 | 1 | 4 |
| Pink-eared duck | 1 | 4 | 4 | 2 | 4 | 2 | 4 | 4 |
| Plumed whistling-duck | 1 | 2 | 4 | 2 | 1 |  |  |  |
| Purple swamphen | 1 | 1 | 4 | 3 | 3 | 1 | 3 | 4 |
| Red knot2 |  |  |  |  |  |  |  | 1 |
| Red-backed kingfisher |  | 1 |  |  |  |  |  |  |
| Red-capped plover |  | 1 |  |  |  | 1 | 2 | 3 |
| Red-kneed dotterel |  | 3 | 4 | 3 | 1 | 2 | 3 | 3 |
| Red-necked avocet | 1 | 3 | 3 | 2 |  | 2 | 2 | 4 |
| Red-necked stint |  |  |  |  |  | 1 | 2 | 3 |
| Royal spoonbill | 1 | 1 | 3 | 4 | 3 | 1 | 1 | 4 |
| Ruddy turnstone5 |  |  |  |  |  |  |  | 1 |
| Ruff5 |  |  |  |  |  |  |  | 1 |
| Sacred kingfisher | 1 | 3 | 4 | 3 | 4 | 2 | 1 |  |
| Sanderling5 |  |  |  |  |  |  |  | 3 |
| Sharp-tailed sandpiper5 |  |  | 3 | 3 |  | 1 | 3 | 3 |
| Silver gull | 1 |  |  | 1 |  | 2 | 2 | 4 |
| Sooty oystercatcher |  |  |  |  |  |  |  | 4 |
| Spotless crake |  |  | 1 | 1 |  |  | 1 |  |
| Straw-necked Ibis | 1 | 3 | 4 | 4 | 3 | 3 | 3 | 4 |
| Swamp harrier |  |  | 4 | 3 | 2 | 1 | 3 | 1 |
| Tawny grassbird |  |  | 1 | 1 |  |  |  |  |
| Wandering whistling-duck |  |  | 2 |  |  |  |  |  |
| Whimbrel5 |  |  |  |  |  |  |  | 1 |
| Whiskered tern | 1 | 2 | 3 | 4 | 2 |  |  | 4 |
| White-bellied sea eagle4 | 1 | 2 | 3 | 3 | 4 | 3 | 2 | 3 |
| White-faced heron | 1 | 4 | 4 | 4 | 4 | 3 | 2 | 4 |
| White-necked heron | 1 | 4 | 4 | 4 | 3 | 3 | 3 | 2 |
| Wood sandpiper5 |  | 1 |  |  |  |  | 2 |  |
| Yellow-billed spoonbill | 1 | 4 | 4 | 4 | 3 | 3 | 3 | 4 |

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

2 Listed as endangered nationally under the EPBC Act.

3 Listed as vulnerable nationally under the EPBC Act.

4 Listed as threatened under state legislation.

5 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).

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

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

1. JAMBA (Japan–Australia Migratory Bird Agreement); CAMBA (China–Australia Migratory Bird Agreement); ROKAMBA (Republic of Korea– Australia Migratory Bird Agreement). [↑](#footnote-ref-1)
2. Wetlands International 5th Waterbird Population Estimates (2012). [↑](#footnote-ref-2)
3. Note that Commonwealth environmental water was delivered to Gunbower Creek, a portion of which lies within the Gunbower Forest Ramsar Site. [↑](#footnote-ref-3)
4. Murray cod are listed as Vulnerable under the EPBC Act, Murray-Darling rainbowfish and un-specked hardyhead are listed under the Victorian Flora and Fauna Guarantee Act. [↑](#footnote-ref-4)
5. Note that this is the first report that has included data collected from the Coorong and Lower Lakes, which has added additional (typically coastal) species to this list. [↑](#footnote-ref-5)