Australian Government

MURRAY–DARLING BASIN AUTHORITY

Waterbirds of the Murray-Darling Basin

2017 Basin Plan Evaluation

December 2017

Environment | Report

Basin Plan Evaluation

Published by the Murray–Darling Basin Authority

MDBA publication no: 40/17
ISBN (online): 978-1-925599-46-6
ISBN (print): 978-1-925599-47-3

GPO Box 1801, Canberra ACT 2601
02 6279 0100
engagement@mdba.gov.au
mdba.gov.au

Accessibility

The Murray–Darling Basin Authority makes its documents and information available in accessible formats. On some occasions the highly technical nature of the document means that we cannot make some sections fully accessible. If you encounter accessibility problems or the document is in a format that you cannot access, please contact us.

Acknowledgement of the Traditional Owners of the Murray–Darling Basin

The Murray–Darling Basin Authority acknowledges and pays respect to the Traditional Owners, and their Nations, of the Murray–Darling Basin, who have a deep cultural, social, environmental, spiritual and economic connection to their lands and waters. The MDBA understands the need for recognition of Traditional Owner knowledge and cultural values in natural resource management associated with the Basin.

The approach of Traditional Owners to caring for the natural landscape, including water, can be expressed in the words of the Northern Basin Aboriginal Nations Board:

> …As the First Nations peoples (Traditional Owners) we are the knowledge holders, connected to Country and with the cultural authority to share our knowledge. We offer perspectives to balance and challenge other voices and viewpoints. We aspire to owning and managing water to protect our totemic obligations, to carry out our way of life, and to teach our younger generations to maintain our connections and heritage through our law and customs. When Country is happy, our spirits are happy.

The use of terms 'Aboriginal' and 'Indigenous' reflects usage in different communities within the Murray–Darling Basin.

Contents

List of figures

List of tables

Executive Summary

The 2017 Evaluation represents the first evaluation of the Basin Plan since implementation in 2012. This evaluation forms part of the monitoring and reporting processes required to enable adaptive management. The Evaluation will examine progress towards full implementation of the Plan as well as early social, economic and environmental outcomes. Evaluation findings will identify how effective the Basin Plan has been, future risks to achieving long-term outcomes and opportunities for improvement.

This report focuses on determining the current condition and impacts of the Basin Plan on waterbirds. We examine multiple lines of evidence to identify early signs of progress towards delivering on long term expected environmental outcomes.

Overall there are positive early signs that waterbird populations are posivitely responding to the Basin Plan. Species richness has remained steady and breeding abundances have increased since the end of the millennium drought. Waterbird numbers may be in the process of stabilising following a long-term decline, however 2016 surveys recorded the second lowest numbers on record, indicating that further monitoring is required to confirm this trend. Migratory shorebird numbers have demonstrated a slight decline over time, likely driven by habitat degradation both in Australia and overseas.

There is tangible evidence that environmental water has played a critical role in supporting waterbird populations, especially at catchment scales. Environmental water has been successfully applied to ensure thousands of waterbird chicks recruit to juvenile populations. Flows have maintained foraging habitat during dry conditions and have primed wetlands for a productive response to floodplain inundation. Environmental water is being used effectively and efficiently in response to prevailing conditions. However it will only achieve its full effect through the implementation of other important Basin Plan mechanisms.

Despite these positive signs it is difficult to predict whether waterbird populations will increase in numbers from 2024, a key expected outcome under the Basin-wide environmental watering strategy. Waterbird abundances continue to fluctuate year-to-year and it will take time for populations to build following successsul breeding events. Just five years into the implementation of the Basin Plan there is not yet sufficient data available to render year-to-year noise obsolete. This is not unexpected; at large spatial scales long term data sets are required to confirm substantive shifts in the pattern or magnitude of bird abundances. In addition waterbird numbers are closely tied to water availability. Should climate conditions deteriorate there remains a risk that populations will rapidly decline. While we know that environmental water is essential in supporting waterbirds during dryer periods, it remains difficult to determine whether environmental flows planned for delivery under the Basin Plan will alone achieve long-term outcomes.

Since implementation of the Basin Plan our knowledge base has grown significantly. However, further monitoring and complementary research is required to understand the recruitment and movement of waterbirds as well as the relative influence of non-flow related threats. The development of a strong community of practice for waterbirds would ensure research is targeted and shared to inform management.

At this early stage there are encouraging signs of that environmental water is contributing to the health of waterbird populations. The long-term expected outcomes of the Basin Plan for healthy, resilient waterbird populations appear ambitious but remain achievable, particularly if complementary actions, such as removal of flow constraints and protection of environmental flows, are implemented. Given typically high variability in waterbird numbers, continued monitoring, research and evaluation is essential to consolidate knowledge and build our ability to adaptively manage environmental water and waterbird populations.

Introduction

The 2017 evaluation of the Basin Plan

The 2017 Basin Plan evaluation is the first evaluation of the Plan by the Murray-Darling Basin Authority (MDBA). It examines the social, economic and environmental outcomes associated with the first five years of Basin Plan implementation (2012-2017), and assesses whether the Plan is on track to deliver a healthy working basin. The 2017 evaluation (the evaluation) also identifies opportunities for governments to improve Basin Plan implementation in the coming years.

The environment is one of 11 themes the evaluation examines. This theme covers the implementation of the Environmental Management Framework, and assesses outcomes for river flows and connectivity, environmental assets, native vegetation, waterbirds and native fish.

This report focuses on waterbirds in the Murray-Darling Basin.

Waterbirds of the Murray-Darling Basin

Waterbirds are dependent on healthy wetland ecosystems for breeding, foraging and roosting. They flock to sites with readily-available resources that offer protection from predators and that provide good habitat. Birds move at regional, national and international scales, sometimes seasonally and other times in response to rainfall events hundreds of kilometres away. As a result, sites with abundant and diverse waterbird assemblages are generally highly productive, ecologically-important systems; making waterbird populations a good indicator of overall ecosystem health at a range of scales.

The Murray-Darling Basin supports more than 120 species of waterbirds, providing habitat for 25 internationally-listed and 16 nationally-listed waterbirds (Appendix 4 & 5). The Basin contains almost half of all Australian wetlands in which colonial-nesting waterbirds breed and 16 of 65 Australian-listed Ramsar sites.

Waterbirds play an important role in freshwater ecosystems. By feeding on fish, frogs, invertebrates and plants, waterbirds regulate vegetation growth, fauna abundance and recycle nutrients back into the environment. Waterbird chicks and eggs provide an important food source for reptiles and predatory birds. Birds can also benefit rural landscapes by feeding on agricultural pests, including locust larvae and ticks.

Culturally, waterbirds are a totemic species for Aboriginal nations. Some species' feathers are used in traditional ceremonies and many have been a historically important food source. For local communities, waterbirds provide aesthetic and recreational benefits, supporting local eco-tourism ventures and environmental education.

The Basin Plan

River regulation has changed the size, frequency and timing of natural flows in the Murray-Darling Basin. This has contributed to a decline in the health of the Basin's water-dependent ecosystems – its rivers, floodplains and wetlands. Flow regulation began in the Murray-Darling Basin in the late 19th century, with intensive development of regulators occurring along the Murray River between 1920 and 1940 (Maheshwari et al 1995). As more water has been diverted for people, agriculture and other economic activities, flow through the system to the sea has reduced by 75% on average (BWS 2014).

The Sustainable Rivers Audits 1 (2004-2007) and 2 (2007-2010) found key ecological components of the Murray-Darling Basin (fish, macroinvertebrates, vegetation, physical form and hydrology) to be in poor condition across most river valleys (Davies et al. 2008, Davies et al. 2010).

Since the 1980s waterbird numbers have reduced by more than 70%, based on aerial waterbird surveys. The diversity of species recorded breeding has declined significantly, by 72%, whilst the number of nests and broods have also steadily diminished over time (Kingsford et al. 2013). Surveys in the Coorong and Lower Lakes, the most important site for shorebirds in the Basin, have demonstrated similar trends. Total shorebird populations have diminished with once common migratory species including sharp-tailed sandpipers and red-necked stint declining significantly between 1984 and 2007 (Gosbell and Grear 2003).

The Basin Plan was legislated in 2012 with the aim of returning the basin to a healthy working system. The focus of the plan is to improve the Basin's environment, while balancing social and economic needs, in a sustainable way. The plan sets an environmentally sustainable level of water take for consumptive use (sustainable diversion limit) and secures a share of available water for the environment. This 'environmental water' allows managers to restore some of the critical elements of the flow regime so that plant and animal species can complete their lifecycles and help build population resilience in healthy habitats.

The Basin Plan sets out three overall environmental objectives for water-dependent ecosystems. These are to:

a) protect and restore water-dependent ecosystems of the Murray-Darling Basin
b) protect and restore the ecosystem functions of water-dependent ecosystems
c) ensure that water-dependent ecosystems are resilient to climate change and other risks and threats.

These are long-term objectives; and implementation of the plan and environmental recovery will take time. Therefore the plan aims to achieve 'no net loss or degradation in the recruitment and populations of native water-dependent species including vegetation, birds, fish and macroinvertebrates' (Schedule 7, BP) up to 2019, and looks for improvement beyond 2019.

The Basin-wide Environmental Watering Strategy

The Basin-wide Environmental Watering Strategy (BWS), released in 2014, expands on the Basin Plan. It guides the management of water for the environment at a basin scale over the longer term with the aim of halting the decline and then improving the condition of key water-dependent ecosystems.

The BWS describes how waterbirds, fish, vegetation and flows are expected to respond to environmental water delivery over the next decade, given current operating rules and procedures. It lists quantified environmental expected outcomes (expected outcomes) for flows, native fish, waterbirds and native vegetation beyond 2019, and further expected outcomes to be achieved beyond 2024. This acknowledges that populations will take time to respond to mechanisms of the Basin Plan. The expected outcomes set out in the BWS describe how the plan should work to: maintain and improve the ways rivers flow and connect on to floodplains; improve species diversity, extend population distributions, and improve successful completion of critical stages of lifecycles.

The expected outcomes for waterbirds identified in the BWS were developed using a modelled relationship between historic Basin waterbird and flow regime data (Appendix 1). This modelled relationship allowed the Murray-Darling Basin Authority (MDBA) to project the most likely ecological response of waterbirds to a 2,400-3,200 GL water recovery volume under the Basin Plan. The baseline scenario represented the consumptive use, rules and water sharing arrangements as at June 2009 (Murray–Darling Basin Authority 2014).

Table 1 Waterbird quantified expected outcomes at a Basin-scale under a 2,400-3,200 GL recovery scenario (MDBA 2014)

Objective	Expected Outcome	From
Maintain current species diversity	The number and type of waterbird species present in the Basin will not fall below current observations.	**2024**
Increase abundance	A significant improvement in waterbird populations in the order of 20 to 25% over the baseline scenario, with increases in all waterbird functional groups.	**2024**
Improve breeding	Breeding events (the opportunities to breed rather than the magnitude of breeding per se) of colonial nesting waterbirds to increase by up to 50% compared to the baseline scenario.	**2024**
Improve breeding	Breeding abundance (nests and broods) for all other functional groups to increase by 30-40% compared to the baseline scenario, especially in locations where the Basin Plan improves overbank flows.	**2024**

Objective	Expected Outcome	From
Maintain migratory species populations	At a minimum, to maintain populations of the following four key species: curlew sandpiper, greenshank, red-necked stint and sharp-tailed sandpiper, at levels recorded between 2000 and 2014.	**By 2019**

The BWS also describes strategies to manage and use environmental water to maximise outcomes; how partners will work together to plan and manage environmental water; and the approach to determining the Basin annual environmental watering priorities so as to achieve the long-term outcomes.

2017 evaluation measures of success

The decline in the condition of the Basin's water-dependent ecosystems has occurred over many decades. Redressing this decline is a long-term process and improvements in the Basin's environment will take some time to secure and measure. Some responses, such as improving water connections across floodplains and along rivers, will occur sooner in response to delivering water for the environment, while other responses, like restoring populations of plant and animal species, will take longer to respond to an improved flow regime and water quality. Critical life-cycle functions must be restored before there are comprehensive signs of improved Basin-scale health and resilience (www.mdba.gov.au/sites/default/files/pubs/Final-BWS-Nov14.pdf).

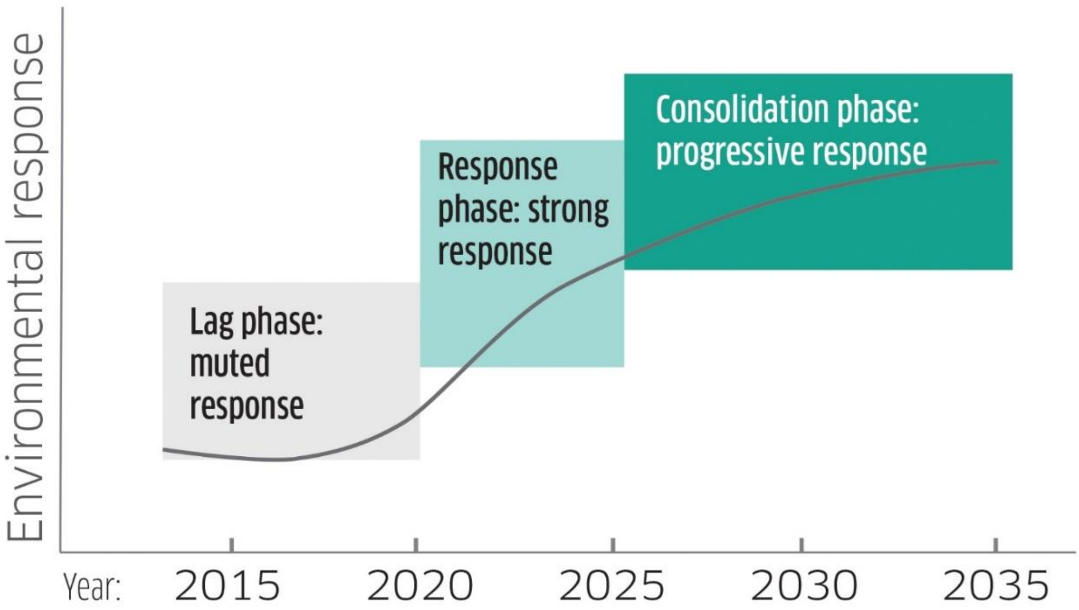


Figure 1 Illustrative environmental response to Basin Plan implementation

Evaluating progress in 2017 poses a challenge as most expected outcomes in the BWS are based on expected outcomes after 2017. Similarly, the targets in the Basin Plan are also longer-term than 2017. Therefore, in order to assess whether the Basin Plan implementation is on track a mix of interim measures of success are required. The achievement of these measures is then interpreted as a positive indication that we are on track to meet the 2019 and/or 2024 expected outcomes in the BWS, linking then, to the long-term objectives of the Basin Plan.

The measures of success for waterbirds are based on our best scientific understanding of longer term healthy population-cycle trajectories. Waterbirds will take some time to respond to an improved flow regime at broad spatial scales, as breeding and recruitment must take place before adult populations increase. Therefore, at this early stage in the Basin Plan implementation, we expect to see environmental flow events provide waterbird refuges during dry conditions, improve habitat condition, increase food availability and extend floodplain inundation to support waterbird breeding. These actions will have short-term implications, providing more opportunities for successful breeding and reducing waterbird mortality. Over the medium term (2020–25) improved breeding responses and survival will support an increased abundance of birds and in the long-term, the Basin Plan will contribute towards healthy resilient populations of waterbirds ().

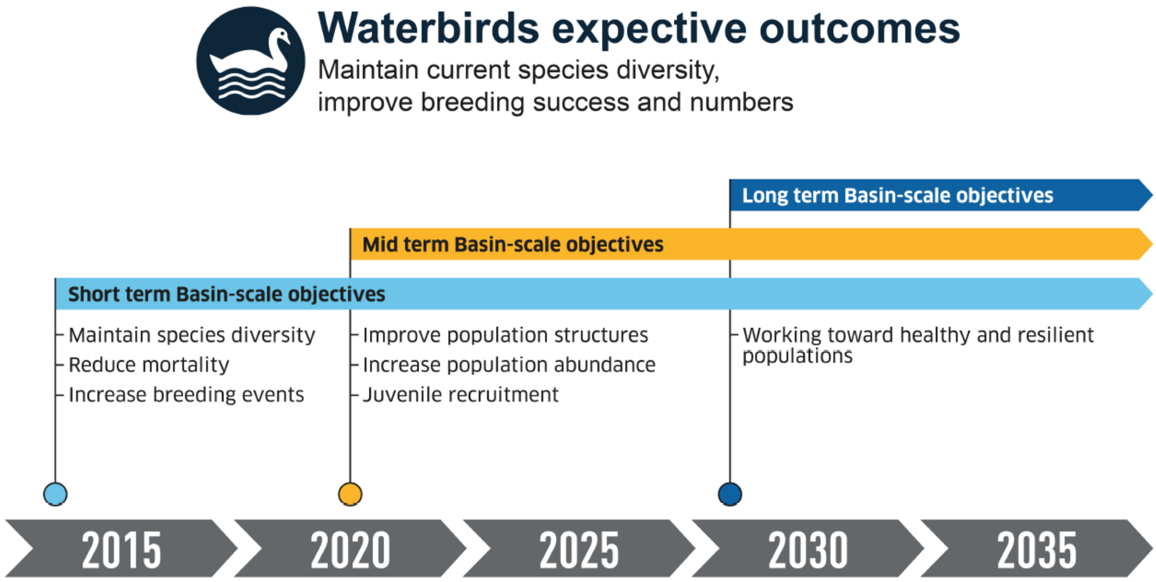


Figure 2 General indicators of success in order to reach the long-term Basin scale objectives for waterbirds

The Measures of Success (and their linkages to the expected outcomes from the BWS), which were evaluated for waterbirds in this report, are shown below in Table 2.

Table 2 The expected outcomes and correlated mreasures of success for 2017

Indicator	Quantified Environmental Expected Outcome	2017 Measure of success
Diversity	The number and type of waterbird species present in the Basin will not fall below current observations from 2024.	Maintenance of species richness across the Basin.
Abundance	A significant improvement in waterbird populations in the order of 20 to 25% over the baseline scenario, with increases in all waterbird functional groups by 2024.	No decline in waterbird populations, including in all functional groups.
Breeding	Breeding events (the opportunities to breed rather than the magnitude of breeding per se) of colonial nesting waterbirds to increase by up to 50% compared to the baseline scenario from 2024.	Improvement in opportunities for waterbird breeding under the Basin Plan.
Breeding	Breeding abundance (nests and broods) for all other functional groups to increase by 30-40% compared to the baseline scenario, especially in locations where the Basin Plan improves overbank flows from 2024.	Improvement in breeding abundances where the Basin Plan improves overbank flows.
Migratory shorebird abundance	At a minimum, to maintain populations of the following four key species: curlew sandpiper, greenshank, red-necked stint and sharp-tailed sandpiper, at levels recorded between 2000 and 2014 by 2019.	Maintenance of populations of curlew sandpiper, greenshank, red-necked stint and sharp-tailed sandpiper at levels recorded between 2000 and 2014.

Contribution of the Plan to the Basin environment

Healthy rivers and floodplains of the Murray-Darling Basin rely on a healthy flow regime and good water quality, which in turn support the water-dependent ecology of the system (e.g. birds, fish, vegetation, etc.). Water for the environment is expected to provide tangible benefits for waterbirds, restoring flow regimes to support waterbird breeding and survival. Improved connectivity and more frequent floodplain inundation will improve productivity across the Basin, indirectly supporting waterbirds by providing more abundant foraging resources and healthier wetland habitats. While the Basin Plan can support the flows and water quality of the Basin system, there are other factors that are needed to support the ecology. There are also risks that can threaten it (e.g. unsustainable land management practices, disease, invasive species and climate change).

Figure 3 below demonstrates the needs and threats for waterbirds, and how the Basin Plan can contribute to their overall health and recovery. The figure also shows what information the MDBA collects to understand how the needs and threats are affecting waterbirds, and some of the measures that could be implemented to increase overall health and recovery. This figure shows the importance of the Basin Plan, as well as highlighting the importance of broader catchment management measures that are required, in order to get the most efficient and effective use of environmental water.

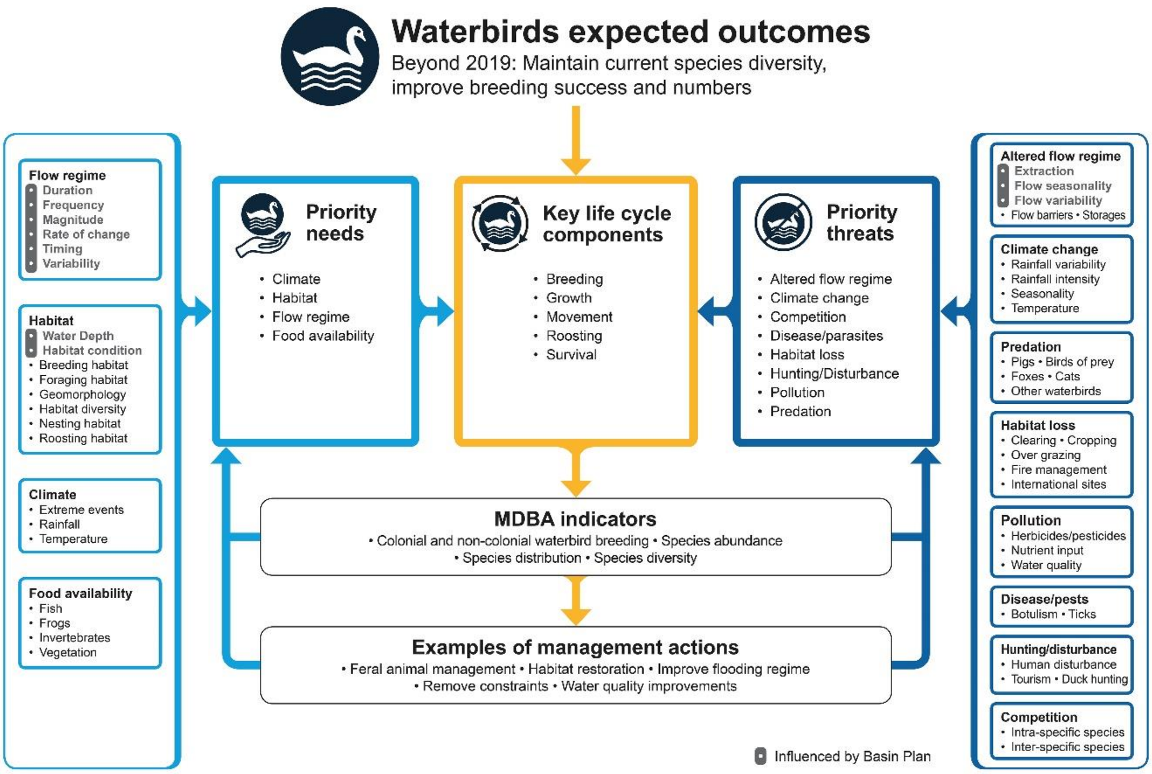


Figure 3 Links between waterbird lifecycle components, waterbird needs, threats and management actions

One of the most influential factors affecting the environmental condition of the Basin is the climate (long term) and the weather (shorter term). The climate of the Basin is highly variable with extreme weather events such as prolonged drought and floods. Climatic conditions also significantly influence environmental outcomes as they play a critical role in determining how much environmental water is available for delivery within a season and the types of outcomes that may be targeted in any given year.

The climate over the period since implementation has been variable, starting with near average conditions in 2012–13, steadily becoming drier and hot from 2013–14 to mid–2015–16 and then closing the period with above average rainfall and inflows across much of the Basin. Areas of Queensland, New South Wales and Victoria entered drought at various points through the reporting period (2012-2017) and maximum and minimum temperatures exceeded the highest on record in some areas.

The amount of water in the rivers of the Murray-Darling Basin is expected to be affected by climate change (CSIRO 2008). Under a median climate change scenario, water in the northern basin rivers is predicted to decline by 8% by 2030, and in the southern basin rivers by 12%. Under a dry climate change scenario, those reductions increase to 26% in the northern Basin and 37% in the southern Basin. Under these changing and variable conditions, the use of resource availability scenarios will become increasingly important and relevant in the role of determining the provision of water for the environment.

Method

Multiple lines of evidence

Many people and organisations contributed to this evaluation. This included Government agencies across the Basin (QLD, NSW, ACT, VIC and SA), research institutions, and community groups and individuals who contributed regional and local knowledge.

The key technical data/information used in this evaluation are shown below in Table 3.

Table 3 Waterbird datasets

Dataset Name	Description	Application
Eastern Australia Waterbird Surveys - UNSW	Aerial waterbird transect surveys taking place over south-eastern Australia in October each year. This survey has been conducted since 1983 and forms the basis of the Basin-wide environmental watering strategy waterbird QEOs.	These surveys provided an ongoing record of waterbird abundance, diversity and breeding each year across Eastern Australia, including the Basin.
Murray-Darling Basin aerial waterbird surveys - UNSW	Annual aerial waterbird surveys carried out in October at 33 selected waterbird sites from 2014 onwards. These surveys replaced hydrological indicator site surveys conducted from 2010 to 2014 and Murray channel site surveys conducted from 2007-2010.	These surveys provide a high resolution count of waterbird presence and breeding at specific wetlands, allowing a comparative analysis of waterbird numbers at wetlands across the Basin over time.
The Living Murray (TLM) monitoring program	The Living Murray icon sites are regularly monitored to track waterbird population numbers and following watering events to identify the effect of environmental water at sites (such as	This data was used to inform some of the case studies in this report.

Dataset Name	Description	Application
	the Coorong and Lower Lakes as specified below).	
Coorong waterbird census (TLM monitoring)	Annual waterbird counts carried out in the Coorong since 2000. These counts formed the basis of the BWS shorebird quantified expected environmental outcome. Counts from the Lower Lakes were not applied in this evaluation as data only commences in 2009.	Dataset was used to identify trends in waterbird and migratory shorebird diversity & abundance.
Spring waterbird surveys - NSW OEH	Each year in October-November the Office of Environment and Heritage surveys waterbird numbers at eight key wetland regions in the NSW Murray-Darling Basin. The timing of the ground surveys aligns where possible with the UNSW aerial survey programs. The ground survey data spans from 5-7 years in length, depending on the site.	Data from the Macquarie, Narran lakes and Lowbidgee wetlands were compared to Basin waterbird trends and applied to inform regional case studies.
Waterbird breeding colony surveys - NSW OEH	Each water year from October to April the Office of Environment and Heritage conducts additional ground and aerial event-based surveys of waterbird breeding sites at key wetlands in NSW. This data spans from 2007–17.	Data from a range of important wetlands was used to inform breeding records in NSW from 2007–17 (Figure 11).
Environmental Water Knowledge Research (EWKR) project - CSIRO/CEWO	This monitoring project aims to improve our knowledge of waterbird populations, their movement, breeding and recruitment. This study incorporates tracking of straw-necked ibis and carefully observing the development of waterbird nests to improve our knowledge base.	Insights from this research were applied to inform the interpretation of waterbird data.
Matter 9.3 reports	Each water year environmental water holders report on the purpose, volume and use of environmental water. Data is available for the 2013–14, 2014–15 and 2015–16 water years.	Environmental water outcomes were mapped to watering deliveries which took place from 2013-2016 to determine the contribution of environmental water at a Basin scale.
State & CEWO watering outcome reports	Each water year since 2013 the States and Commonwealth Environmental Water Holder have published reports on	A compilation approach was taken to assessing the impacts of environmental water on

Dataset Name	Description	Application
	the ecological outcomes of water for the environment.	waterbird populations. The outcomes of environmental watering events in reports were matched to watering events listed in Matter 9.3 reports. These were collated and organised to provide Basin-scale and regional insights.
Media releases and publications	Government, researchers and water managers may publish or provide information for media releases to publicise the outcomes of environmental watering events.	Media releases and other publications can provide informative snapshots on the outcomes of environmental watering events; sometimes in more detail than is provided in State & CEWO reports.

To confirm whether similar trends are being observed across the Basin we have estimated the correlation between various datasets (Appendix 2). We found generally strong agreement between UNSW aerial surveys as well as with NSW OEH spring ground surveys undertaken at three sites for similar periods. In the southern Basin consistency between waterbird trends was moderate (Appendix 2). Discrepancies between datasets are anticipated and demonstrate the importance of using multiple lines of evidence to minimise the limitations associated with different survey methods or timing.

Evaluating against the 2017 Measures of Success

We used to following method to determine whether each Measure of Success was met in 2017:

Table 4 Evaluation method and dataset applied for each 2017 waterbird measure of success

Measure of success	Dataset	2017 Evaluation method
Maintenance of species richness across the Basin	Eastern Australian Waterbird Survey	Analysis of whether average species richness were maintained from 2012-2017 at levels recorded from 1983-2011.
No decline in waterbird populations, including in all functional groups	Eastern Australian Waterbird Survey	Analysis of whether average species abundances were maintained or improved from 2012-2017 compared to 2007-2011.

Measure of success	Dataset	2017 Evaluation method
		A polynomial regression model was also applied to identify the trajectory of waterbird populations and their significance.
Improvement in opportunities for waterbird breeding under the Basin Plan compared to the baseline scenario	All available breeding records (Table 3)	Analysis of whether breeding events for waterbirds at priority sites increased from 2012-2017 compared to 2007-2011.
Maintenance in breeding abundances where the Basin Plan improves overbank flows compared to the baseline scenario	All available breeding records (Table 3)	Analysis of whether breeding abundances for waterbirds were improved from 2012-2017 compared to 2007-2011.
Maintenance of populations of curlew sandpiper, greenshank, red-necked stint and sharp-tailed sandpiper at levels recorded between 2000 and 2014	Coorong waterbird census	Analysis of whether average species population numbers have been maintained from 2015-2017 compared to 2000-2014.

Determining Basin Plan contribution

To determine the responses of waterbirds to the Basin Plan we undertook a meta-data analysis[1] where we looked at each watering event, identified what strategy had been applied and then used State reporting and monitoring to identify whether the strategy had been successful. We grouped watering actions into the following four broad strategies which map be applied to support waterbird populations:

Maintaining waterbird refuge sites:

- During years with low water availability, waterbird foraging sites dry and food resources become limited. Environmental flows are important in improving habitat condition and connectivity to provide invertebrate, fish, frogs and vegetation resources for waterbirds.

Priming wetland ecosystems for breeding:

- Managers have some ability to predict the likelihood of large natural flow events based on long-range water availability and rainfall forecasts. In anticipation of flows environmental water can be used to freshen ecosystems, priming them for a rapid productive response to

[1] Meta-data analysis: procedure for combining data from multiple studies

inundation. Priming flows aim to improve vegetation condition so that it is suitable for waterbird nesting and provides habitat for fish, frogs, reptiles and invertebrates.

Supporting waterbird breeding:

- Waterbirds have an extensive breeding season with some birds requiring up to five months to pair, nest and raise chicks. Some colonial waterbird species are particularly sensitive to falling water levels during a breeding event, for example straw-necked ibis will abandon their nests and eggs and/or chicks will fail. River regulation and extraction has reduced the duration of large natural flood events which triggers large-scale (tens of thousands nests) colonial waterbird breeding. Environmental water can be delivered to some colonies to extend the duration of natural flooding, maintaining water levels in breeding and feeding habitats so that waterbirds can complete their breeding cycle. This environmental water application ensures that chicks successfully fledge and contribute to juvenile waterbird populations.

Triggering small-scale waterbird breeding:

- At some sites it is possible to use environmental water to trigger small-scale breeding events for some waterbird species (e.g. egrets, cormorants and herons). This can be a risky strategy because there must be enough environmental water available to support breeding once initiated through to completion. To date these events have been a secondary outcome of flows delivered to maintain vegetation or frog communities. Generally only small-medium breeding events can be triggered, making this strategy most effective during a series of years where there have been few opportunities for breeding, to support recruitment.

Results and Discussion

Waterbird Condition

Diversity

Table 5 Expected outcomes and 2017 Measures of Success

Expected Outcome	2017 Measure of success
The number and type of waterbird species present in the Basin will not fall below current observations from 2024	Maintenance of species richness across the Basin

Aerial monitoring indicates that waterbird species richness has fluctuated with flows, but that the long term average has remained broadly stable (Figure 4). This means that, despite declines in waterbird abundance at the Basin scale, no individual waterbird species has been recorded as lost, meeting 2017 evaluation expectations. However, some species have still experienced a significant decline in abundance, with 60% of all species reducing in numbers since 1983 (Kingsford et al. 2017).

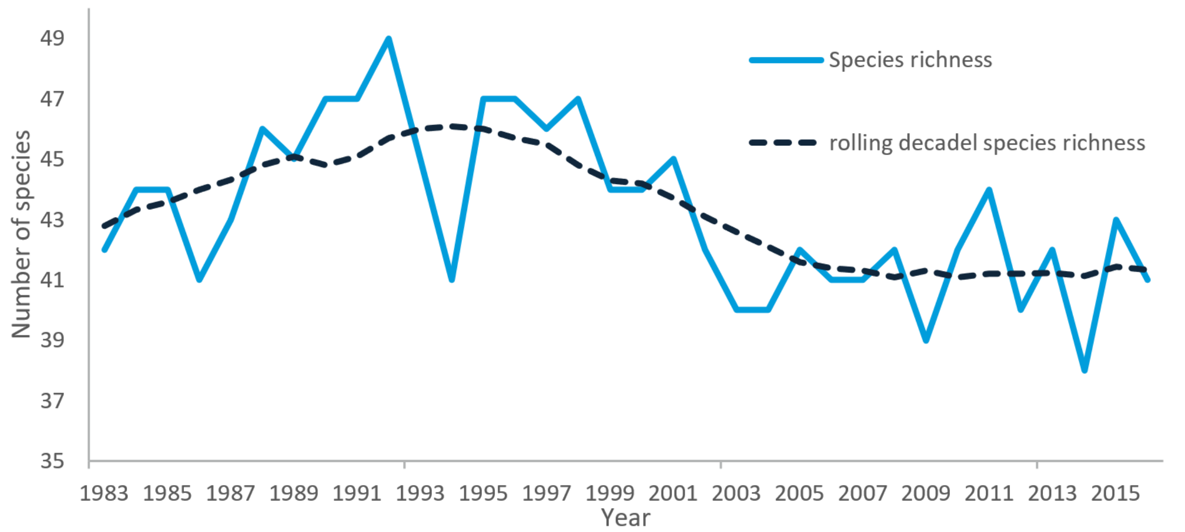


Figure 4 Waterbird species richness across the Basin. Pre-water recovery (2009) and post-water recovery there has been no significant change in species richness ($p>0.05$)

Ground surveys demonstrate a similar story at a Basin-scale but provide more detail on species that are difficult to detect. For example, in 2016 ground surveys in the Macquarie Marshes identified Blue-billed ducks (a species listed as vulnerable in NSW) for the first time since surveys began in 2012 (Spencer et al. 2016). Research programs such as the 'Bitterns in Rice' work provide valuable regional insights on the where endangered Australasian bittern lives and how we can support their populations (link to website). Field monitoring in the Coorong has also detected changes in vulnerable species, with at least five internationally-listed species continuing to decline since 2012 (Paton, 2017). As species populations diminish in size, the impacts of flow alteration, habitat loss, predation and disease become more threatening (Department of the Environment and Energy, 2016)**.** Community datasets could become a valuable resource in the next Basin Plan evaluation. Such datasets are increasingly abundant and may provide high-resolution insights on the distribution of rare species.

Basin Plan contribution

Since 2013 more than 2,600 GL of environmental water has provided foraging and roosting opportunities for waterbirds. These volumes represent only that portion of the total flows delivered in the Basin which listed waterbird outcomes as a purpose. Additional flows delivered to support ecosystem function, fish and vegetation also indirectly benefit birds by improving food availability.

Flows have been delivered across all manageable priority waterbird sites listed in the Basin-wide environmental watering strategy to ensure a mosaic of wetlands are available to support a diversity of waterbird species (Figure 5).

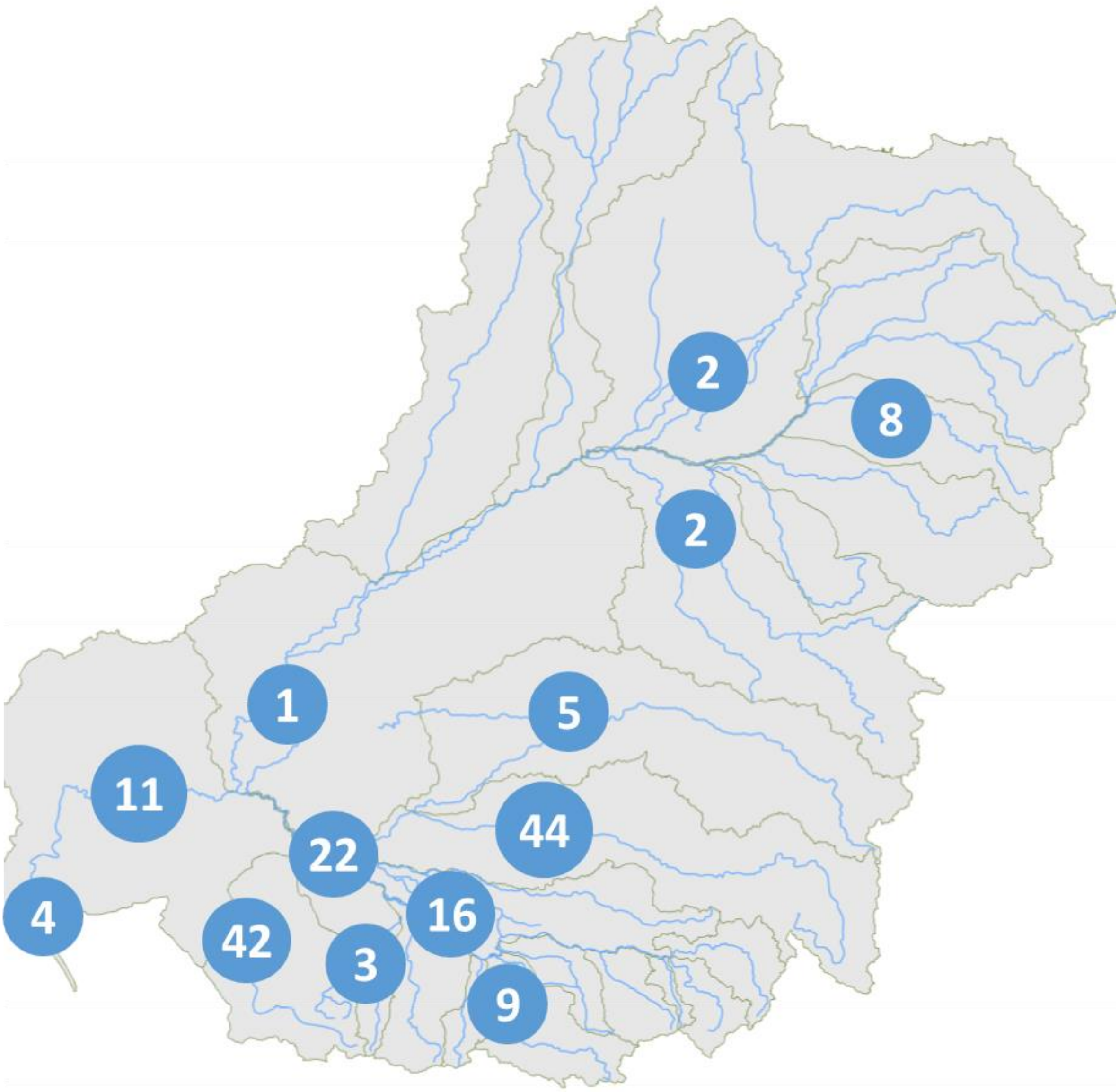


Figure 5 Number and location of water delivery events where waterbirds were listed as a primary, secondary or priority purpose from 2013–16 (Matter 9.3 reports)

Are we on track?

Table 6 Metrics and results

Metrics	Results
2017 Measure of success Species richness has been maintained across the Basin	**Met**
Expected outcome	**On track**

Metrics	Results
The number and type of waterbird species present in the Basin will not fall below current observations from 2024	

Abundance

Table 7 Expected outcomes and 2017 Measures of Success

Expected Outcome	2017 Measures of success
A significant improvement in waterbird populations in the order of 20 to 25% over the baseline scenario, with increases in all waterbird functional groups	No decline in waterbird populations, including in all functional groups

Since the early 1980's waterbird abundances have declined by at least 70% across the Basin (Kingsford et al. 2013). Increasing levels of water extraction and regulation have reduced floodplain inundation, limiting opportunities for colonial waterbird breeding events. A reduction in low and medium flow events means that resource availability has also become more constrained during drought. Other factors such as habitat loss and expansion of introduced predators have also increased waterbird mortality. However, while populations have continued to decline over the past few decades, the rate of population decline has progressively decreased and populations may now be in the process of stabilising (Figure 6).

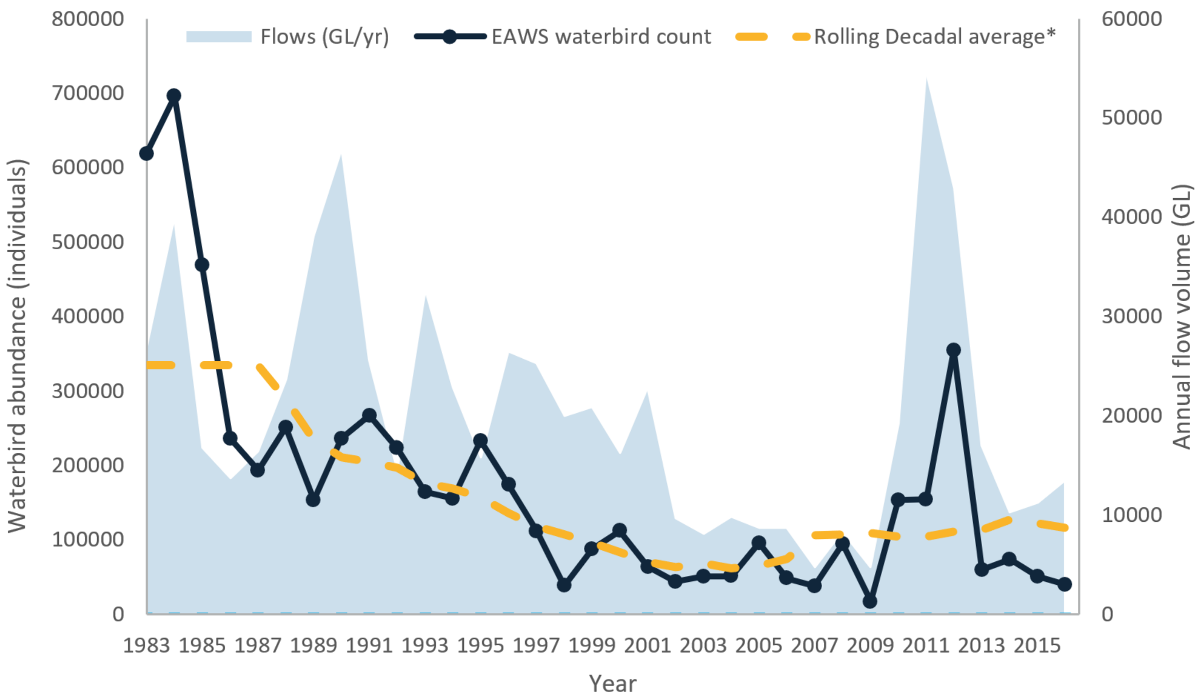


Figure 6 Waterbird abundance across the Murray-Darling Basin 1983–16 (estimated by aerial waterbird surveys) (Porter et al. 2016). *Where less than five years of data were available either side of a given year,

rolling decadal averages denote an average across the previous five years and any years following a given year.

A natural driver for the potential stabilisation of waterbird numbers over the last five years was the return to wetter conditions following the millennium drought. Waterbird numbers are closely correlated with flow, with waterbird numbers peaking in 1984, 1991, 1995, and 2012, approximately one year after large flooding events (Figure 6). During flooding, extensive wetland inundation results in productivity booms, supporting the establishment of large waterbird colonies. Following flooding in 2010–11 this meant waterbirds were able to return to the Basin's inland wetlands to take advantage of the suddenly resource-rich floodplains which had been dry for over a decade. However, since water availability has receded waterbird abundances have declined (Figure 6). In 2016 aerial transect surveys recorded the second lowest abundances on record, underlining the difficulty associated with identifying a clear population trend over the short term.

At regional scales waterbird abundances demonstrate predictable patterns but provide few insights into population trends. Waterbird numbers increase when there is high water availability and decrease as wetlands dry and birds fly to better sites. This underlines the importance of observing waterbird numbers across broad spatial and temporal scales to detect changes in total population size.

Functional group abundance

To gain further insights into which processes may be driving abundance trends, species are sometimes aggregated into 'functional groups' based on shared behavioural or physiological characteristics. This is a common way of identifying what management interventions may be required to protect vulnerable groups of species. For example, if all fish-feeding birds are declining at a site, there may be a scarcity of fish in that location. Observing the distribution of functional groups can also provide information on which sites are vital for particular birds across the Basin and are declining in quality (Appendix 3).

Typically aerial surveys have grouped waterbirds into five functional groups described in Table 8.

Table 8 Waterbird functional groups in the Basin with trends from 1983-2016 (estimated by Eastern australian waterbird surveys)

Functional group	Description	Example	Decline
Shorebirds (Sh)	Feed on macro-invertebrates, ruppia, other; shallow tidal habitats, saline	Stilts, avocets	**81%**
Ducks (Du)	Ducks & grebes, small, can fly long distances	Blue-billed duck	**77%**
Herbivores (He)	Feed on macrophytes, algae, submerged and semi-submerged vegetation	Black swan	**63%**

Functional group	Description	Example	Decline
Piscivores (Pi)	Feed on fish, prefer deep water habitat	Cormorants, pelicans	**59%**
Large Waders (La)	Feed on macroinvertebrates, small fish, frogs, large-bodied, colonially-breeding, prefer shallow floodplain habitat for feeding	Ibis, Egrets	**56%**

Across the Basin all functional groups have experienced a decline. However, similar to total waterbird abundance, the rate of decline has decreased over time (Figure 7). Each functional group differs in their response to flow events and are influenced by a range of other threats as specified in Table 9.

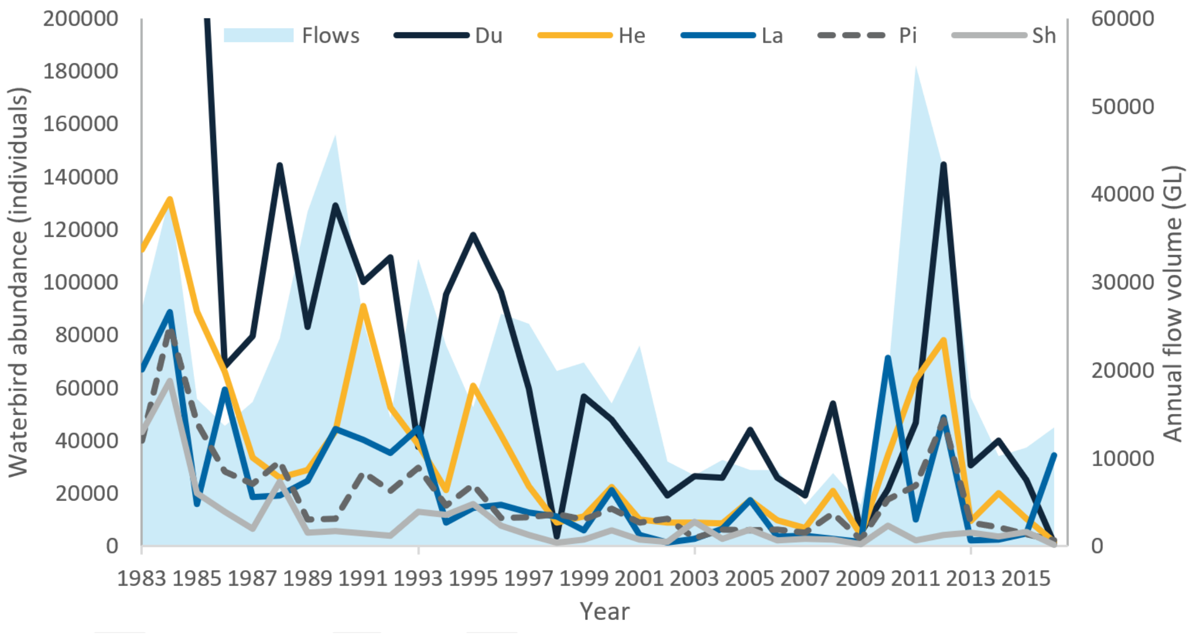
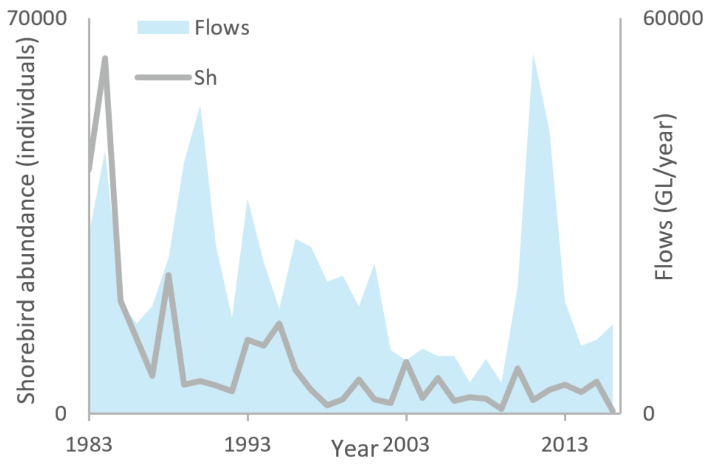


Figure 7 Functional group abundances (ducks (Du), herbivores (He), large waders (La), piscivores (Pi) and shorebirds (Sh)) across the Murray-Darling Basin from 1983-2016 (estimated by Eastern australian waterbird surveys)

Table 9 Description of functional group response to environmental flows events and driver of trends over time across functional groups

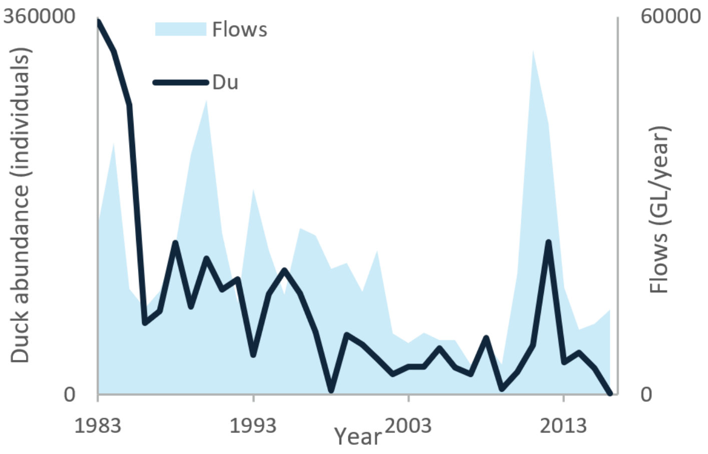
Shorebirds

Response to flow	Driver of trends
Shorebirds demonstrate the weakest relationship with Basin-wide flow volumes and often peak unpredictably. However there does appear to be increases in shorebird numbers in years immediately prior to large floods as conditions become wetter. Increased freshwater input	**Shorebird** populations have reduced by 81% since 1983. Part of this decline is the reduction in populations of international-migratory species. The Basin

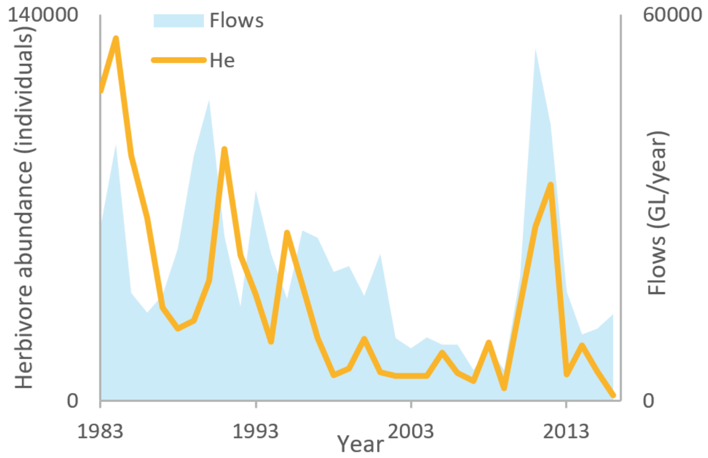
Response to flow	Driver of trends
would be associated with increases in productivity. However as flows from upstream begin inundating tidal flats many shorebird species, which are small in size with short or curved beaks, are no longer able to feed along tidal flats. The birds move to other inland sites, including the Lake Eyre Basin and return as water levels recede. Although very high flows make Basin habitats unsuitable for shorebirds, these flows as well as rainfall are critical to promote productivity in tidal flats. As a result small increases in flows benefit populations by improving foraging resource availability. 	supports 25 internationally-listed shorebirds which fly from Australia to the Northern hemisphere each year, foraging at multiple 'staging' sites along the way (Appendix 5). Research indicates that a major driver of recent declines in migratory populations is intense development and habitat loss in the Yellow Sea region (Piersma et al. 2016). However nationally-listed resident shorebird species in the Basin are also decreasing in abundance (Appendix 4). It is likely that predation, habitat transformation and reduced resource availability are also impacting the Basin's shorebirds. Predation is particularly threatening for Australian resident shorebirds which nest on exposed sand dunes.

Ducks

Response to flow	Driver of trends
Ducks are a nomadic functional group with extreme but variable responses to flows in the Basin. Increases in duck abundances are linked to flood peaks both inside and outside the Basin. Following widespread inundation population numbers can rapidly build, lagging behind flow peaks a year or more.	**Ducks** have experienced the second-most severe decline of all functional groups based on survey records. Numbers declined dramatically from 1983-1986, reducing by 60% in the first decade of monitoring. However, given surveys started when duck numbers were at their highest, what appears to be a sudden decline in duck abundance may actually represent a peak. This peak was in response to concurrent flooding in the Murray-Darling and Lake Eyre Basins in 1984 (Kingsford and Porter 1993). As resources became limiting, duck populations reduced back to baseline numbers.

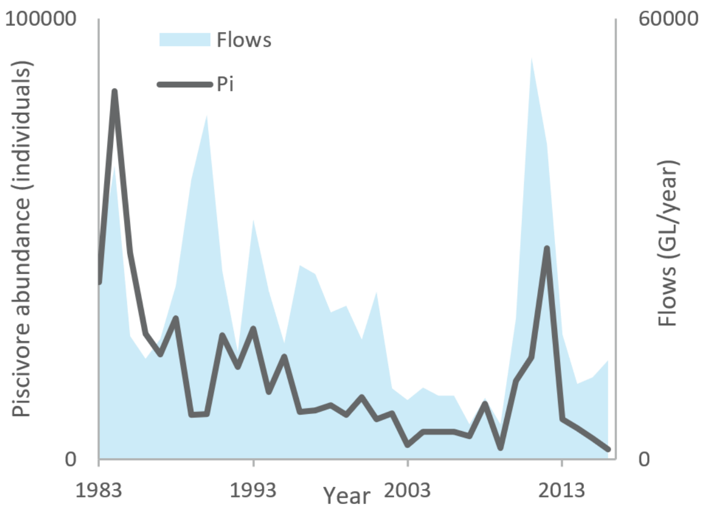
Response to flow	Driver of trends
	Still, over the past 30 years ducks have responded less strongly to flood peaks and populations have declined more rapidly during drought. This is likely a result of river regulation limiting resource availability, but could also be linked to increased predation and hunting.

Herbivores

Response to flow	Driver of trends
Herbivores respond reliably to flood peaks, with an increase in numbers generally observed one or more years after a flow peak. Wide-scale inundation across the Basin results in rapid increases in the productivity of wetlands. Resident species are able to take advantage of these conditions, using the available resources to raise chicks. The increased abundance of herbivores observed in years following flooding is a result of recruitment of juveniles to the adult population. 	**Herbivores** have declined by 63% across the Basin; with 40% of that decline occurring from 1983-1987. Herbivores feed on similar substrates to ducks but fewer of these species are nomadic, with many species in the herbivore functional group preferring to reside at particular sites. Reduced abundances of herbivores is likely driven by habitat modification and predation.

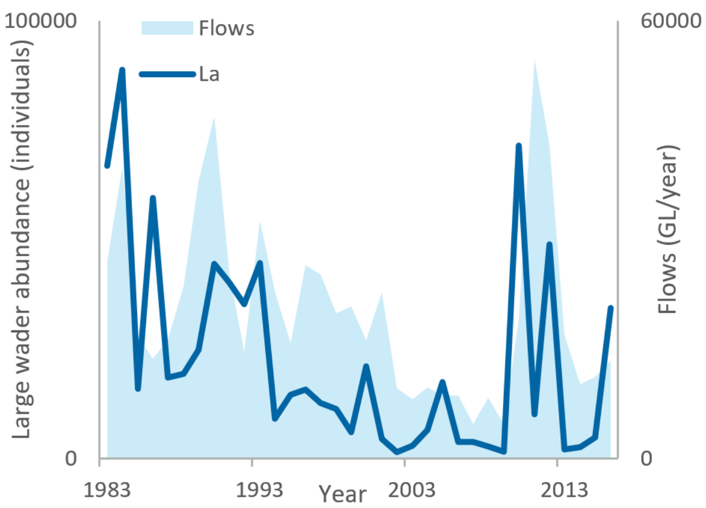
Piscivores

Response to flow	Driver of trends
Piscivores respond indirectly to flows; with abundances increasing as fish populations boom in response to high flows due to increased connectivity and nutrient mobilisation.	**Piscivores** have declined by 59% across the Basin over the past 33 years due to reduced fish resources, habitat transformation and other factors. Some piscivores, such as cormorants and pelicans, nest in large breeding colonies, at sites with abundant resources for juvenile birds. Reductions in flood frequency, duration, reliability and extent may have reduced breeding opportunities for these birds.



Large waders

Response to flow	Driver of trends
The abundance of large waders generally increases immediately following a flow peak when they form large breeding colonies. Wet conditions provide ample resources for chicks and protects juveniles from predation.	**Large wader** populations have halved since the early 80's. Many of these species nest in large colonies of thousands of birds. These nesting colonies form following widespread floodplain inundation when wetlands are highly productive. Since flow regulation, reductions in flood frequency, duration and extent has resulted in reduced breeding opportunities for large waders. However, habitat modification, predation and disease would also have contributed to observed declines. For example, avian botulism, a natural occurring soil-borne pathogen, can cause mortality across waterbird breeding colonies (Wassens 2017).



Basin Plan contribution

The Basin Plan is likely to have played a supporting role in maintaining waterbird abundances. Data collected since 2013 demonstrates that at least 199 environmental flow events contributed towards providing foraging and roosting habitat for waterbirds. Of these, 21 events were delivered to support naturally-triggered breeding colonies and successfully maintained food availability for chick recruitment. Where environmental water has been applied, monitoring has consistently demonstrated a resulting increase in bird numbers as more species are able to forage and roost at the site.

Water for the environment can provide refuges for waterbirds during drought by maintaining productivity and availability of food resources. From 2013-2016 at least 1,115 GL of water was aimed at maintaining the condition of wetlands for waterbirds during low flow years, reducing the risk of waterbird mortality. For example environmental water delivery to Hattah Lakes during dry conditions in 2014 resulted in a rapid increase in waterbird abundances (Biosis 2015).

As conditions improve environmental flows also aim to prime wetlands for a rapid productive response to inundation. From 2013 more than 553 GL of water was delivered to improve vegetation condition so that it was suitable for waterbird nesting and provided habitat for fish, frogs, invertebrates and other waterbird food resources. In the Murrumbidgee and Lachlan wetlands these flows primed the system for large-scale breeding events in 2016–17.

As we cycle through wet and dry periods, environmental water is critical to optimise foraging, roosting and breeding opportunities to ensure waterbird populations have the capacity to increase in number to meet Basin quantified expected outcomes.

Are we on track?

Table 10 Metrics and results

Metrics	Results
2017 Measure of success There has been no decline in waterbird populations, including in all waterbird functional groups	**Met**, however, see below.
Expected outcome A significant improvement in waterbird populations in the order of 20 to 25% over the baseline scenario, with increases in all waterbird functional groups by 2024	**Too early to tell**

Since the implementation of the Basin Plan, average waterbird abundances have not decreased; however high variability in counts makes it difficult to identify a clear trend. We applied polynomial regression to identify whether waterbird trajectories are positive based on available data. The model demonstrated a strong trend ($p<0.001$) and identified that while there has been a significant decline in waterbird populations, this decline has slowed (Figure 8). Since 2009 it appears that populations may be stabilising based on the long-term dataset. Nonetheless, very low abundances in 2016 highlight that it is difficult to identify a clear population trend over the short term. Additional years of monitoring will be critical to confirm waterbird population trajectories.

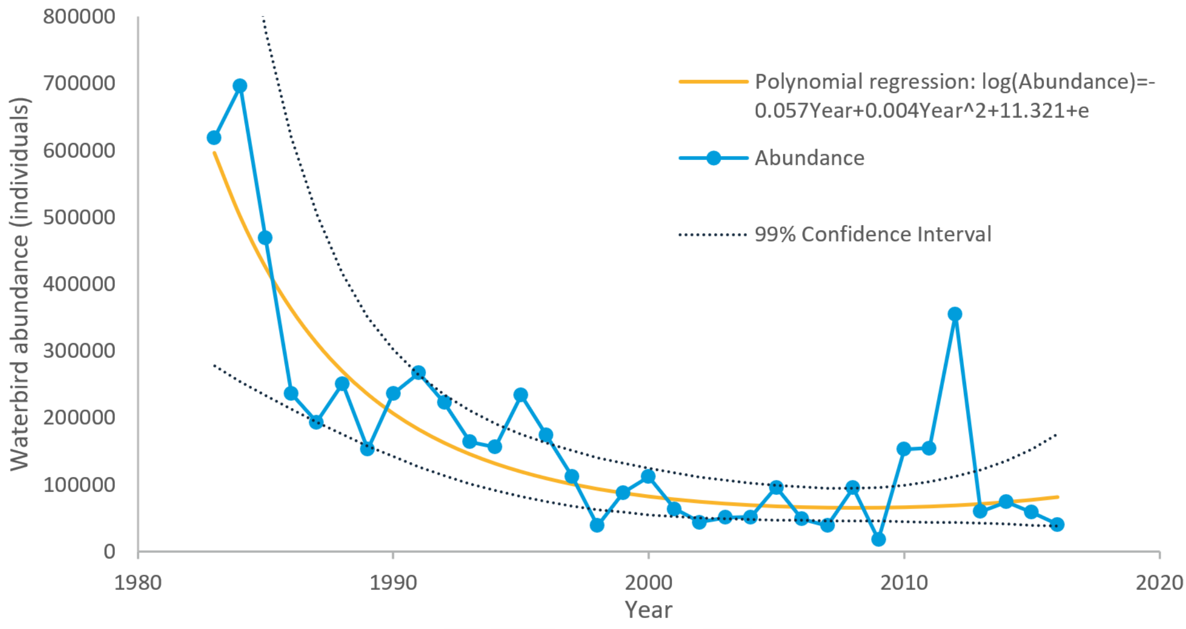


Figure 8 Polynomial regression analysis of long-term waterbird trends in the Basin

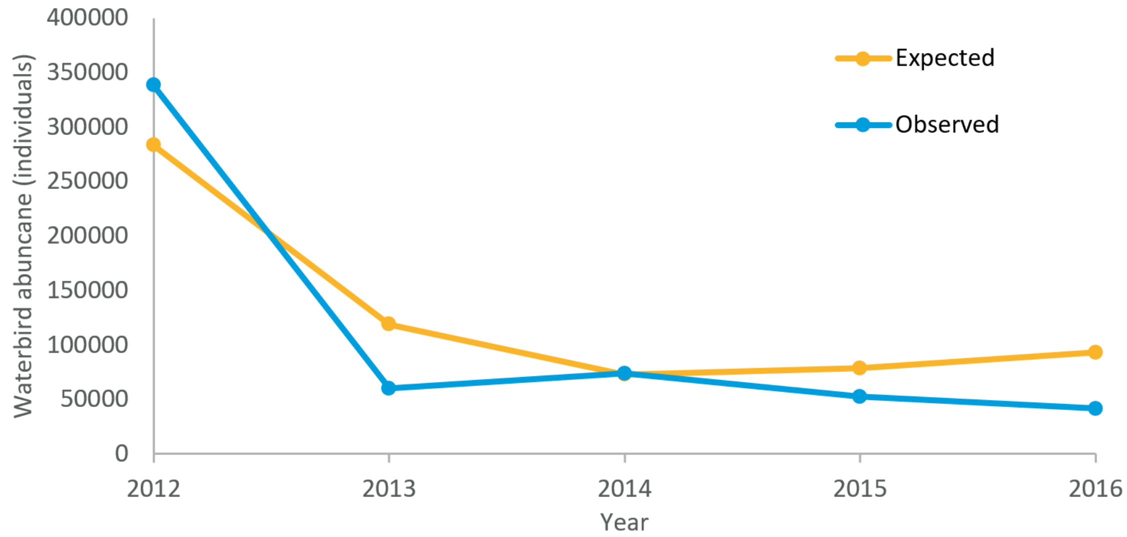


Figure 9 Observed versus expected waterbird numbers 2012-2016

Through mapping expected waterbird numbers modelled under the Basin Plan recovery scenario against observed waterbird numbers it is evident that in 2013, 2015 and 2016 observed waterbird counts were lower than those projected (Figure 9). However, this model assumes the Basin Plan has been fully implementation with 2,400-3,200 GL recovered. However, this is not yet the case with key

Basin Plan mechanisms still in the process of being implemented. Therefore while waterbird numbers appear to have fallen short of expected abundances in three out of five years it is important to acknowledge that this is likely because we are only partway through the water reform process.

Breeding

Table 11 Expected outcomes and 2017 Measures of Success

Expected Outcomes	2017 Measures of success
Breeding events (the opportunities to breed rather than the magnitude of breeding per se) of colonial nesting waterbirds to increase by up to 50% compared to the baseline scenario from 2024	Improvement in opportunities for waterbird breeding under the Basin Plan
Breeding abundance (nests and broods) for all other functional groups to increase by 30-40% compared to the baseline scenario, especially in locations where the Basin Plan improves overbank flows from 2024	Improvement in breeding abundances where the Basin Plan improves overbank flows

Breeding has improved since water recovery began in 2009, however peaks in breeding activity shown in Figure 10 are likely linked to natural inundation events. Analysis of aerial data demonstrates that during the 1980's colonial waterbird breeding events occurred every few years and that over time these events diminished in frequency (Figure 10). The 2010–11 floods brought about a rapid resurgence in waterbird breeding and flows in 2016–17 consolidated the 2010 response. However, limited opportunities for waterbird recruitment from the early 1990's have contributed towards an overall reduced population size, meaning that it will take time for these large breeding events to contribute towards increased adult abundances.

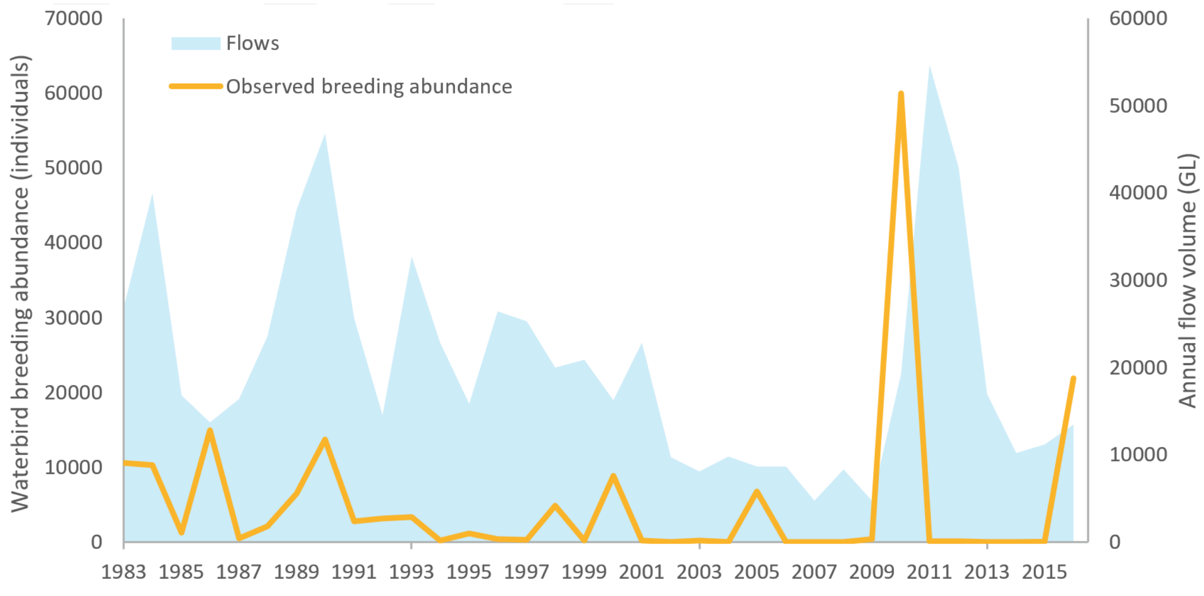


Figure 10 Abundance breeding of waterbirds across the Murray-Darling Basin 1983-2016 (Porter et al. 2016)

Regular breeding opportunities are important to ensure a healthy age-structure of waterbird populations so that adults have a capacity to respond to suitable breeding conditions when they arise. Currently it appears that large-scale breeding events (>10,000 birds) take place approximately once every six years (Figure 10 and 11), which is believed to be insufficient for several species, such as egrets, which require two year breeding intervals (Arthur et al. 2012). Small to moderate breeding opportunities become important to sustain populations during intervening dry years. Sites such as the Coorong and Kerang Lakes provide reliable breeding habitat annually (Figure 11) while large floodplains of the Macquarie Marshes, Lowbidgee Floodplain and Narran Lakes for example, support large-scale breeding at more irregular intervals. This spatial variability in habitat is important for waterbirds, as it supports dispersion of breeding risks and benefits. Waterbirds are able to migrate from dry to wetter sites to maintain population resilience.

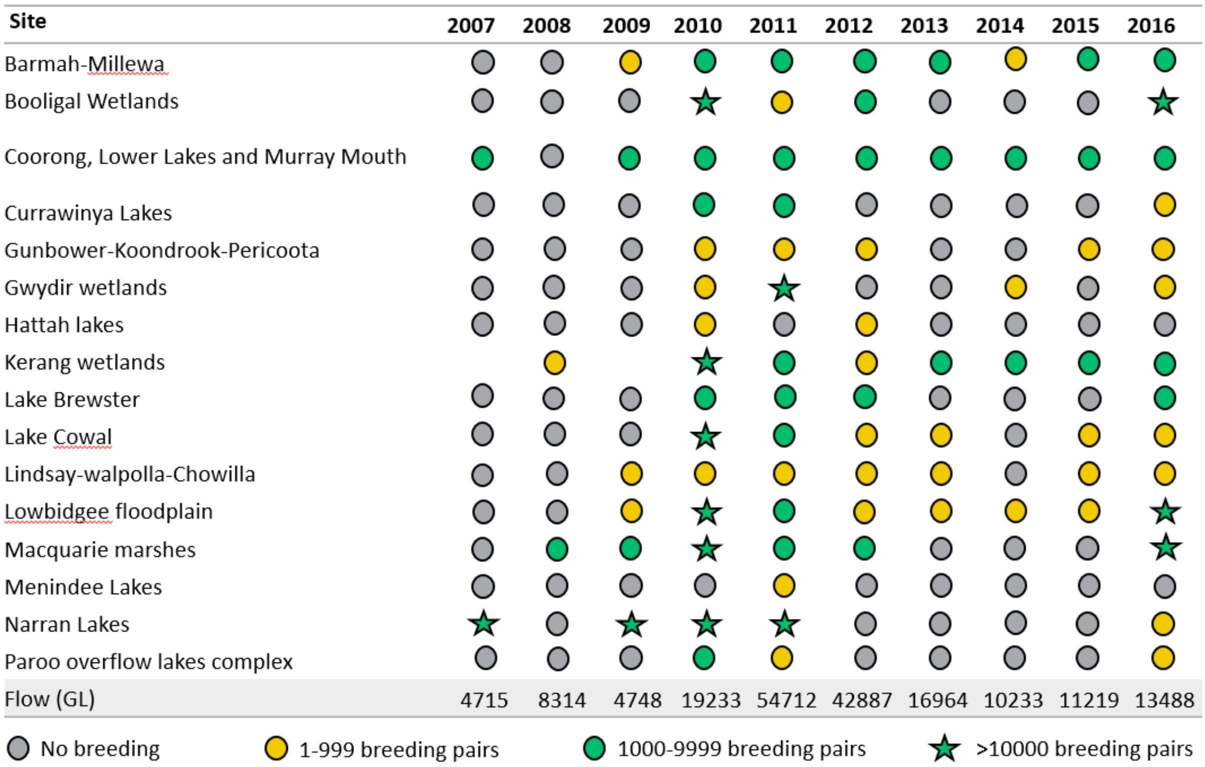


Figure 11 Waterbird breeding across sixteen important wetlands in the Basin. No symbol indicates that data was not collected in that water year. Years represent water years (e.g. 2007=July 2007-June 2008 water year)

Juvenile recruitment is also essential to ensure chicks reach maturity and can, in turn, breed successive generations of waterbirds. However, early monitoring data have suggested that for some large wader species, such as Straw-necked ibis, juvenile mortality rates are extremely high (McGuinness 2017). These birds are therefore unable to complete their lifecycle and contribute to building populations. A better understanding of recruitment in the Basin is required to determine if waterbird breeding is contributing towards adult populations. This knowledge could inform the use of water for the environment.

This evaluation has underlined that there are geographical differences in breeding opportunities for waterbirds. Most wetlands in Queensland and northern NSW haven't experienced a large breeding event since the 2011–12 floods and drought persists in the Queensland Murray-Darling Basin. In contrast the Southern Basin and the Macquarie-Castlereagh Catchment received high natural inflows in 2016 triggering large breeding events in the Lowbidgee floodplain, Lower Lachlan wetlands and Macquarie Marshes. Large-scale breeding events are critical for supporting increased waterbird abundances across the Basin.

Basin Plan contribution

Environmental water is critically important for improving breeding success. Since 2013 more than 936 GL of water was delivered to prevent nest abandonment and boost waterbird numbers.

Waterbirds have an extensive breeding season with some birds requiring up to five months to pair, nest and raise chicks. River regulation and extraction has reduced the duration of natural flows and water for the environment plays a critical role in maintaining stable water levels during breeding. If water levels are not maintained during a breeding event some colonial waterbird species, such as straw-necked ibis, will abandon their nests leaving their chicks or eggs to fail. From 2013 at least 21 environmental watering events were delivered to support breeding, ensuring that thousands of chicks successfully fledged at important sites such as the Macquarie Marshes.

At some sites it is possible to use environmental water to trigger small-scale breeding events for some colonial waterbird species (e.g. egrets, cormorants and herons). These types of breeding events have been recorded in a small number of wetlands in the southern basin (e.g. Yanga National Park, Millewa Forest) where environmental water has been delivered to support frog or vegetation communities but has also resulted in successfully triggered small (around 50-250 nests) waterbird breeding colonies which were supported to completion. If there are a series of years during which there have been few opportunities for breeding, supporting small-scale breeding events where they occur may help to sustain low-level recruitment into waterbird populations.

Large wetland complexes in the Northern Basin through to the Murrumbidgee catchment are particularly important regions for waterbird breeding (Figure 11). Recognising the importance of these sites, environmental water has been delivered to these, and other productive wetlands since the 2010–11 floods (Figure 5). Environmental flows delivered to these sites in 2014 and 2015 aimed to prime ecosystems, so that, following high flows in 2016, a number of breeding events could immediately take place. This strategy contributed to numerous breeding colonies forming, with more than 100,000 nests observed in the Lachlan catchment. Based on Figure 11 at least 14 waterbird breeding events took place in 2016 across the Basin, almost matching the number of breeding events which took place in 2010 despite there being significantly less inundation.

Are we on track?

Table 12 Metrics and results

Metrics	Results
2017 Measure of success Opportunities for waterbird breeding have improved under the Basin Plan	**Too early to tell**
Expected outcome Breeding events (the opportunities to breed rather than the magnitude of breeding per se) of colonial nesting waterbirds to increase by up to 50% compared to the baseline scenario from 2024	**Too early to tell**
2017 Measure of success Breeding abundance has improved where the Basin Plan improves overbank flows	**Too early to tell**
Expected outcome Breeding abundance (nests and broods) for all other functional groups to increase by 30-40% compared to the baseline scenario, especially in locations where the Basin Plan improves overbank flows from 2024	**Too early to tell**

At priority breeding sites (see Figure 11) the number of breeding events which took place increased from 39 events from 2007-2011 to 43 events from 2012-2016. However, in the latter years there were fewer large breeding events. Instead breeding waterbird abundances dramatically peaked in 2010–11 and 2016–17 as a result of natural flooding.

While environmental water likely played a role in priming wetlands for a productive response to inundation (such as occurred in the Murrumbidgee & Lachlan catchment), at a Basin-scale it is difficult to separate the influence of environmental flows from natural flows. Nonetheless, intervention monitoring demonstrates that where environmental flows were applied to extend flood duration, breeding outcomes were enhanced (Spencer et al. 2016).

There are encouraging signs that more breeding sites are becoming active as a result of environmental water (Murrumbidgee & Lachlan case study) however additional data is required, across a range of water availability scenarios, to evaluate against the BWS expected breeding outcomes.

Migratory shorebird populations

Table 13 Expected outcomes and 2017 Measures of Success

Expected Outcome	2017 Measures of success
At a minimum, maintain populations of the following four key species: curlew sandpiper, greenshank, red-necked stint and sharp-tailed sandpiper, at levels recorded between 2000 and 2014 by 2019	Maintenance of populations of curlew sandpiper, greenshank, red-necked stint and sharp-tailed sandpiper at levels recorded between 2000 and 2014

Each year, migratory shorebirds fly thousands of kilometres between breeding grounds in the northern hemisphere and non-breeding grounds in the southern hemisphere (Piersma et al. 2016). The birds rely on multiple staging sites along the way for feeding and resting opportunities (Figure 12). As a result, if one site is degraded it can impact the entire migratory shorebird population.

To promote coordination and habitat protection across the international flight path multiple international agreements exist to ensure threatened migratory shorebirds are protected. Despite these agreements, analyses of long-term monitoring datasets in Australia have revealed that over the past 30 years there has been a severe decline in shorebird abundance (Straw 2004). Recent estimates have indicated a 76% reduction in shorebird abundance within the Basin, with up to 85% reductions in the populations of some species (Kingsford et al. 2013, Kingsford et al. 2017).

Although much of this decline may be driven by development at other international foraging and resting sites, such as in the Yellow Sea (Piersma et al. 2016); within Australia, shorebird habitat has also been lost or degraded through altered water regimes, land use development and disturbance .

Figure 12 East-Asian Australasian Flyway (reference) Migratory shorebird species that use this flyway spend their non-breeding season in Australia and New Zealand to re-fuel before migrating annually through SE and Central Asia to the high Artic for their breeding season

The Coorong, Lower Lakes and Murray Mouth (CLLMM) in the Murray-Darling Basin is particularly significant for migratory shorebirds. The CLLMM provides habitat for forty-six species listed under Australia's migratory bird agreements and sixteen of these at internationally significant numbers (>1% of the global flyway population) (Bamford et al. 2008). The majority of species in the Coorong are shorebirds (Figure 13) and therefore it is important that tidal habitats and mudflats are conserved to maintain waterbird numbers.

Shorebird numbers in the CLLMM are highly influenced by estuarine water levels. As water levels rise as a result of increased flows from the Murray, foraging habitat is inundated, limiting resource availability for migratory shorebirds (Figure13). However, these freshwater flows are important for promoting primary productivity in estuarine ecosystems. Increases in productivity create a more resilient ecosystem, so that during low flow years foraging resources are available.

During the millennium drought the CLLMM was an important refuge site. Despite low flows, the Coorong supported numerous waterbirds for a series of years. Small freshwater flows received in 2006 and 2009 boosted ecosystem condition and were associated with immediate increases in bird numbers (Figure 13).

Since a return to wetter conditions in 2011, total waterbird and shorebird numbers in the Coorong progressively increased up to 2015, but did not recover to pre-drought levels (Paton 2017). In 2016–17, high water levels prevented shorebirds from accessing productive environments and surveys recorded the lowest waterbird numbers on record (Figure 13 & 14). Three of the four migratory species which make up the migratory shorebird BWS expected outcome had their lowest counts recorded in 2017.

The decrease in both migratory shorebird numbers and total waterbird numbers since 2015 is a concerning trend, which indicates the system is declining in condition (Figure 13 & 14). While international development may be driving some decline, other studies have found that reduced shorebird numbers in the CLLMM surpasses population reductions seen elsewhere in Australia (Straw 2004, Clemens et al. 2016). These studies highlight that threats are intensifying at these sites or that habitat and foraging resources are disappearing. For example in 2016–17 it was not only water levels which diminished foraging habitat for waterbirds, but there also a widespread outbreak of filamentous algae in the southern Coorong. The algae blanketed shorelines and submerged vegetation, further limiting food resources for shorebirds (Paton 2017).

Whilst low waterbird numbers may indicate poor site condition, it may also indicate that birds have moved to other highly productive inland sites which have experienced recent inundation or that migratory shorebird populations are declining elsewhere. Recent waterbird tracking studies will provide valuable insights to aid environmental water decision-making.

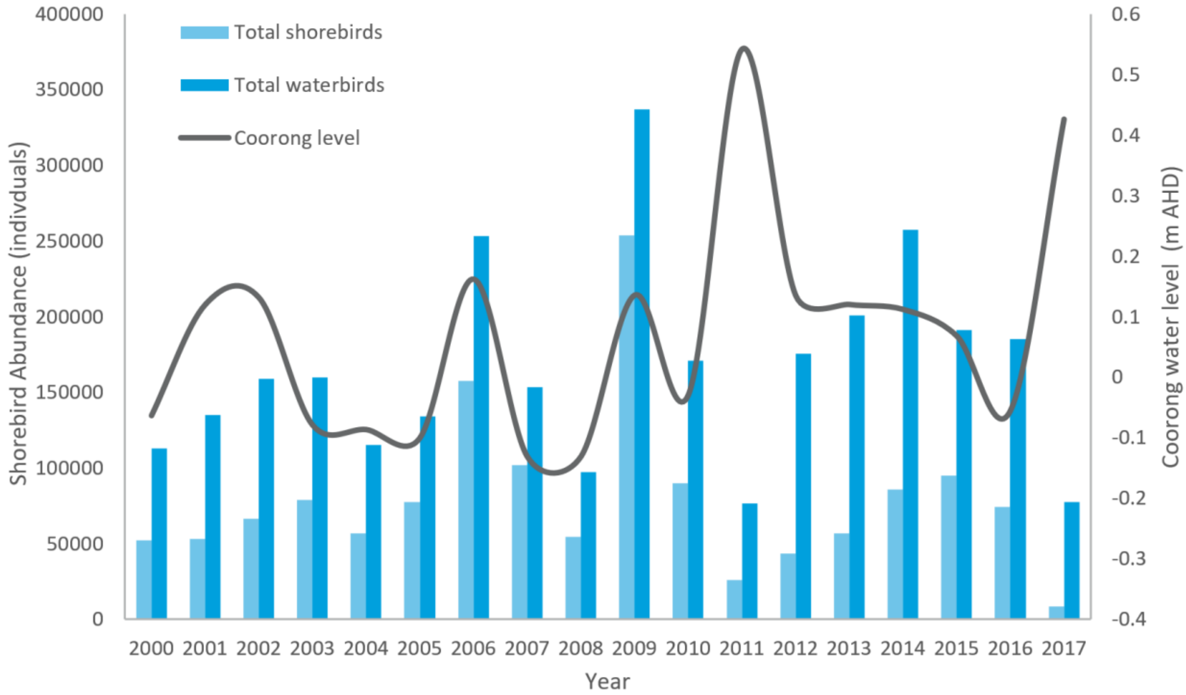


Figure 13 Total waterbird and shorebird counts in the Coorong.The grey line indicates average Coorong water levels in January (m AHD) from 2000–17 (Paton, 2017)

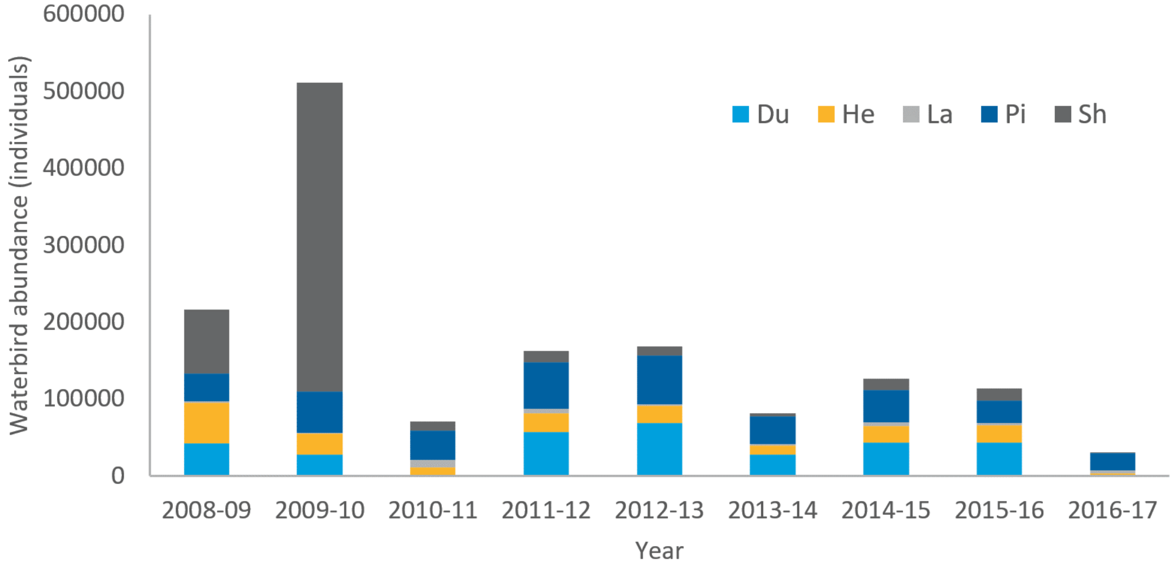


Figure 14 Aerial waterbird survey counts at the Coorong, Lower Lakes and Murray Mouth. Bars (i.e. total counts each year) have been separated into waterbird functional group (Du=ducks, He=herbivores, La=Large waders, Pi=Piscivores, Sh=Shorebirds)

Basin Plan Contribution

Environmental flows delivered through the system under the Basin Plan aim to support the recovery of shorebird populations, by improving the vegetation, invertebrate, fish and water quality in the Coorong. 374 GL of water were delivered in 2015 and a further 272 GL in 2016 maintaining transporting local nutrients through the system (link to CEWO report). Naturally high flows in 2016–17 are expected to further improve water quality in 2017 and 2018, promoting ecosystem productivity. However, even with these actions in place, it may prove difficult to arrest declines in shorebird numbers if issues with filamentous algae persist and international staging sites continue to degrade. Improving habitat in the Coorong will be important to safeguard one critical asset in the flyway, while also benefitting resident Australian-breeding waterbird species in the Basin.

Are we on track?

Table 14 Metrics and results

Metrics	Results
Measure of success Populations of curlew sandpiper, greenshank, red-necked stint and sharp-tailed sandpiper have been maintained at levels recorded between 2000 and 2014	**Too early to tell**
Expected outcome	**Too early to tell**

Metrics	Results
At a minimum, maintain populations of the following four key species: curlew sandpiper, greenshank, red-necked stint and sharp-tailed sandpiper, at levels recorded between 2000 and 2014 by 2019	

Ground surveys which have taken place since 2000 demonstrate that numbers for each of the four migratory shorebirds fluctuate year-to-year (Figure 15). An analysis of migratory shorebird numbers from 2015–17 compared to 2000-2014 demonstrated that while average species abundances decreased for curlew sandpiper, greenshank and sharp-tailed sandpipers this decline was not significant. It is likely that additional years of data will be required to detect any significant change in population sizes. However, numbers of red-necked stints and sharp-tailed sandpipers were at their lowest on record in 2017, demonstrating a negative trend.

While it is likely that declines in migratory shorebirds are partly driven by international habitat loss (Piersma et al. 2016), studies have also demonstrated a decline in ecosystem condition in the Coorong (Straw 2004, Paton et al. 2009). The Coorong is now listed as 'critically endangered' under the IUCN redlist of ecosystems and has been threatened with de-listing under the Ramsar convention (Keith et al. 2013). Given the Coorong is an internationally-listed site which provides critical habitat for many waterbird species, it is important that further steps are taken to maintain the ecological character of this biodiverse estuarine environment – this includes ongoing provision of environmental water under the Plan.

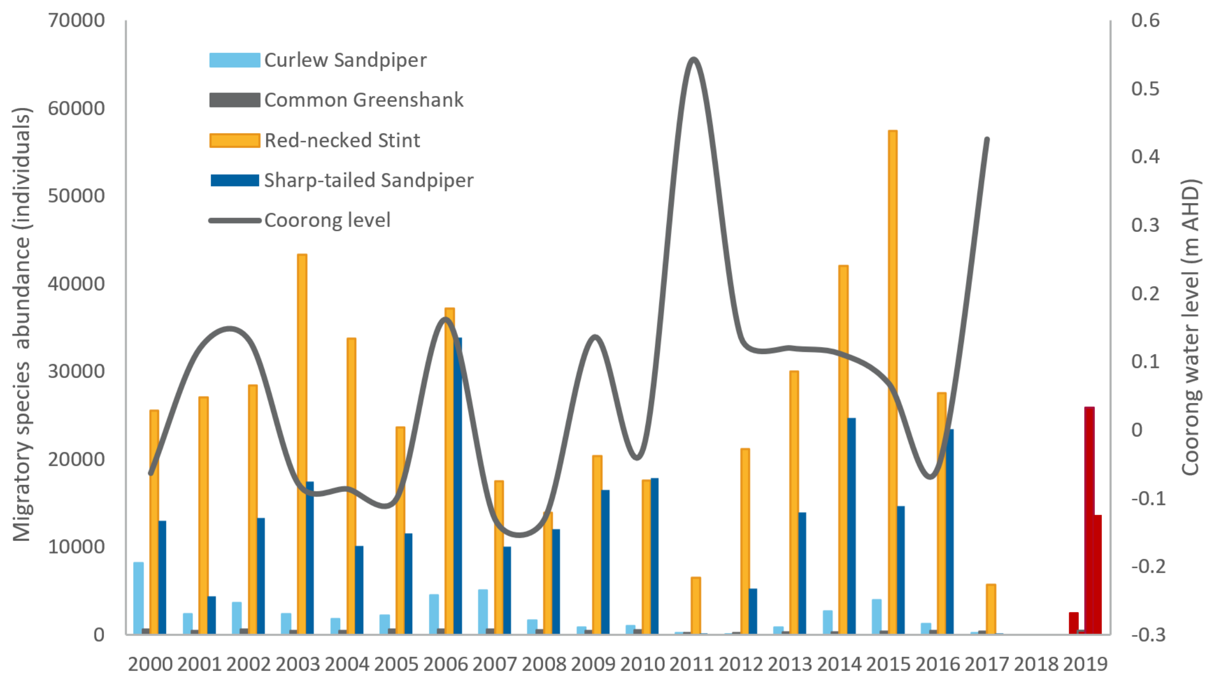


Figure 15 Counts of Curlew Sandpiper, Common greenshank, Red-necked Stint and Sharp-tailed sandpiper and average Coorong water levels in January from 2000-2017 (Paton, 2017). The 2019 red bars represent species' targets by 2019

Linkages to other themes

Hydrology

Expected outcomes for waterbirds are based on projected changes in the hydrology of the Basin. Although only partway through implementation of the Basin Plan, the Hydrology 2017 Evaluation report has highlighted that some expected hydrological outcomes listed under the BWS are on track to being achieved, while for others it is too early to tell.

Longitudinal flows have improved across the Basin, for example in the Murray River environmental water has contributed to at least a 30% increase in flow. This longitudinal connectivity improves water quality, provides foraging habitat and increases food availability for waterbirds along channels.

However, it is not yet clear that latitudinal connectivity has improved across the Basin. This is a significant finding with respect to achieving waterbird outcomes. It is enhanced latitudinal connectivity, specifically floodplain flows, that improves waterbird populations by providing breeding and recruitment opportunities. Whilst there are examples of environmental flows extending the duration or extent of floodplain inundation, our capacity to assess inundation at a Basin-scale is still developing.

Over the next few years, the application of remote sensing techniques to identify lateral connectivity will help to clarify the link between inundation extents and waterbird breeding abundances. This information will help water managers to deliver environmental water to the right sites at the right times to optimise waterbird outcomes.

The Coorong system, which is particularly important for migratory shorebirds, has also benefitted from the Basin Plan. Environmental watering has supplemented freshwater flows to the Lower Lakes and Coorong since implementation of the Plan, with Commonwealth environmental water contributing to 100% of barrage releases between September 2015 and June 2016.. These flows maintain productivity in the Coorong, which is critical for shorebird survival, and ensure that there is tidal exchange through the Murray Mouth. However, the report also highlighted that flows through the barrages were only just above target values. With migratory shorebirds numbers at their lowest in 2017, effective management of the Coorong continues to be a priority.

Environmental Management Framework

The environmental management framework provides a mechanism for the strategic use and coordination of flows for waterbirds.

The Environmental Management Framework 2017 evaluation report highlighted that each year water delivery strategies are coordinated across States, the Commonwealth and environmental water holders achieve optimal outcomes. Watering proposals are developed and refined based on monitoring data and prevailing conditions. Environmental water has achieved the following outcomes for waterbirds:

- maintenance of waterbird refuge sites

- priming of wetland ecosystems for breeding
- supporting of waterbird breeding and,
- triggering of waterbird breeding.

These watering strategies are carefully selected and applied depending on historical and anticipated resource availability in combination past and, where possible, real-time monitoring to guide deliveries. Watering is coordinated through a range of committees to ensure water is delivered efficiently and responsively.

Since 2013 watering actions have aligned well with watering strategies, demonstrating that environmental flows are being delivered strategically (Figure 16). In low water availability years the majority of flows were delivered to protect refuges, providing important foraging opportunities for waterbirds (Figure 16). Where natural flows were low across a series of years, water used to maintain vegetation condition also successfully triggered small-scale waterbird breeding. While these events only support a few hundred individuals, they are important to maintain resilient populations during drought. As water availability increased in 2015–16 environmental water was delivered to maintain refuges in the Northern Basin where dry conditions persisted (Figure 18). Further south where conditions improved water for the environment was used to prime ecosystems for high flows and support future productivity. As water availability continued to increase in 2016–17, environmental water continued to prime ecosystems but also supported naturally-triggered waterbird breeding outcomes, reducing chick mortality.

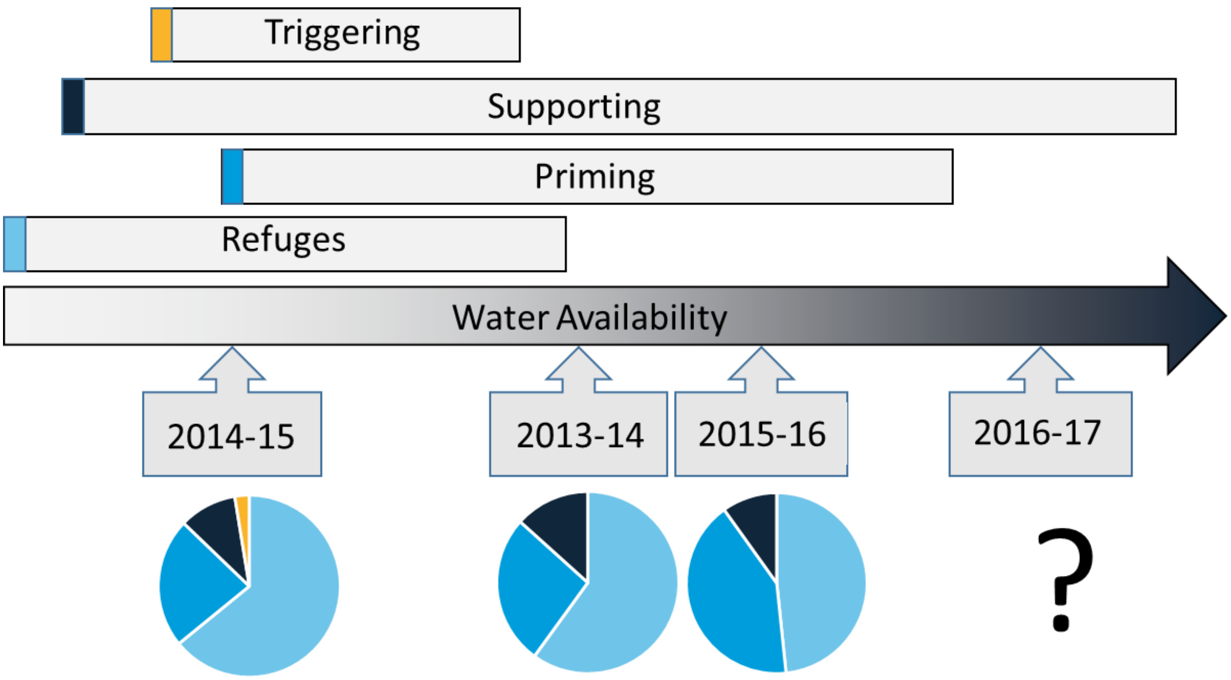


Figure 16 Above water availability arrow: Planned watering strategies in different water availability conditions. Below water availability arrow: Each water year is placed according to the water availability at that time (i.e. 2014–15 had the least water availability at a Basin scale). The pie charts demonstrate the

proportion of water events delivered to maintain refuges, prime ecosystems, support or to trigger waterbird breeding based on Matter 9.3 data (Table 3).

Evaluation findings and management implications

Flows in the Murray-Darling Basin have played an important role in supporting waterbird populations. Under the Basin Plan 2,106.5 gigalitres of water has been recovered for the environment and almost 200 flows have been delivered to achieve a positive waterbird response. Targeted monitoring programs have demonstrated many cases where waterbirds have benefitted from the provision of environmental water. Environmental flows have improved foraging opportunities for birds when resources are limited, prevented nest abandonment by adult birds and increased juvenile recruitment for species such as egrets, spoonbills and ibis across many wetlands. At Basin-scale water for the environment appears to have contributed towards large breeding events in 2016–17 by priming wetlands for a productive response to natural floods.

Delivery of environmental flows is providing local benefits for waterbirds. Coordinated approaches that target system scale outcomes can provide broader benefits. The evidence of waterbirds responding to the delivery of flows provides confidence that longer term outcomes can be achieved.

The inundation of large productive wetlands has been particualrly beneficial for waterbirds. These environments have high food availability and are able to host vast breeding colonies of waterbirds. Waterbirds are highly responsive to local rainfall patterns and, as one site dries, they will move on to other resource-rich floodplains. Although it is difficult to provide environmental water to inundate some of these sites, environmental water managers are able to build on natural flow events to extend inundation and amplify waterbird outcomes. As constraints are relaxed across the Basin and flows are protected, environmental water will be even more effective in inundating rich floodplain environments.

A network of wetlands is important for supporting waterbird populations. Improving our ability to deliver water and protect flows which fill these productive environments hasten the recovery of waterbirds.

During dry conditions, more permanent waterbodies become critical foraging sites for waterbirds. Our analysis has demonstrated that the Coorong continues to support the majority of waterbirds across the Basin, particularly during drought. The Coorong is especially important for shorebirds and international migratory species which forage intensively at these sites prior to their northward migration.

The Coorong remains a critical refuge site for many waterbird species, especially migratory shorebirds. The delivery of flows through the barrages and management of other threats is important to maintain its ability to support waterbirds.

Low numbers of shorebird numbers in the Coorong in 2016–17 is likely a result of local and international habitat degradation but local threats such as predation and the growth of filamentous algae in the Southern Lagoon may also affect numbers. An integrated catchment management approach would help to consolidate waterbird outcomes not only in the Coorong, but across the Basin, by managing other threats including predation, disease, hunting, pollution and habitat loss.

A coordinated approach to broader catchment management measures will complement the Basin Plan and increase confidence in the recovery of waterbird populations.

Although current Basin-scale monitoring programs are valuable they provide only a coarse understanding of waterbird dynamics. There are numerous valuable site-scale and regional-scale monitoring programs taking place, however inconsistent survey methods across Basin wetlands limits out ability to scale-up insights. In addition, inconsistent funding means that datasets may miss critical periods. Improved monitoring of movement and recruitment, with reliable multi-year funding, would aid our ability to determine at what scales populations operate. Future evaluations may also consider the inclusion of community and citizen-collected records to complement more robust datasets.

Continued work to develop more strategic monitoring approaches will ensure that outcomes can be assessed with more confidence in the future, and that appropriate information is available to inform adaptive management.

Knowledge on waterbird and flow relationships has improved markedly since the implementation of the Basin Plan. Many of the successful waterbird outcomes achieved through the delivery of flows can be attributed to managers' strong knowledge base and the willingness of water holders to work with researchers, site managers and river operators to achieve outcomes. Adaptive management is ensuring that flows are strategically delivered to maximise outcomes. Nonetheless there are many areas where our knowledge base could be improved. Our current understanding of waterbird population structures, seasonal and non-seasonal movement patterns, recruitment rates and the impact of other threats at broad scales is rudimentary. The Native Fish Strategy was highly effective in promoting cooperative research to inform management efforts and a similar strategy for waterbirds may facilitate knowledge building. The establishment of a strong community of practice, including planners, researchers and managers, to advise on the best way to achieve the BWS expected outcomes for waterbirds will help to ensure environmental water use and monitoring is strategic.

Knowledge of waterbird and flood relationships have improved. Maintaining this momentum is critical to ensure key knowledge gaps are filled. Refinement of management tools and strategies will be valuable for achieving waterbird outcomes.

Case studies

At a regional scale the benefits of environmental water can be more easily observed. Inundation maps and monitoring of ecological outcomes assist in linking environmental flows to ecosystem responses.

Maintaining drought refuges in Hattah lakes

During the millennial drought many sites remained dry for a series of years, resulting in the die back of river red gum forests and other riparian vegetation. Aerial surveys of waterbirds which took place during the drought indicated that total numbers of waterbirds plummeted as site conditions deteriorated. To prevent further ecosystem loss, water was pumped directly from the River Murray onto adjacent floodplains and lake beds. Following small-scale successes, works were installed to allow permanent management of water levels at many priority The Living Murray sites. Through intervention these sites become refuges in an otherwise dry landscape.

Since the breaking of the drought in 2010–11 water for the environment is still effectively applied to create drought refuges for species to retreat to as conditions dry. These refuges provide semi-permanent water sources and associated feeding and roosting habitat. Satellite imagery over Hattah Lakes demonstrates that during the dry years spanning from 2013–16 the delivery of more than 100 GL of environmental water in 2014–15 resulted in widespread inundation (Figure 19).

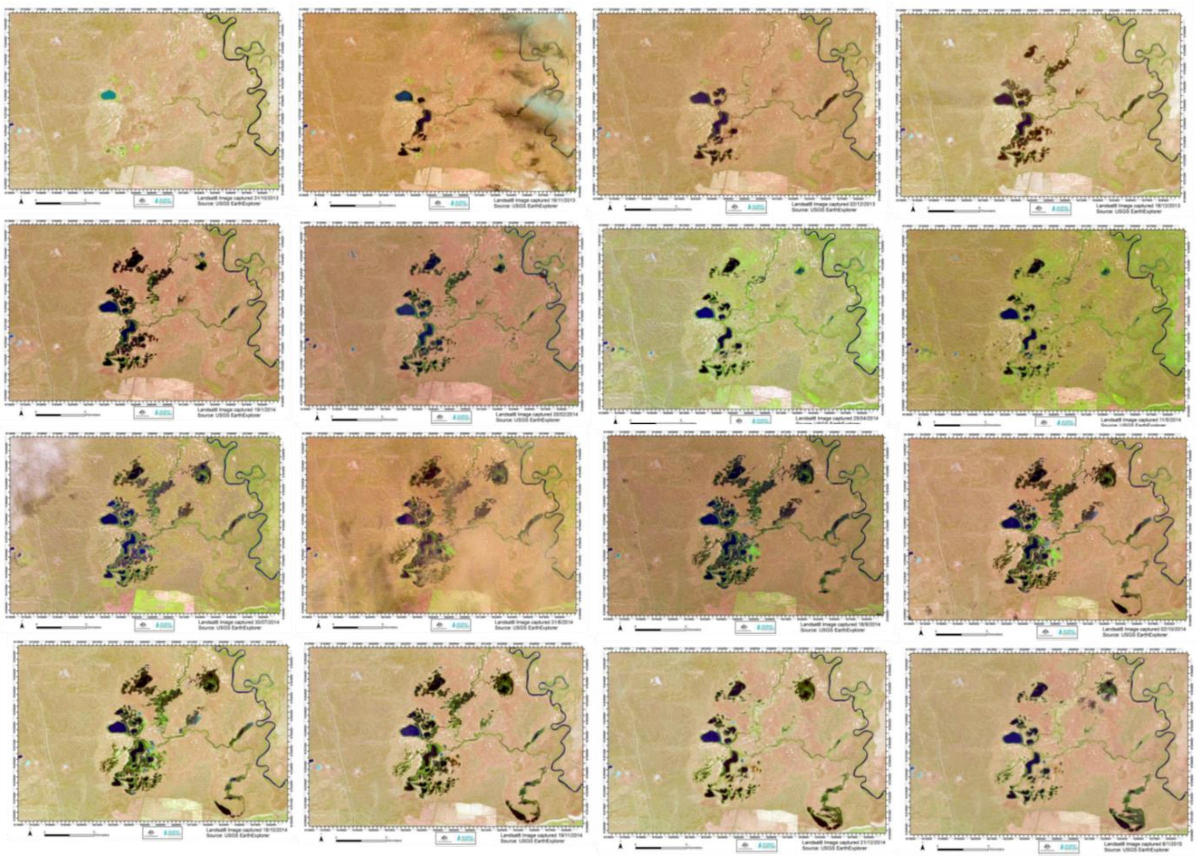


Figure 17 Landsat time step imagery over Hattah Lakes from October 2013 to January 2015

Filling the lakes attracted many waterbird species, boosting numbers in 2014–15 (Figure 20). Environmental water also triggered colonial-waterbird nesting with cormorant and darter nests observed (Biosis 2015).

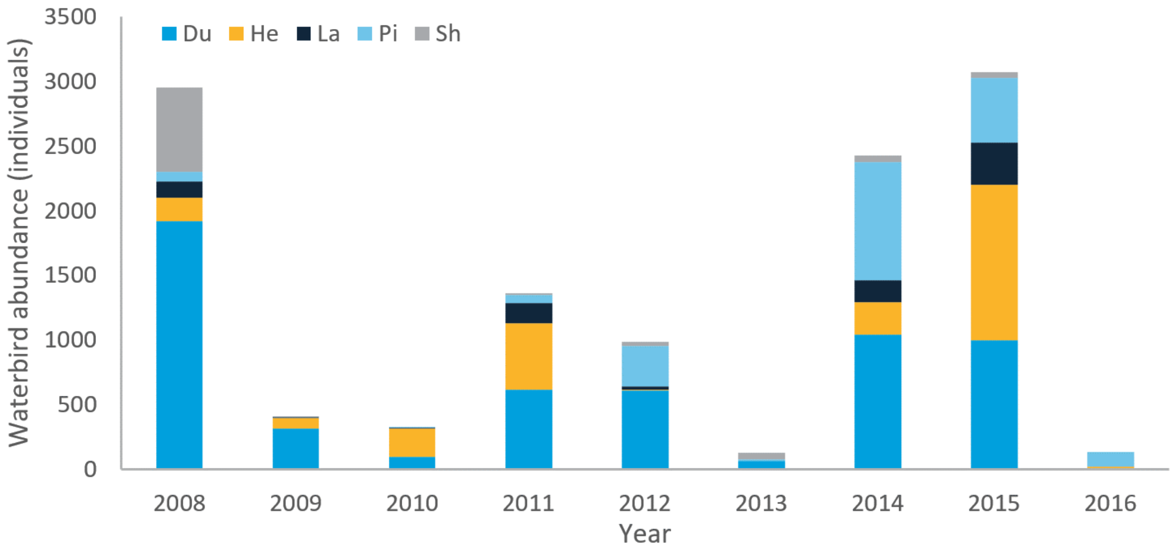


Figure 18 Functional group abundance at Hattah Lakes

Without the environmental works program many waterbirds dependent on the open water habitat of Hattah lakes, such as ducks, swans and cormorants would have lost an important foraging and breeding site. These species migrate across the Basin and sites such as Hattah lakes supports regional communities of ducks and fish-feeding species (Appendix 3). The red gum forests watered at Hattah Lakes also provide valuable habitat for endangered terrestrial birds such as the Regent parrot.

Since the implementation of the Basin Plan 112 environmental flow events have been delivered to provide drought refuges for waterbirds.

Priming wetlands in the Murrumbidgee and Lachlan wetlands

The Murrumbidgee and Lachlan catchments host some of the largest breeding colonies of waterbirds. These large-scale breeding events are often episodic because they require wide-spread and prolonged flooding to inundate suitable floodplain habitat. To support their role in the Basin, water for the environmental is often used in the long periods between major flood events, to maintain these core breeding grounds in 'event ready condition', and hence, primed for a productive response when conditions are ideal (Table 15).

In the Murrumbidgee Catchment, the delivery infrastructure associated with some colony sites has also made it possible to also support small-scale colonial bird breeding events in the absence of natural flooding. These small egret and cormorant nesting events have been triggered flowing the delivery of environmental water for maintaining vegetation and the nationally-threatened Southern bellfrog (Spencer et al. 2016).

Table 15 All environmental water deliveries by water year in the Lachlan and Murrumbidgee catchments (these volumes do not include translucent flows in the Lachlan)

Lachlan - Year	Lachlan - Environmental water delivered	Murrumbidgee - Year	Murrumbidgee - Environmental water delivered
2010–11	7,021 ML	2010–11	193,346 ML
2011–12	20,159 ML	2011–12	83,000 ML
2012–13	51,060 ML	2012–13	156,000 ML
2013–14	23,017 ML	2013–14	136,600 ML
2014–15	5,000 ML	2014–15	154,214 ML
2015–16	36,020 ML	2015–16	103,038 ML

The ongoing maintenance of wetland vegetation in the Lachlan and Murrumbidgee catchments helped to facilitate a large waterbird breeding events to occur in 2016–17 (Figure 21). The preceding years of habitat maintenance habitat maintenance meant there was an abundance of high quality breeding/nesting sites and foraging resources available for an immediate and broad-scale response to natural flooding. Waterbirds flocked to wetlands in the Lower Lachlan where more than 100,000 colonial-breeding waterbird nests were counted. In the Lowbidgee wetlands 1,000's of birds were counted across a network of sites.

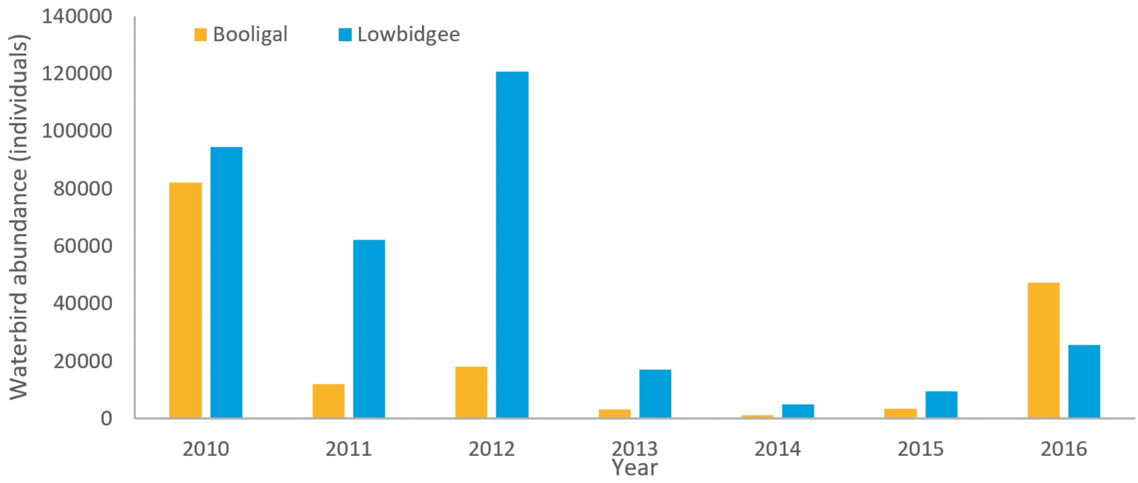


Figure 19 Aerial waterbird counts at the Booligal and Lowbidgee wetlands taken in November from 2010-2016

Large-wading species, such as ibis and spoonbills were the first to take advantage of high water levels in these systems and as water continued to be delivered other species, such as ducks, swans and fish-eating species will persist at these productive sites through winter.

Recruitment from large-scale breeding events in catchments like the Murrumbidgee and Lachlan support waterbird populations across the Basin. Chicks raised in these wetlands will disperse to many other sites (McGuinness 2017).

Since the implementation of the Basin Plan 64 environmental flow events have been delivered across the Basin to prime wetlands for a productive waterbird response.

Supporting waterbird breeding in the Macquarie Marshes

Flow regulation upstream of internationally-recognised waterbird sites has reduced the frequency, duration and extent of natural inundation events. This poses a threat to colonial-nesting waterbird species which have an extensive breeding cycle, lasting anywhere from 40 to 160 days (Brandis 2010). During the breeding period adults and chicks are reliant on local foraging opportunities. If water levels fall and resources become limited, adult waterbirds may abandon their nests. Even if abandonment does not occur, reduced food reliability can result in starvation of chicks and juvenile birds. Although nest abandonment is a natural phenomenon, water regulation can also cause nest abandonment through sudden reduction in river flows as dam releases are changed or water is extracted.

Managing environmental water requires an adaptive approach to prevailing conditions. Where there is a risk that nest abandonment will occur, environmental water holders are able to plan to ensure that water levels remain stable until the majority of chicks have fledged.

In 2016–17 this was the case in the Macquarie Marshes. High natural flows resulted in widespread inundation of the Macquarie Marshes triggering colonies of waterbirds to begin nesting. At the peak of the breeding event approximately 50,000 egret, ibis and spoonbill nests were counted, many with multiple chicks per nest. However, as flood waters began to recede egret and spoonbill chicks had not yet fledged and juveniles were reliant on local food sources. There was a risk that if water levels fell, resources would also diminish and adults would not be able to forage effectively for chicks, risking starvation of young birds. In response to this threat environmental water managers released environmental flows to extend floodplain inundation for another month until a minimum of 85% of egret nests had been completed (i.e. chicks had fledged) in the two major colonies (Figure 22).

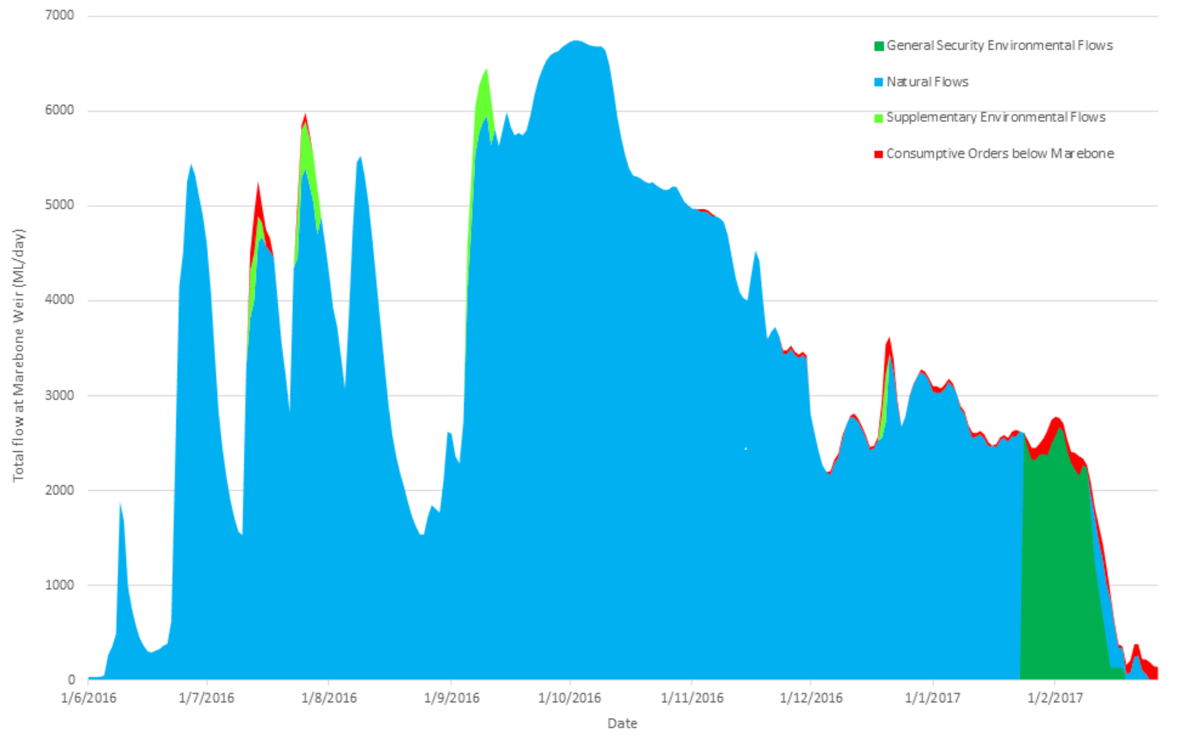


Figure 20 Flow at Marebone Weir in the Macquarie Marshes 2016–17 (NSW OEH, 2017)

The ability of managers to rapidly respond to natural conditions has provided multiple opportunities to adaptively and effectively apply environmental water to promote the survival of juvenile waterbirds across the Basin.

Since the implementation of the Basin Plan at least 21 environmental flow events have been delivered to support waterbird breeding outcomes. These events prevent nest abandonment and ensure resources are available for young birds. Supporting watering events are not always successful, sometimes because waterbirds have already abandoned their nests before water for the environment can reach its destination or because water levels are not the cause of nest abandonment. However our ability to meet waterbird requirements is constantly improving through monitoring and evaluation of outcomes.

References

Arthur, A. D., J. R. W. Reid, R. T. Kingsford, H. M. McGinness, K. A. Ward and M. J. Harper (2012). "Breeding Flow Thresholds of Colonial Breeding Waterbirds in the Murray-Darling Basin, Australia." Wetlands **32**(2): 257-265.

Bamford, M., D. Watkins, W. Bancroft, G. Tischler and J. Wahl (2008). Migratory Shorebirds of the East Asian - Australasian Flyway; Population Estimates and Internationally Important Sites. Canberra, Australia.

Biosis (2015). Monitoring waterbird abundance in response to environmental watering at the Hattah Lakes Icon Site: 2015.

Clemens, R. S., D. I. Rogers, B. D. Hansen, K. Gosbell, C. D. T. Minton, P. Straw, M. Bamford, E. J. Woehler, D. A. Milton, M. A. Weston, B. Venables, D. Weller, C. Hassell, B. Rutherford, K. Onton, A. Herrod, C. E. Studds, C.-Y. Choi, K. L. Dhanjal-Adams, N. J. Murray, G. A. Skilleter and R. A. Fuller (2016). "Continental-scale decreases in shorebird populations in Australia." Emu **116**(2): 119-135.

CSIRO (2008). Water availability in the Murray-Darling Basin. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. CSIRO, Australia.

Gosbell, K. and B. Grear (2003). The Importance of Monitoring Shorebird Utilisation of the Coorong and Surrounding Wetlands in South Australia. Australasian Shorebirds Conference, Canberra, Wetlands International.

Keith, D. A., J. P. Rodriguez, K. M. Rodriguez-Clark, E. Nicholson, K. Aapala, A. Alonso, M. Asmussen, S. Bachman, A. Basset, E. G. Barrow, J. S. Benson, M. J. Bishop, R. Bonifacio, T. M. Brooks, M. A. Burgman, P. Comer, F. A. Comin, F. Essl, D. Faber-Langendoen, P. G. Fairweather, R. J. Holdaway, M. Jennings, R. T. Kingsford, R. E. Lester, R. Mac Nally, M. A. McCarthy, J. Moat, M. A. Oliveira-Miranda, P. Pisanu, B. Poulin, T. J. Regan, U. Riecken, M. D. Spalding and S. Zambrano-Martinez (2013). "Scientific foundations for an IUCN Red List of ecosystems." PLoS One **8**(5): e62111.

Kingsford, R. T., G. Bino and J. L. Porter (2017). "Continental impacts of water development on waterbirds, contrasting two Australian river basins: Global implications for sustainable water use." Global Change Biology **23**(11): 4958-4969.

Kingsford, R. T., G. Bino, J. L. Porter and K. Brandis (2013). Waterbird communities in the Murray-Darling Basin, 1983-2012. Canberra, Australian Wetlands, Rivers and Landscapes Centre, University of New South Wales.

Kingsford, R. T. and J. L. Porter (1993). "Waterbirds of Lake Eyre, Australia." Biological Conservation **65**: 141-151.

Maheshwari, B. L., K. F. Walker and T. A. McMahon (1995). "Effects of regulation on the flow regime of the River Murray, Australia." River Research and Applications **10**(1): 15-38.

McGuinness, H. (2017). "Waterbird Theme preliminary research results- an overview." Environmental Water Knowledge and Research Project Retrieved February, 2017, from https://research.csiro.au/ewkrwaterbirds/research-results/.

Murray–Darling Basin Authority (2014). Basin-wide environmental watering strategy. K. Molloy. Murray–Darling Basin Authority, Canberra.

Office of Environment and Heritage (2017). Birds of a Feather Flock Together in the Macquarie Marshes. OEH, New South Wales Office of Environment and Heritage,.

Paton, D. C. (2017). Condition Monitoring of the the Coorong, Lower Lakes and Murray Mouth Icon Site: Waterbirds in the Coorong and Lower Lakes 2017 Adelaide, University of Adelaide, The Department of Environment, Water and Natural Resources.

Piersma, T., T. Lok, Y. Chen, C. J. Hassell, H.-Y. Yang, A. Boyle, M. Slaymaker, Y.-C. Chan, D. S. Melville, Z.-W. Zhang and Z. Ma (2016). "Simultaneous declines in summer survival of three shorebird species signals a flyway at risk." Journal of Applied Ecology **53**(2): 479-490.

Spencer, J., J. Ocock, T. Hosking, R. Webster, J. Humphries, M. Todd, K. Hutton and P. Berney (2016). Monitoring Waterbird Outcomes in NSW: Summary Report 2015-16. NSW Office of Environment and Heritage. Sydney. **Unpublished report**.

Straw, P. (2004). Status and Conservation of Shorebirds in the East Asian-Australasian Flyway. Australasian Shorebirds Conference, Canberra, Australasian Wader Studies Group and Wetlands International - Oceania.

Wassens, S. a., Spencer, J.a,b,c, Thiem, J.d, Wolfenden, B.a, Thomas, R.a,b,c, Jenkins, K.a, Brandis, K. b, Lenon, E.f, Hall, A.a, Ocock, J.a,b,c, Kobayashi, Ta,c, Bino, G.b, Heath, J c., and Callaghan, D. (2017). Commonwealth Environmental Water Office Long-Term Intervention Monitoring Project Murrumbidgee River System evaluation report 2014-17. D. o. E. a. E. Commonwealth Environmental Water Office. Canberra, Commonwealth of Australia.

State & Commonwealth watering outcome reports

Bonifacio, R., T. J. Hobbs, D. J. Rogers, S. Jellinek, N. Willoughby and D. Thompson (2016). An assessment of ecosystems within the Coorong, Lower Lakes and Murray Mouth (CLLMM) region. DEWNR Technical Note 2016/32. Adelaide, Department of Environment, Water and Natural Resources

Commonwealth Environmental Water Office (2011). Commonwealth Environmental Water: 2010-11 Outcomes Report. Department of the Environment. Canberra, Department of the Environment,.

Commonwealth Environmental Water Office (2017). Restoring our rivers: The Pulse 2015-16. Canberra, Commonwealth Government of Australia.

Gawne, B., J. Hale, S. Brooks, C. Campbell, S. Capon, P. Everingham, M. Grace, F. Guarino, R. Stoffels and M. Stewardson (2016). 2014–15 Basin-scale evaluation of Commonwealth environmental water — Synthesis Report. Final report prepared for the Commonwealth Environmental Water Office by The Murray–Darling Freshwater Research Centre.

Hale, J. (2016). 2014-15 Basin-scale evaluation of Commonwealth environmental water - Generic Diversity. Final Report prepared for the Commonwealth Environmental Water Office by The Murray–Darling Freshwater Research Centre.

Hale, J. (2017). 2015–16 Basin-scale evaluation of Commonwealth environmental water – Generic Diversity. Draft Report prepared for the Commonwealth Environmental Water Office by The Murray–Darling Freshwater Research Centre.

NSW OEH (2017). Environmental water use in New South Wales: Outcomes 2015-16. New South Wales.

Office of Environment and Heritage (2011). Environmental water use in New South Wales: Annual Report 2010-11. Office of Environment and Heritage. NSW, Office of Environment and Heritage.

Office of Environment and Heritage (2016). Monitoring Waterbird Outcomes in NSW: Summary Report 2015-16. New South Wales, New South Wales Office of Environment and Heritage,.

Victorian Environmental Water Holder (2014). Reflections - Victorian Environmental Water Holder, Environmental watering in Victoria 2013-14, Victorian Environmental Water Holder.

Victorian Environmental Water Holder (2015). Reflections - Victorian Environmental Water Holder, Environmental watering in Victoria 2014-15, Victorian Environmental Water Holder.

Victorian Environmental Water Holder (2016). Reflections - Victorian Environmental Water Holder, Environmental watering in Victoria 2015-16, Victorian State Government.

Appendixes

Appendix 1: The expected outcomes of the Basin-wide environmental watering strategy

Table 16 The Basin-wide environmental watering strategy details five expected outcomes for waterbirds.

Objective	Expected Outcome	From
Maintain current species diversity	the number and type of waterbird species present in the Basin will not fall below current observations	**2024**
Increase abundance	a significant improvement in waterbird populations in the order of 20 to 25% over the baseline scenario, with increases in all waterbird functional groups	**2024**
Improve breeding	breeding events (the opportunities to breed rather than the magnitude of breeding per se) of colonial nesting waterbirds to increase by up to 50% compared to the baseline scenario	**2024**
Improve breeding	breeding abundance (nests and broods) for all other functional groups to increase by 30-40% compared to the baseline scenario, especially in locations where the Basin Plan improves overbank flows	**2024**
Maintain migratory species populations	at a minimum, to maintain populations of the following four key species: curlew sandpiper, greenshank, red-necked stint and sharp-tailed sandpiper, at levels recorded between 2000 and 2014	**By 2019**

The MDBA used two methods to develop the expected outcomes:

a) Models were applied to predict how waterbird populations would respond to environmental water using modelling scenarios developed for the Basin Plan. These predictions informed expected outcomes where the objective was to ‘improve or increase’ compared to the baseline.
b) Expert advice was used in combination with a statistical analysis of waterbird survey datasets was applied to determine the acceptable limits of change where the objective was to ‘maintain’ compared to the baseline.

The above methods and the resulting expected outcomes were reviewed and supported by the scientific community.

Method A

Based on historic correlations between surveyed waterbird populations and flow in the Basin, waterbird populations were modelled under different flow scenarios, including:

- a 'no-development' scenario which represents the Basin as a natural system
- a baseline scenario, which represents the Basin with the consumptive use and the rules and sharing arrangements as at June 2009, and
- the Environmentally Sustainable Level of Take set at 2,400 GL, 2,800 GL and 3,200 GL.

To calculate the expected environmental outcomes associated with water recovery, MDBA compared the model's prediction for waterbird populations under the baseline scenario with the model's predictions for the various level of take scenarios (2,400, 2,800 and 3,200 GL recovery). This modelling technique was used to develop quantified expected outcomes for waterbird abundance and breeding abundance in 2024. To develop the quantified expected outcome for breeding events we analysed how often colonial waterbird breeding flow requirements (specific flow indicators) were historically met under each scenario. Specific flow indicators were developed as part of the Environmentally sustainable level of take (ESLT) work. The ESLT work adopted targets for colonial nesting waterbird breeding at sites across the Basin, on the basis of historic evidence of those events.

Method B

A different technique was used for species richness (see 'worked example 2') and for the abundance of migratory shorebirds in the Coorong, and Lakes Albert and Alexandrina. Rather than seek improvement, the MDBA opted to maintain at the historical baseline. For species richness, this meant at levels recorded between 1983 and 2012, and for migratory shorebirds, at levels recorded between 2000 and 2014.

It is important to note that in order to evaluate whether these outcomes have been achieved, a temporal window is required, not just one point in time. The ideal temporal window is described in Figure 46 of the BWS as the 'consolidation phase'. This window goes from about 2024 to 2035. Hence while there might be short term declines in waterbird abundance, it should be the average count of abundance over a window of 10 years.

This is problematic for the 2017 evaluation, as the outcomes are not yet 'in play', and the environmental response is in the 'lag phase' described by Figure 46 of the BWS. This has meant that a different evaluation technique needed to be applied, one that looked for evidence of stabilising numbers, be it abundance or breeding.

Appendix 1a

Table 17 Description of each expected outcome, the method by which it was developed, dataset used, baseline values and expected outcome quantitative values. For simplicity, expected outcomes were usually expressed as percentages, rather than raw numbers, and generally were rounded to the nearest 5%. Also,

while annual averages are used here, any evaluation will need to measure the outcome over a period of years (say, five to ten years) and consider other statistical measures.

Expected Outcome	QEO Method	Dataset	Baseline	Expected outcome value
From 2024 the number and type of waterbird species present in the Basin will not fall below current observations	B	**Eastern Australian Waterbird Survey**	**Average species richness from 1983-2012**: Average of 44 species, varying from 41 to 50 species	**From 2024:** Annual average of 44 species, with 41 to 50 species acceptable
From 2024 a significant improvement in waterbird populations in the order of 20 to 25% over the baseline scenario, with increases in all waterbird functional groups	**A**	**Eastern Australian Waterbird Survey**	**Modelled baseline scenario:** average annual abundance of 168,000 waterbirds	**From 2024:** annual average of 202,000 -214,000 waterbirds
From 2024 breeding events (the opportunities to breed rather than the magnitude of breeding per se) of colonial nesting waterbirds to increase by up to 50% compared to the baseline scenario	**A**	**Specific Flow Indicators for colonial waterbird breeding**	**Modelled baseline scenario:** Annual average breeding events (opportunities) of 3.4	**From 2024:** Annual average breeding events (opportunities) of 5.2
From 2024 breeding abundance (nests and broods) for all other functional groups to increase by 30-40% compared to the baseline scenario, especially in locations where the Basin Plan improves overbank flows	**A**	**Eastern Australian Waterbird Survey**	**Modelled baseline scenario:** average annual breeding abundance of 495 nests and broods	**From 2024:** annual average breeding abundance of 634 – 695 nests and broods
By 2019 at a minimum, to maintain populations of the following four key species: curlew sandpiper, greenshank, red-necked stint and sharp-tailed sandpiper, at levels	**B**	**Coorong, Lower Lakes and Murray mouth waterbird census**	**Average abundances of four key species from 2000 to 2014**: curlew sandpiper- 2486 greenshank- 439	**By 2019:** Average abundances of each species being: curlew sandpiper- 2486 greenshank- 439

Expected Outcome	QEO Method	Dataset	Baseline	Expected outcome value
recorded between 2000 and 2014			red-necked stint- 25850 sharp-tailed sandpiper- 13616	red-necked stint- 25850 sharp-tailed sandpiper- 13616

For further reading see Kingsford et al. (2013), Bino et al. (2014) & Murray-Darling Basin Authority (2011)

Appendix 2

Table 18 Correlation between key datasets used to inform the 2017 evaluation. The surveys compared will have some level of discrepancy given the areas surveyed, even for the same sites, differ between datasets.

Dataset Name	Indicator tested	Correlation coefficient (R)	Source of variability
1. Eastern Australian waterbird survey 2. Murray-Darling Basin aerial waterbird survey	Abundance 2010–16	0.85	There is negligible difference in the abundance trends between these datasets. The MDB aerial survey covers a larger area and surveys all waterbird sites listed in the Basin-wide environmental watering strategy (33 in total), rather than only those sites which fall along a transect (EAWS). For this reason the MDB aerial survey may be able to more accurately identify Basin-scale waterbird response to flows.
1. Murray-Darling Basin aerial waterbird survey 2. NSW OWH spring waterbird surveys	Abundance 2008/2012–16	Narran lakes: 0.79 Macquarie marshes: 0.43 (0.85 without 2016 data point) Lowbidgee wetlands: 0.80	There is a strong correlation in the abundance trends between these datasets. This is encouraging as NSW OEH spring surveys are conducted on ground while MDB surveys are flown. In 2016 there was a large discrepancy between waterbird counts at the Macquarie marshes negatively affecting their correlation coefficient. This discrepancy is due to NSW OEH survey not including known colony sites, which are included in the system wide MDBA aerial surveys. NSW OEH carry out additional event-based ground and aerial surveys for monitoring colony activity across spring and summer. Abundant breeding colonies of waterbirds in 2016 therefore boosted aerial

Dataset Name	Indicator tested	Correlation coefficient (R)	Source of variability
			surveys but did not contribute to total waterbird abundance recorded during the spring ground surveys of established monitoring sites.
1. Murray-Darling Basin aerial waterbird survey **2. TLM monitoring**	Abundance 2007–16	Barmah-Millewa forest: 0.3	These datasets have a low correlation score. These surveys take place at different times and therefore, given the high mobility of waterbirds it is unsurprising that correlation scores are low.

Appendix 3

Functional group distribution at key sites across the Basin. The pie charts are scaled by the average total waterbird abundance at each site from 2007–16 and are split into five functional groups - Ducks, Herbivores, Piscivores, Shorebirds and Large waders (based on MDB aerial dataset)

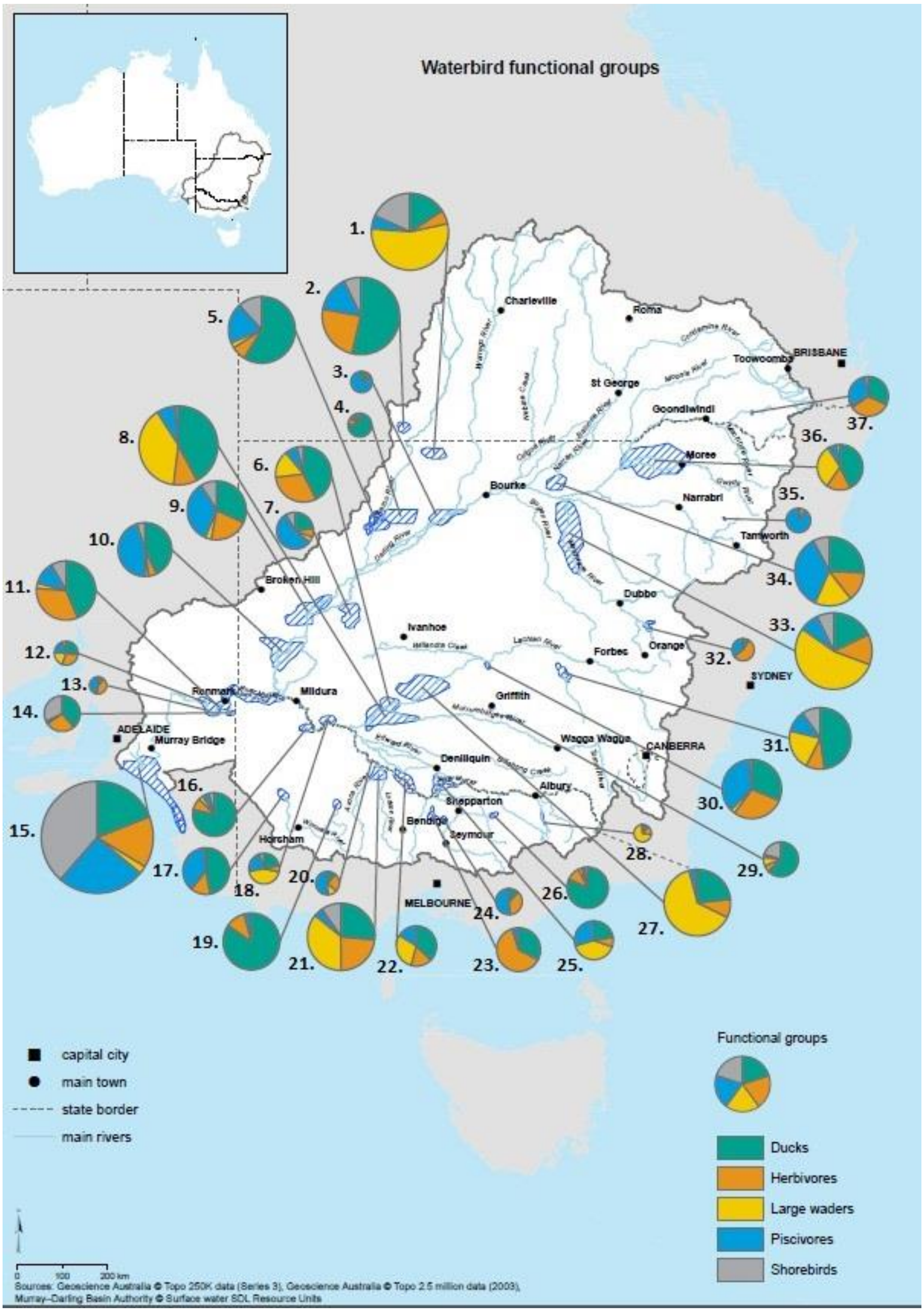


Figure 21 Waterbird functional groups

Table 19 Site names and numbers

Site number	Site name
1	Yantabulla
2	Currawinya Lakes
3	Lower Darling River
4	Cuttaburra channels
5	Paroo overflow lakes
6	Great cumbung swamp
7	Talywalka system
8	Lowbidgee swamp
9	Menindee lakes
10	Darling anabranch
11	Lindsay-wallpolla-chowilla
12	Banrock station
13	Pyap lagoon
14	Noora evaporation Basin
15	Lower lakes, Coorong and Murray mouth
16	Hattah lakes
17	Lake Albacutya
18	River Murray and Euston lakes
19	Lake Buloke
20	River Murray channel
21	Kerang wetlands
22	Gunbower-koondrook-pericoota
23	Corop wetlands
24	Waranga Basin
25	Barmah-Millewa

Site number	Site name
26	Winton wetlands (lake makoan)
27	Booligal wetlands
28	Kiewa river
29	Fivebough swamp
30	Lake Brewster
31	Lake Cowal
32	Burrendong dam
33	Macquarie marshes
34	Narran Lakes
35	Split rock reservoir
36	Gwydir wetlands
37	Coolmunda dam

Appendix 4

Table 20 Environmental Protection and Biodiversity Conservation Act - listed species; their functional group, conservation status and Coorong population trend based on ground census

Species	Functional group	EPBC status	Coorong trends
Curlew Sandpiper	Shorebird	Critically endangered	Decrease
Great Knot	Shorebird	Critically endangered	Decrease
Bar-tailed Godwit	Shorebird	Critically endangered	Stable
Eastern Curlew	Shorebird	Critically endangered	Decrease
Australasian Bittern	Large Wader	Endangered	N/A
Red Knot	Shorebird	Endangered	Stable
Lesser Sand Plover	Shorebird	Endangered	Decrease
Australian Painted Snipe	Shorebird	Endangered	N/A
Cape Barren Goose	Herbivore	Vulnerable	Increase
Greater Sand Plover	Shorebird	Vulnerable	N/A
Australian Fairy Tern	Piscivore	Vulnerable	Stable
Hooded Plover	Shorebird	Vulnerable	Decrease

Appendix 5

Table 21 Internationally-listed birds found in the Murray-Darling Basin; their functional groups and Environmental Protection and Biodiversity Conservation Act conservation status

Species	Functional group	International agreement	EPBC status
Curlew Sandpiper	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	Critically endangered
Great Knot	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	Critically endangered
Bar-tailed Godwit	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	Critically endangered

Species	Functional group	International agreement	EPBC status
Eastern Curlew	Shorebird	N/A	Critically endangered
Red Knot	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	Endangered
Lesser Sand Plover	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	Endangered
Australian Painted Snipe	Shorebird	N/A	Endangered
Greater Sand Plover	Shorebird	N/A	Vulnerable
Hooded Plover	Shorebird	N/A	Vulnerable
Cattle Egret	Large wader	Bonn, CAMBA, JAMBA	N/A
Common Sandpiper	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	N/A
Ruddy Turnstone	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	N/A
Ruddy Turnstone	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	N/A
Sanderling	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	N/A
Sharp-tailed sandpiper	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	N/A
Red-necked Stint	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	N/A
Latham's Snipe	Shorebird	Bonn, JAMBA & ROKAMBA	N/A
Gull-billed Tern	Piscivore	JAMBA	N/A
Caspian Tern	Piscivore	JAMBA	N/A
Black-tailed Godwit	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	N/A
Eastern Curlew	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	N/A
Glossy Ibis	Large wader	Bonn	N/A

Species	Functional group	International agreement	EPBC status
Pacific Golden Plover	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	N/A
Common Tern	Piscivore	CAMBA, JAMBA & ROKAMBA	N/A
Little Tern	Piscivore	Bonn, CAMBA, JAMBA & ROKAMBA	N/A
Crested tern	Piscivore	JAMBA	N/A
Wood Sandpiper	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	N/A
Common Greenshank	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	N/A
Marsh Sandpiper	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	N/A
Common Redshank	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	N/A
Terek Sandpiper	Shorebird	Bonn, CAMBA, JAMBA & ROKAMBA	N/A