Full Paper

Betteridge, B. et al. (2021) Narrative-based reporting to evaluate river-basin management for waterbirds

Narrative-based reporting to evaluate river-basin management for waterbirds

Betteridge, B.[1], Meehan, A.[1], Dawe, K.[2] and Palmer, L.[2]

1 Riverine Ecology, Murray-Darling Basin Authority, Canberra, ACT, Australia

2.River Connectivity and Climate Change, Murray-Darling Basin Authority, Canberra, ACT, Australia

Key Points

- We found a narrative-based reporting approach useful to draw on multiple lines of evidence (flow indicator analysis with climate adjustment, environmental water delivery and habitat condition) to evaluate environmental policy response for colonial waterbirds.
- We found that the number of breeding opportunities was low but expected since 2012 given mostly dry and very dry climate categorisations. We also found that flow indicators were not predicting events well, with actual observed breeding events occurring with unmet flow indicators. The narrative-based approach was useful to explain across limited monitoring data sets, and test uncertainty in colonial nester responses to environmental water.
- Future work for evaluating colonial waterbird responses could focus on colonial waterbird habitat requirements (beyond inundation time), and further analysis of successful colonial waterbird breeding events that have occurred when specific flow conditions have not been met.

Abstract

Evaluating the Basin Plan (BP) for 2020 required a new methodology to assess the contribution of BP Policy levers to waterbird outcomes. We developed a program logic framework to integrate quantitative and qualitative data in a narrative-style report. We assessed Specific Flow Indicators (SFIs) for colonial waterbird breeding opportunities under baseline hydrologic conditions. This baseline was compared to observed SFI data adjusted by catchment for climatic and inflow conditions to give an expected number of colonial waterbird breeding opportunities. This SFI analysis was compared to actual observed breeding events at key colonial waterbird breeding sites in the Murray-Darling Basin. These findings were tested using a participatory research network of waterbird experts. We found that the number of breeding opportunities was low but expected since 2012 given mostly dry and very dry climate categorisations. We also found that SFIs were not predicting events well, with actual observed breeding events occurring with unmet SFIs. The narrative-based approach was useful to explain across limited monitoring data sets, and test uncertainty in colonial nester responses to environmental water. The example of colonial waterbird breeding shows the methodological ability to integrate modelled hydrological data, on-ground ecological monitoring and expert opinion.

Keywords

Waterbirds, Evaluation, Environmental Policy, Narrative reporting, Flow Analysis, Quantitative Analysis

Introduction:

The Basin Plan began in 2012 with the objective to protect and restore water-dependent ecosystems, including their waterbird populations. Overall, observed populations of waterbirds in the Murray-Darling Basin have declined since monitoring started in the 1980s. Colonial waterbirds are a primary indicator function group for environmental flows, as the relationship between environmental flows and waterbird recruitment is substantiated. The first evaluation of the Basin Plan in 2017 was inconclusive about waterbird response to improved stream management due to limitations with the evaluation approach. Evaluating the Basin Plan for 2020 prompted using a new methodology to assess the contribution of Basin Plan policy levers to waterbird outcomes. We developed a program logic framework to answer waterbird research questions in a narrative-style report that could integrate quantitative and qualitative data, along with expert opinion. In this paper we focus on the empiric example of colonial bird breeding opportunities and events, and how well these have been supported by environmental watering.

Narrative-based reporting is one type of policy evaluation and reporting tool used in the literature. Collaborative Outcomes Reporting, Participatory Performance Story Reporting and Multiple Lines of Evidence reporting are other terms for the reporting tool. Narrative reports can be described as 'a succinct summary of the performance of a program' (Mathison, 2005). As well as explaining what a program has achieved, a narrative-based reporting also describes the causal links that show how the achievements were accomplished (ibid). Common across narrative-based reporting is the ability to assess multiple lines of evidence for contribution towards outcomes. The strength of narrative-based reporting is that they strike a balance between depth of information and brevity and are easily interpretable for staff and stakeholders (Dart, 2008). The narrative-based reporting approach has been in several NRM-related policy examples (Clear Horizon Consulting, 2008; Dart and O'Connor, 2008; Dart, J. and Roberts, M., 2016; Kennett, R. and Kitchens, J., 2009). For the 2020 MDBA Evaluation, we applied two other evaluation tools: a program logic and key evaluation questions.

Evaluating outcomes from the Basin Plan is a key step in an adaptive management pathway, allowing the assessment of how well the Basin Plan policy levers are contributing to ecological outcomes.

Colonial Waterbird Requirements:

Colonial nesting waterbirds are those that breed in large colonies, and include pelicans, cormorants, egrets, ibis, spoonbills and terns. Colonial waterbird breeding is highly dependent on significant river flows and extended flooding, with volume, timing and duration complementary for successful breeding events (Brandis, 2010). Peaks in colonial waterbird nesting typically coincide with large natural flow events. Colonial waterbirds have particular habitat requirements, requiring inundated vegetation for up to 5 months to complete their breeding season (ibid). Some colonial waterbird species are particular sensitive to falling water levels during a breeding event e.g. straw-necked ibis, as falling water levels can cause nest abandonment.

River regulation and extraction has reduced the large natural flood events that trigger large magnitude (>10000 nests) colonial waterbird breeding. Environmental water can be delivered to some colonies at manageable wetlands, maintaining water levels in the breeding and foraging habitat. This allows waterbirds to complete their breeding cycles, chicks successfully fledge and recruit to the juvenile waterbird population.

Environmental water plays an important role in providing foraging habitat. For example, environmental water can maintain a mosaic of wetland habitats through seasonal flooding of sedgelands, marsh grasslands, lignum shrublands, forests and open lagoons—thus ensuring a diversity of habitats to support different waterbird functional groups and keeping wetlands primed to support future breeding events (Spencer, 2017). Broad-scale flooding outside the breeding colony sites (either adjacent or close by) is also vital to generate food resources, such as plants, bugs, insects and frogs (McGinness et al., 2019).

Treatment of colonial waterbird breeding requirements in the Basin Plan:

At major wetlands across the Basin, Specific Site Flow Indicators (SFIs) were developed in the establishment of the Basin Plan to represent threshold flows required to meet various biota needs (Swirepik et al., 2015). Many of these wetlands had environmental flow requirements established for colonial waterbird requirements. Site-specific flow indicators are strongest when used in relation to long-term flow datasets (i.e. multi-decadal) and in whole of Basin or catchment scale studies. Applying SFIs at shorter time scales or at sub-catchment geographic scales requires careful interpretation.

SFI Method

The hydrologic model baseline scenario (run 845) for pre-Basin Plan development has been analysed for SFI Achievement. The hydrologic condition analysis for the 2020 Basin Plan Evaluation drew on data of estimated flows derived from hydrologic modelling done during the development of the Basin Plan 2012. This hydrologic model was used to establish the Baseline Diversion Limits and Sustainable Diversion Limits for the Basin Plan.

The percentage of SFI Achievement was calculated for each given climate category and catchment. Five climate categorisations were calculated based on Bureau of Meteorology Australian Landscape Water Balance model (AWRA-L v6) with conversion to a daily inflow (ML/day) for each catchment. The water years were assigned a category of 'Very Dry' if the cumulative annual volume ranked in the bottom 10% for the catchment, 'Dry' if they ranked between >10% and <25%, 'Moderate' for >25% - <75%, 'Wet' for >75%<90% and 'Very Wet' for >90%. The 2012-2018 (post-Basin years) were based on the previously derived percentage of SFI achievements to calculate an expected baseline accounting for climate. The post-Basin Plan years (2012-2018) have been weighted based on the catchment's sequence of climate categorisation. The observed post baseline data was analysed to determine actual SFI event achievement compared to the climate-weighted baseline. If the predicted number of events is partial (e.g. less than 1), the expected events is rounded down to zero as you cannot have partially met SFI events.

Environmental Water Delivery

Environmental watering delivery (known as Matter 9.3 reporting from Schedule 12 of the Basin Plan) was used to assess the Basin Plan contribution in colonial bird breeding since 2012. Matter 9.3 reporting includes both Held Environmental Water (HEW) and Planned Environmental Water (PEW) delivery. The following analyses were made to assess environmental water delivery contributing to colonial waterbird breeding opportunities:

a) Volumes of environmental water delivered to 5 key waterbird sites (where Waterbirds was the primary purpose for the environmental water delivery event)
b) Overall volume of environmental water delivered for waterbird (where the primary AND secondary delivery purpose was for Waterbirds) for Water Years 2013 – 2014 to 2018 – 2019 inclusive.
c) Overall volume of environmental water by seasonality of watering event*
d) Event count of Seasonality watering events*
e) Duration of watering event length for Water Years 2013 – 2014 to 2018 – 2019 inclusive
f) Interrelationship of primary and secondary coded events (i.e. between vegetation and lateral connectivity events)
g) Duration, seasonality and volume for Water Years 2013-2014 to 2018-2019 inclusive

**Seasonality is determined by the season the majority of the watering event occurs in. In cases of equal watering between seasons, then the start date determines the watering or in long-watering events, the first chronological equal majority season after the start date.*

Colonial bird breeding records were collated to determine the presence and extent of colonial bird breeding at several key Murray–Darling Basin (MDB) wetlands used for colonial bird breeding. These records were compared to the relative climate categorisation at the catchment-level, and whether environmental water had been delivered to the site. These sites were selected on the following criteria: i) pre and post BP data availability, ii) Importance to colonial waterbird breeding and iii) a selection of sites across the MDB including terminal and non-terminal wetlands.

Waterbird Habitat

The Wetland Insights Tool (WIT) developed by Geoscience Australia was used as a surrogate for waterbird habitat. This is because breeding and foraging habitat (amount, type and quality are not currently monitored by the MDBA). The closest indicator monitored (at the Basin-scale) is wetland area. The WIT tool summarises the amount of water, green vegetation, dry vegetation, and bare soil has varied over time at each wetland (Dunn et al., 2019). The tool achieves this by presenting a combined view of Water Observations from Space, Tasseled Cap Wetness and Fractional cover measurements from the Landsat satellite record (Dunn et al., 2019). The results at the wetland scale are presented as a stacked line plot over time.

The WIT tool was used to compare pre and post Basin Plan levels (with t-testing for significance) of median cover for open water, wet, green vegetation, dry vegetation, and bare soil at the key MDB wetlands for colonial nesting waterbirds. The key colonial waterbird sites analysed were Gunbower-Koondrook-Perricoota, Gwydir Wetlands, Riverland Chowilla floodplain (including Lindsay-Mulcra-Wallpolla), Lower Murrumbidgee River floodplain and Narran Lakes using t-tests for pre and post Basin Plan results.

Results:

SFI Analysis

The results of the SFI analysis is that accounting for climate adjustment, all SFIs have performed as per baseline, except for the Wakool and Chowilla (Figure 1). The Macquarie and Lower Murrumbidgee SFI have exceeded their SFI achievement based on the climate adjustment. The SFI measure is for providing a colonial waterbird breeding opportunity, opposed to an actual breeding event occurrence. There are occurrences when colonial waterbirds have successfully bred despite the SFI not being met (for example, Narran Lakes and Gwydir in 2016).

Figure 1. Climate-adjusted specific Site Flow Indicator site achievement for colonial nesting waterbirds.

	SFI Site Location																	
	Barmah - Millewa	Gunbower Koondrook-Perricoota	Wakool	Hattah	Chowilla	Narran	Macquarie			Gwydir		Talyawalka		Lachlan Swamp - Booligal	Lowbidgee			Mid Murrumbidgee
SFI Description	15000 ML	20000 ML	5000 ML	70 GL	40000 ML	154 GL	250 GL	400 GL	700 GL	150 GL	250 GL	30 000 ML	2350 GL	2500 ML	800 GL	1700 GL	2700 GL	26 850 ML
	5 months	5 months	120 days	6 weeks	90 days	3 months						21 days		50 days				45 days
Number of SFI met events since 1/7/2012	0	0	0	0	0	0	2	2	1	1	1	0	0	1	2	1	0	1
Climate Weighted Average expected under 845 baseline scenario (%)	12%	10%	21%	10%	19%	5%	20%	15%	10%	5%	1%	3%	0%	15%	38%	15%	6%	8%
Number of events expected under baseline in 2012-2018	**0.8**	**0.7**	**1.5**	**0.7**	**1.3**	**0.3**	**1.4**	**1**	**0.7**	**0.3**	**0.1**	**0.2**	**0**	**1**	**2.6**	**1**	**0.4**	**0.6**
Baseline met?	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Environmental Water Delivery

The volumes of environmental water delivery from 2013 – 2019 was relatively stable (Figure 2). The lower delivery volumes in the 2017-2018 and 2018-2019 water year corresponded with the expected seasonal peaks of environmental water being delivered. From the environmental watering delivery, there was a strong interrelationship for primary purpose vegetation events being a secondary purpose event for waterbirds. Vegetation watering events support waterbird habitat, and 96/362 primary vegetation events identified waterbirds as the secondary event purpose.

The majority of environmental water delivery by volume was delivered in summer, followed by spring, low autumn volumes and a very small volume for winter watering (Figure 3). The majority of environmental watering events for waterbird primary and secondary purpose were short duration (<90 days) event duration (Figure 4). Figure 5 shows the full relationship between ML volume delivered, event duration and seasonality. Winter designated watering events were always short duration, with 2014-2015 and 2016-2017 having spikes in environmental water delivery. This likely means limited volumes of overwintering water to support foraging habitat for colonial nesters, noting different species have different habitat requirements.

Figure 2. Primary and Secondary purpose environmental water delivery (HEW/PEW) for the water years 2013 – 2014 to 2018 – 2019. *Note, some flows delivered for vegetation and lateral connectivity would have supported colonial waterbird habitat.*

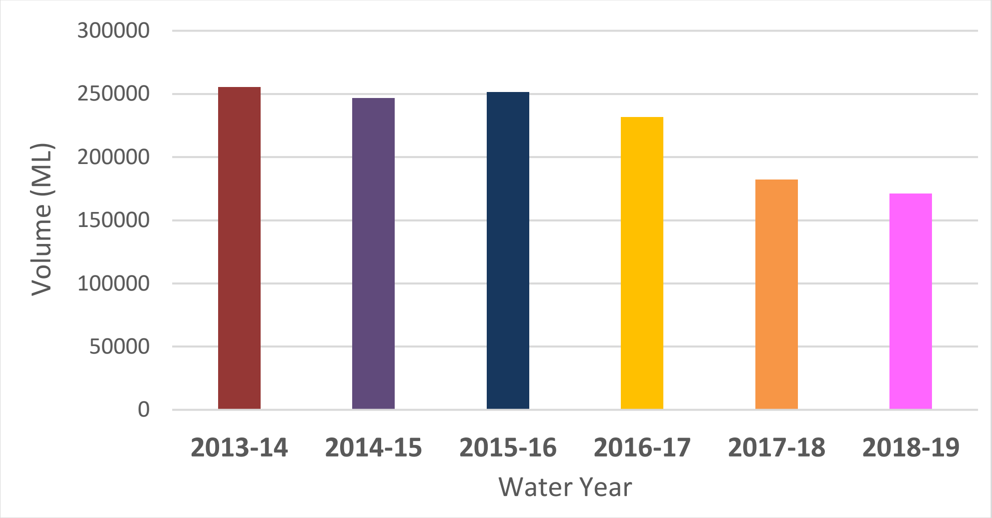


Figure 3. Primary and Secondary Waterbirds purpose seasonal environmental water delivery (HEW/PEW) for the water years 2013 – 2014 to 2018 – 2019.

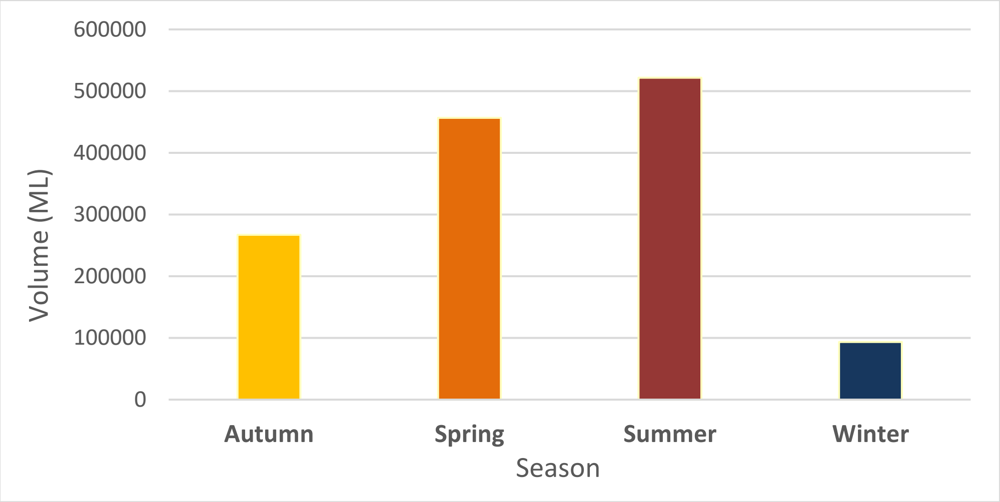


Figure 4. Primary and Secondary Waterbirds purpose environmental water delivery (HEW/PEW) event duration (<90 days, 90 – 119 days and >= 120 days) for the water years 2013 – 2014 to 2018 – 2019.

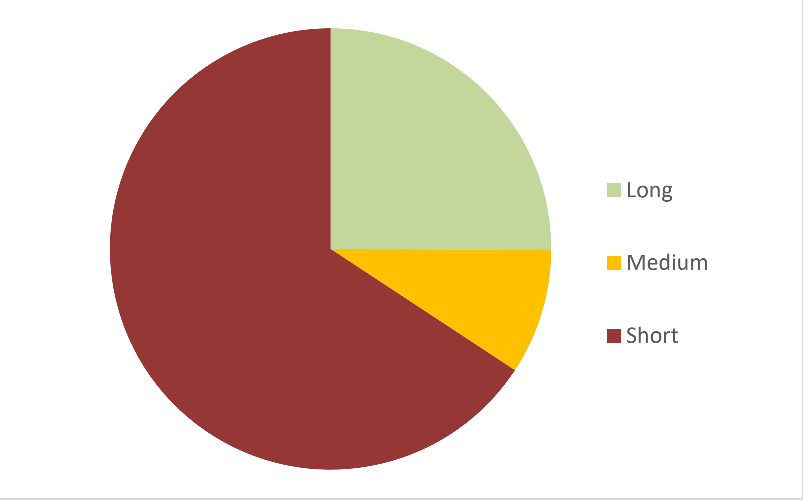
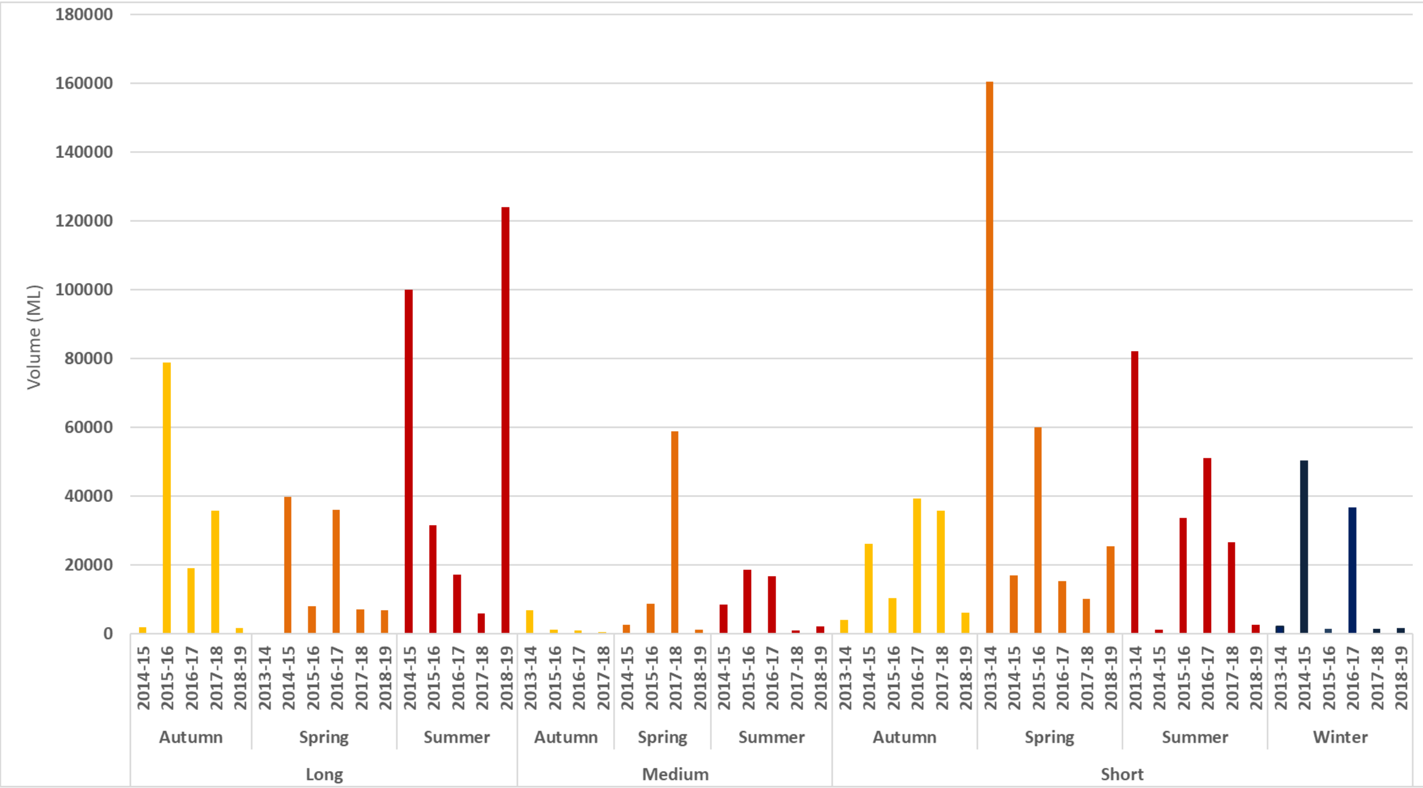


Figure 5. Primary and Secondary Waterbirds purpose environmental water delivery (HEW/PEW) for the water years 2013 – 2014 to 2018 – 2019 by volume, event duration and ML volume.



Analysis of key colonial waterbird sites in the Basin showed large magnitude colonial bird breeding events corresponded with large natural flood events (Figure 6). Umbrella Ecosystem Assets are sites that represent broader river reach or valley environmental water requirements (Swirepik et al., 2015). However, smaller colonial breeding events were supported by environmental watering at some sites (e.g. Lindsay-Walpolla-Chowilla).

Figure 6. Analysis of key colonial waterbird sites (Umbrella Ecosystem Assets) in Basin breeding magnitude based on aerial and ground data from The Living Murray, Department of Primary Industries – Environment, Energy and Science and MDB Asset Aerial Survey Data.

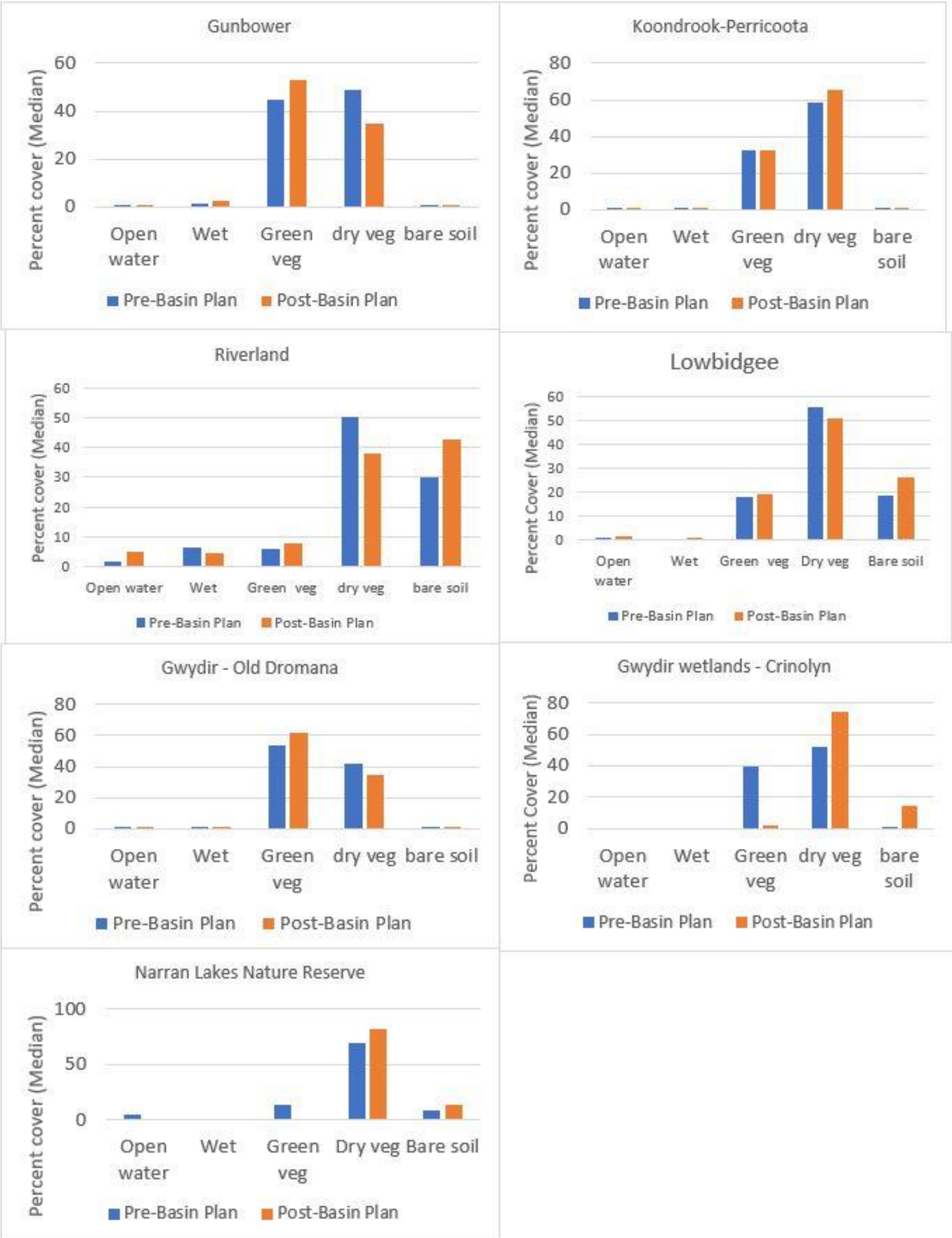
Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017/18	2018/19
Gunbower–Koondrook–Perricoota	no breeding	no breeding	no breeding	1 - 999	1 - 999	1 - 999	no breeding	no breeding	1 - 999	1 - 999	no breeding	no breeding
Gwydir Wetlands	no breeding	no breeding	no breeding	1 - 999	> 10, 000	no breeding	no breeding	1 - 999	no breeding	1 - 999	no breeding	no breeding
Lindsay–Walpolla–Chowilla	no breeding	no breeding	1 - 999	1 - 999	1 - 999	1 - 999	1 - 999	no breeding	1 - 999	1 - 999	1 - 999	1 - 999
Lowbidgee Floodplain	no breeding	no breeding	1 - 999	> 10, 000	1000 - 9 999	1 - 999	1 - 999	1 - 999	1 - 999	> 10, 000	1 - 999	no breeding
Narran Lakes	> 10, 000	no breeding	> 10, 000	> 10, 000	> 10, 000	no breeding	no breeding	no breeding	no breeding	1 - 999	no breeding	no breeding

grey circle	no breeding
yellow circle	1 - 999 breeding pairs
green circle	1000 - 9 999 breeding pairs
green star	> 10, 000 breeding pairs

Waterbird Habitat

The Koondrook-Perricoota site has had similar percentages of open water, wet vegetation and green vegetation pre- and post-Basin Plan (Figure 7). The Riverland graph (including Chowilla floodplain and the Lindsay-Mulcra-Walpolla site) and the Gunbower forest site have had increased amounts of open water, wet vegetation and green vegetation post-Basin Plan Implementation. The Gwydir wetlands was analysed in two different areas - Old Dromana and Crinoyln. At Old Dromana, the amount of green vegetation increased, and the amount of dry vegetation decreased post the Basin Plan. Comparatively, at Gwydir's Crinolyn, the amount of green vegetation substantially decreased post Basin-Plan, and the amount of dry vegetation and bare soil increased. For the lower Murrumbidgee, open water and wet vegetation increased substantially post-Basin Plan, and green vegetation increased slightly. Dry vegetation also decreased post Basin-Plan, while bare soil increased substantially. The Narran Lakes have largely been dry since the Basin Plan commenced (with the exception of 2013 and 2016). The WIT tool shows that the amount of open water, wet vegetation and green vegetation are much lower post Basin-Plan, while dry vegetation and bare soil have increased. From terminal wetlands analysis, the Narran Lakes is the only terminal wetland found to have degradation from baseline hydrologic conditions (based on observed and modelled data for the sum of inflow each water year).

Figure 7: Summary of key wetland (Umbrella Ecosystems Assets) results using the WIT tool with pre- and post-BP medians.



The preliminary results of the narrative-reporting were tested with a network of waterbird experts at participatory workshop. This allowed further refinement to the analytical methods, and recommendations of further scientific literature to consider in the Basin Plan evaluation for waterbirds.

Discussion:

Overall, we found a narrative-based approach useful for drawing on multiple lines of evidence to assess environmental policy response. We also found that the use of visual aids (graphs and Power BI dashboards) helped communicate complex findings from the 2020 Evaluation to a variety of stakeholders.

The expert workshop was an opportunity to explore the best methods of abstracting from limited data, particularly in a policy evaluation where a pre and post baseline had to account for climate change impacts. Another limitation was the length of pre-Basin Plan time-series, with data limited to around 3 years at some wetlands, and non-existent at others. For example, some key hydrologic indicator sites for waterbirds have only had systematic and detailed waterbird monitoring from 2014. We found that narrative-based reporting was able to reflect these data caveats to a wide variety of stakeholder audiences. The continued and systematic monitoring of colonial nesting waterbird abundance, species diversity, nesting and recruitment are vital for increased understanding of how environmental water delivery can enhance colonial waterbird breeding success.

The protection and delivery of environmental water is the strongest mechanism of the Basin Plan to support and protect ecological outcomes, hence the focus on Matter 9.3 reporting and environmental water delivery to assess the Basin Plan's contribution to outcomes. The sites receiving high volumes of environmental water tend to perform better for waterbird nesting and breeding. There is some evidence that the delivery of environmental water supports waterbirds. However, the flow durations and lack of overwintering water do not match the lifecycle requirements of colonial nester waterbirds, indicating opportunities for environmental water deliveries to better support the lifecycle requirements for colonial nesters. There are operational challenges in delivering e-water for the required duration and flow for colonial nesters. However, overall, the delivery of environmental water has supported maintaining colonial waterbird sites in event-ready condition during dry and very dry climate scenarios. More interrogation of colonial bird breeding event succeeding despite unmet SFIs could reveal new information about the lifecycle, temporal scales of movement or habitat requirements of colonial-nesting watering waterbirds.

The use of the WIT tool as a surrogate indicator for colonial waterbird habitat conditions was a useful Basin-wide condition indicator. Broadly, the use of WIT supported findings of sites that had experienced e-water delivery since Basin Plan implementation. For future work, a better understanding of the physical characteristics (inundation and vegetation requirements) of successful colonial waterbird breeding sites in the MDB would allow for more targeted environmental water delivery. Another limitation of this narrative-based reporting to colonial waterbird outcomes is that it does not cover on all the threats to colonial waterbirds. Threats such as predation, climate change, adverse weather events, avian diseases and prolonged drought/draining of wetlands for agricultural production also affect colonial waterbird recruitment (Reid et al., 2013). These pressures act beyond the remit of water policy, and therefore were not assessed in this policy evaluation.

Further work for evaluating colonial waterbird responses could focus on colonial waterbird habitat requirements (beyond inundation time), and further analysis of successful colonial waterbird breeding events that have occurred when the SFI has not been met. This would increase the knowledge of life history and ecological information for a variety of Australian colonial waterbird species is not available. Better understanding of the ideal spatial configuration and distance of feeding and breeding habitats in and between catchments would aid in optimising the delivery of environmental water. This would also allow us to refine our evaluation indicators to assess colonial waterbird outcomes with greater analytical sensitivity.

The empiric example of colonial waterbird breeding shows the methodological ability to integrate modelled hydrological data, on-ground ecological monitoring and expert opinion. This integration allows environmental policy interventions to be assessed for their contribution towards ecological outcomes. The narrative-based methodology offers transferable lessons for policy-makers who must not only evaluate environmental policy against complex ecological systems and a highly variable climate, but who must also communicate findings to lay audiences.

Acknowledgments:

We would like to acknowledge input and advice by the MDBA River Connectivity and Climate Adaptation team, MDBA GIS Spatial Services and Data team, MDBA Community of Practice members, Commonwealth Bureau of Meteorology; Jennifer Hale; Commonwealth Environmental Water Office; Commonwealth Geoscience Australia and our state colleagues at the Department of Environment and Science (QLD); Department of Environment, Land, Water and Planning (VIC); Department of Environment, Water and Natural Resources (SA) and the Department of Primary Industries – Environment, Energy and Science (NSW).

References:

Brandis, K. (2010) Colonial waterbird breeding in Australia: Wetlands, water requirements and environmental flows, PhD thesis, University of NSW.

Brandis, K. (2017) High Resolution Monitoring of Waterbird Colonies in the Macquarie Marshes, Report prepared for the Commonwealth Environmental Water Office, Centre for Ecosystem Science, University of New South Wales.

Clear Horizon Consulting. (2008). Telling the Performance Story of Castlemaine500. Retrieved from: https://www.clearhorizon.com.au/f.ashx/C500eBook_Mar09.pdf

Dart, J. (2008). Report on the outcomes and get everyone involved: The Participatory Performance Story Reporting Technique. Retrieved from: https://www.clearhorizon.com.au/f.ashx/report-on-outcomes-and-get-everyone-involved_the-participatory-performance.pdf

Dart, J., O'Connor, P. (2008). Performance Story Report: A Study of the Mount Lofty Ranges Southern Emu-wren and Fleurieu Penninsula Swamps Recovery Program and how it contributed to biodiversity outcomes in the Adelaide and Mount Lofty Ranges natural resources management region**.** Retrieved from: http://nrmonline.nrm.gov.au/catalog/mql:2167

Dart, J., Roberts, M. (2016). Invisible and unbound? The challenge and practice of evaluating embedded facilitation. In R. S. Fierro, A. Schwartz, & D. H. Smart (Eds.), *Evaluation and Facilitation. New Directions for Evaluation, 149*, 107–120.

Dunn B., Lymburner, L., Newey, V., Hicks, A. and Carey, H. (2019). Developing a Tool for Wetland Characterization Using Fractional Cover, Tasseled Cap Wetness And Water Observations From Space, IGARSS 2019–2019, IEEE International Geoscience and Remote Sensing Symposium, 6095–6097.

Kennett R., Kitchens J. (2009) Dugong and Marine Turtle Project Final Report Executive Summary, Northern Australian Indigenous Land and Sea Management ALLIANCE (NAILSMA).

Mathison, S. (2005). *Encyclopedia of evaluation*. Sage Publishing.

McGinness H.M., Brandis, K., Robinson, F., Piper, M., O'Brien, L., Langston, A., Hodgson, J., Wenger, L., Martin, J., Bellio, M., Callaghan, D., Webster, E., Francis, R., McCann, J., Lyons, M., Doerr, V., Kingsford, R., Mac Nally, R. (2019). Murray–Darling Basin Environmental Water Knowledge and Research Project — Waterbird Theme Research Report. Report prepared for the Department of the Environment and Energy, Commonwealth Environmental Water Office by CSIRO and La Trobe University, Centre for Freshwater Ecosystems (formerly Murray–Darling Freshwater Research Centre), CFE Publication, 44p.

Reid J.R.W, Colloff M.J, Arthur AD and McGinness HM (2013). Influence of Catchment Condition and water resource development on waterbird assemblages in the Murray–Darling Basin, Australia, Biological Conservation, 165, 25–34.

Spencer, J. (2017). Evaluation of colonial waterbird breeding in the NSW Murray-Darling Basin: 2006-16.

Swirepik, J.L., Burns, I.C, Dyer, F.J., Neave, I.A., O'Brien, M.G., Pryde, G.M., Thompson, R.M. (2015). Establishing Environmental Watering Requirements for the Murray-Darling Basin, Australia's Largest Developed River System, River Research and Applications, 32, 1153–1165.